



S3 Family 8-Bit Microcontrollers

S3F8S5A

Product Specification

PS032303-0314

PRELIMINARY





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Revision History

Each instance in this document’s revision history reflects a change from its previous edition. For more details, refer to the corresponding page(s) or appropriate links furnished in the following table.

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Overview

Zilog's S3F8 Series of 8-bit single-chip microcontrollers offers a fast and efficient CPU, a wide range of integrated peripherals, and multiple Flash memory sizes. Important CPU features include:

- Efficient register-oriented architecture
- Selectable CPU clock sources
- Idle and Stop power-down mode release by interrupts
- Built-in basic timer with watchdog function

A sophisticated interrupt structure recognizes up to eight interrupt levels. Each level can have one or more interrupt sources and vectors. Fast interrupt processing (within a minimum of four CPU clocks) can be assigned to specific interrupt levels.

S3F8S5A Microcontroller

The S3F8S5A MCU features 48KB or 32KB of Flash ROM. Using a proven modular design approach, the S3F8S5A MCU was developed by integrating the following peripheral modules with the SAM88 core:

- Five programmable I/O ports, including four 8-bit ports and one 4-bit port for a total of 36 pins
- Eight bit-programmable pins for external interrupts
- One 8-bit basic timer for oscillation stabilization and watchdog functions (system reset)
- Three 8-bit timer/counters and two 16-bit timer/counters with selectable operating modes
- Watch timer for real time
- LCD controller/driver
- A/D converter with 8 selectable input pins
- Synchronous SIO modules
- Two asynchronous UART modules
- Pattern generation module

The S3F8S5A MCU is currently available in a 44-pin QFP package and a 42-pin SDIP package.

Features

The S3F8S5A MCU offers the following features:

- SAM88 RC CPU core
- Program memory (full Flash ROM):
 - 48K x 8 bits program memory (S3F8S5AXZZ-QZ8A/S3F8S5AX2A-AQ8A)
 - 32K x 8 bits program memory (S3F8S5AX49-QZ8A/S3F8S5AX29-AQ8A)
 - Internal Flash (program) memory
 - Sector size: 128 bytes
 - 10 years data retention
 - Fast programming time: user program and sector erase available
 - Endurance: 10,000 erase/program cycles
 - External serial programming support
 - Expandable On-Board Program (OBP) sector
- Data memory (RAM)
 - LCD display data memory
 - 1040 x 8 bits data memory
- Instruction set
 - 78 instructions
 - IDLE and STOP instructions added for power-down modes
- 34 I/O pins
 - 12 pins shared with other signal pins
 - 24 pins shared with LCD signal outputs
- Interrupts
 - 8 interrupt levels and 23 interrupt sources
 - Fast interrupt processing feature
- 8-bit basic timer
 - Watchdog timer function
 - 4 types of clock source
- 8-bit Timer/Counter A
 - Programmable 8-bit internal timer
 - External event counter function
 - PWM and capture function
- 8-bit Timer/Counter B

- Programmable 8-bit internal timer
- Carrier frequency generator
- 8-bit Timer/Counter C
 - Programmable 8-bit internal timer
 - PWM function
- Two 16-bit Timer/Counters (D0/D1)
 - Programmable 16-bit internal timer
 - External event counter function
 - PWM and capture function
- Watch timer
 - Interval time: 1.995ms, 0.125s, 0.25s, and 0.5s at 32.768kHz
 - 0.5/1/2/4kHz selectable buzzer output
- LCD controller/driver
 - 18 segments and 8 common terminals
 - 1/2, 1/3, 1/4, and 1/8 duty selectable
 - Resistor bias selectable
- Analog-to-digital converter
 - 8 channel analog input
 - 10-bit conversion resolution
 - 25µs conversion time
- Two UART channels
 - Full-duplex serial I/O interface
 - Four programmable operating modes
 - Autogenerating parity bit
- 8-bit serial I/O interface
 - 8-bit transmit/receive mode
 - 8-bit receive mode
 - LSB-first or MSB-first transmission selectable
 - Internal or external clock source
- 10-bit PWM generator
 - Single PWM output on P2.1
 - Adjustable frequency based on CPU clock
- Pattern generation module
 - Triggered by timer match signal and software

- Low Voltage Reset (LVR)
 - Criteria voltage: 1.9V, 2.8V
 - Enable/disable by Smart Option (ROM address: 3Fh)
- Two power-down modes
 - IDLE: only CPU clock stops
 - STOP: selected system clock and CPU clock stop
- Oscillation sources
 - Crystal, ceramic, or RC for main clock
 - Main clock frequency: 0.4–12.0MHz
 - 32.768kHz crystal oscillation circuit for subclock
- Instruction execution times
 - 333ns at 12.0MHz f_X (minimum)
 - 122.1 μ s at 32.768kHz f_{XT} (minimum)
- Internal voltage converter for 5V operations
- Smart Option
 - Low Voltage Reset (LVR) level and enable/disable are at your hard-wired option (ROM address 3Fh)
 - ISP related option selectable (ROM address 3Eh)
- Operating voltage range
 - 1.8V to 5.5V at 0.4–4.2MHz
 - 2.2V to 5.5V at 0.4–12.0MHz
- Operating temperature range: 40°C to +85°C
- Packages
 - 40-pin QFP
 - 42-pin SDIP

Block Diagram

Figure 1 shows a block diagram for the S3F8S5A MCU, which is available in a 44-pin QFP package and a 42-pin SDIP package.

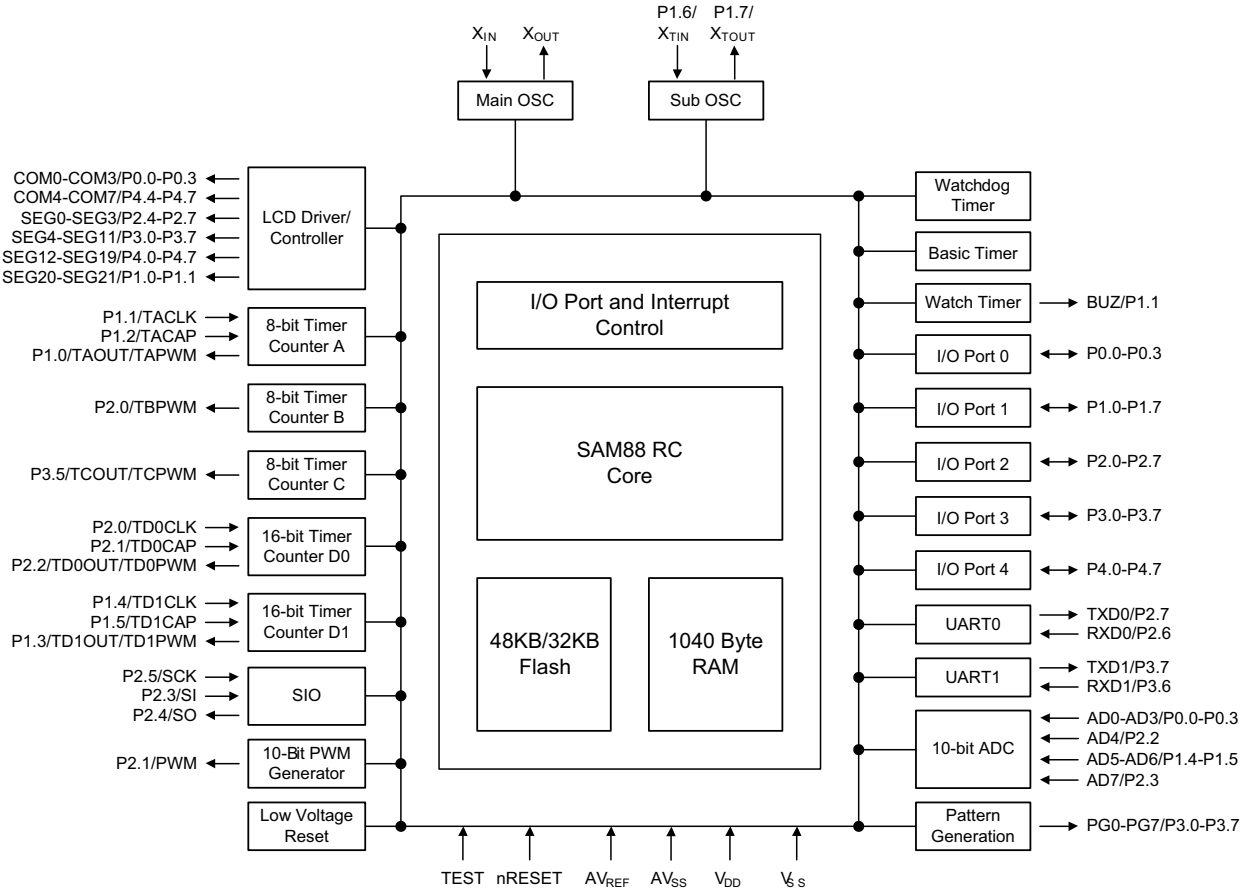


Figure 1. S3F8S5A MCU Block Diagram

Pin Assignments

Figure 2 shows the pin assignments for the 44-pin QFP package.

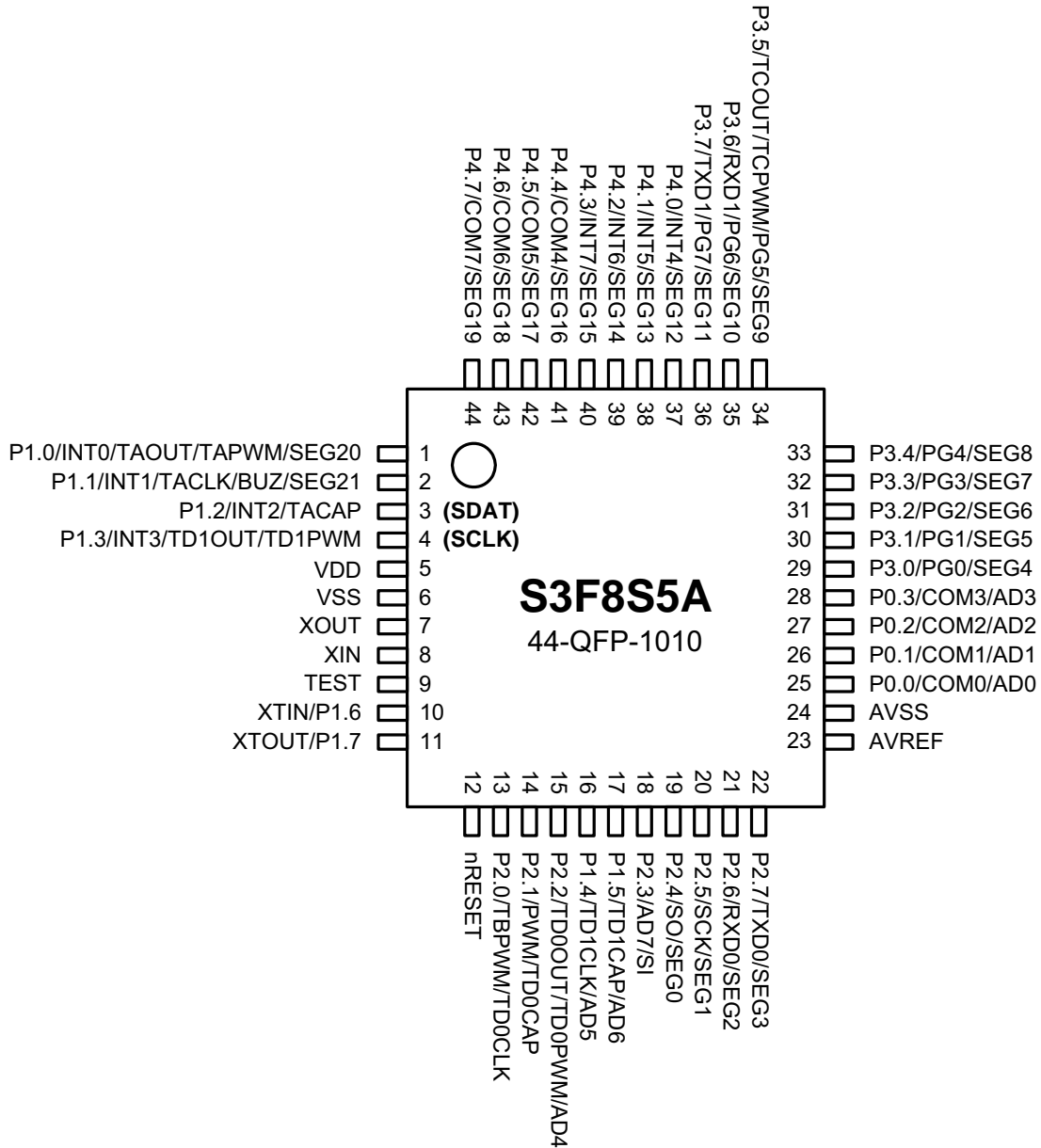


Figure 2. Pin Assignments, 44-QFP Package

Figure 3 illustrates the pin assignments for the 42-pin SDIP package.

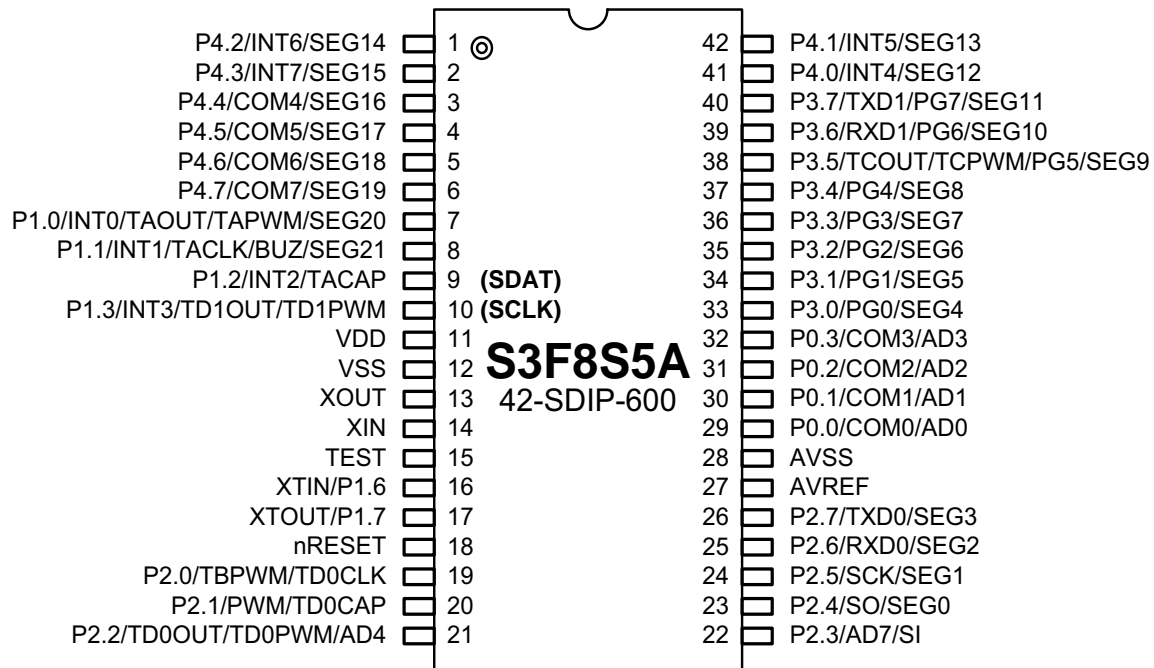


Figure 3. Pin Assignments, 42-Pin SDIP Package

Table 1 identifies each pin in the S3F8S5A MCU's 44-pin QFP package.

Table 1. Pin Descriptions, 44-Pin Device

Pin Name	Pin Description	Pin Type	Circuit Type	Pin No.	Shared Functions
P0.0	I/O port with bit-programmable pins; Input or push-pull output and software assignable pull-ups.	I/O	H-2	25(29)	COM0/AD0 COM1/
P0.1				26(30)	AD1 COM2/AD2
P0.2				27(31)	COM3/AD3
P0.3				28(32)	
P1.0	I/O port with 1-bit-programmable pins; Schmitt trigger input or push-pull, open-drain output and software assignable pull-ups.	I/O	H-4	1(7)	INT0/TAOUT/ TAPWM/SEG20
P1.1				2(8)	INT1/TACLK/ BUZ/ SEG21 INT2/TACAP
P1.2	(noise filters, interrupt enable and pending control).		D-3	3(9)	INT3/TD1OUT/
P1.3				4(10)	TD1PWM

Note: Parentheses indicate pin numbers for the 42-pin SDIP package.

Table 1. Pin Descriptions, 44-Pin Device (Continued)

Pin Name	Pin Description	Pin Type	Circuit Type	Pin No.	Shared Functions		
P1.4	I/O port with 1-bit-programmable pins; Schmitt trigger input or push-pull output and software assignable pull-ups. The P1.4 – P1.5 are not in the 42-Pin package.	I/O	F–1	16	TD1CLK/AD5		
P1.5				17	TD1CAP/AD6 X _{TIN}		
P1.6				10(16)	X _{TOUT}		
P1.7				11(17)			
P2.0	I/O port with bit-programmable pins; Input or push-pull output and software assignable pull-ups.	I/O	D–3	13(19)	TBPWM/TD0CLK		
P2.1				14(20)	PWM/TD0CAP		
P2.2				F–2	15(21)	TD0OUT/ TD0PWM/ AD4 AD7/SI	
P2.3					18(22)	SO/SEG0 SCK/	
P2.4					H–4	19(23)	SEG1 RXD0/SEG2
P2.5						20(24)	TXD0/SEG3
P2.6				21(25)			
P2.7				22(26)			
P3.0–P3.4	I/O port with bit-programmable pins; Schmitt trigger input or push-pull, open-drain output and software assignable pull-ups.	I/O	H–4	29–33	PG0–PG4/ SEG4–SEG8		
P3.1				34(38)	TCOUT/TCPWM/ PG5/SEG9 RXD1/		
P3.2				35(39)	PG6/SEG10 TXD1/		
P3.3				36(40)	PG7/SEG11		
P4.0	I/O port with bit-programmable pins; Schmitt trigger input or push-pull output and software assignable pull-ups.	I/O	H–4	37(41)	INT4/SEG12 INT5/		
P4.1				38(42)	SEG13 INT6/SEG14		
P4.2				39(1)	INT7/SEG15		
P4.3				40(2)	COM4–COM7/		
P4.4–P4.7				41–44	SEG16–19		
				(3–6)			
COM0–COM1	LCD common signal outputs.	I/O	H-2	25–28	P0.0–P0.3/ AD0–AD3		
COM2–COM7				41–44	P2.2–P2.7/ SEG0–SEG5		
				(3–6)			

Note: Parentheses indicate pin numbers for the 42-pin SDIP package.

Table 1. Pin Descriptions, 44-Pin Device (Continued)

Pin Name	Pin Description	Pin Type	Circuit Type	Pin No.	Shared Functions			
SEG0	LCD segment signal outputs.	I/O	H-4	19(23)	P2.4/SO			
SEG1				20(24)	P2.5/SCK			
SEG2				21(25)	P2.6/RXD0			
SEG3				22(26)	P2.7/TXD0			
SEG4-S				29-33	P3.0-P3.4/			
EG8				(33-37)	PG0-PG4			
SEG9				34(38)	P3.5/TCOUT/ TCPWM/PG5 P3.6/			
SEG10				35(39)	RXD1/PG6 P3.7/			
SEG11				36(40)	TXD1/PG7 P4.0/			
SEG12				37(41)	INT4			
SEG13				38(42)	P4.1/INT5			
SEG14				39(1)	P4.2/INT6			
SEG15				40(2)	P4.3/INT7			
SEG16-S				41-44	P4.4-P4.7/			
SEG19				(3-6)	COM4-COM7 P1.0/			
SEG20				1(7)	INT0/ TAOUT/ TAPWM P1.1/INT1/			
SEG21				2(8)	TACLK/BUZ			
AD0-AD 3				A/D converter analog input channels.	I/O	H-2	25-28	P0.0-P0.3/
AD4							(29-32)	COM0-COM3 P2.2/
AD5							15(21)	TD0OUT/ TD0PWM
AD6								P1.4/TD1CLK
AD7		P1.5/TD1CAP						
		P2.3/SI						
		18(22)						
SCK	Serial interface clock.	I/O	H-4	20(24)	P2.5/SEG1			
SO	Serial interface data output.	I/O	H-4	19(23)	P2.4/SEG0			
SI	Serial interface data input.	I/O	F-2	18(22)	P2.3/AD7			
BUZ	Output pin for buzzer signal.	I/O	H-4	2(8)	P1.1/INT1/ TACLK/ SEG21			
TXD0 RXD0	UART 0 data output, input.	I/O	H-4	22(26) 21(25)	P2.7/SEG3 P2.6/ SEG2			
TXD1 RXD1	UART 1 data output, input.	I/O	H-4	36(40) 35(39)	P3.7/PG7/SEG11 P3.6/PG6/SEG10			

Note: Parentheses indicate pin numbers for the 42-pin SDIP package.

Table 1. Pin Descriptions, 44-Pin Device (Continued)

Pin Name	Pin Description	Pin Type	Circuit Type	Pin No.	Shared Functions
PG0–PG4	Pattern generation output.	I/O	H-4	29–33 (33–37) 34(38)	P3.0–P3.4/ SEG4–SEG8 P3.5/TCOUT/ TCPWM/SEG9 P3.6/ RXD1/SEG10 P3.7/TXD1/SEG11
PG5				35(39)	
PG6				36(40)	
PG7					
TAOUT/ TAPWM	Timer A clock and PWM output.	I/O	H-4	1(7)	P1.0/INT0/SEG20
TACLK	Timer A external clock input.	I/O	H-4	2(8)	P1.1/INT1/
TACAP	Timer A capture input.	I/O	D-3	3(9)	3(9)
TBPWM	Timer B PWM output.	I/O	D-3	13(19)	13(19)
TCOUT/ TCPWM	Timer C clock and PWM output.	I/O	H-4	34(38)	34(38)
TD0OUT/ TD0PWM	Timer D0 clock and PWM output.	I/O	F-2	15(21)	15(21)
TD0CLK	Timer D0 external clock input.	I/O	D-3	13(19)	13(19)
TD0CAP	Timer D0 capture input.	I/O	D-3	14(20)	14(20)
TD1OUT/ TD1PWM	Timer D1 clock and PWM output.	I/O	D-3	4(10)	4(10)
TD1CLK	Timer D1 external clock input.	I/O	F-1	16	16
TD1CAP	Timer D1 capture input.	I/O	F-1	17	17
PWM	10-bit PWM generator output.	I/O	D-3	14(20)	14(20)
INT0	External interrupt input pins.	I/O	H-4	1(7)	P1.0/TAOUT/ TAPWM/SEG20
INT1				2(8)	P1.1/TACLK/ BUZ/ SEG21 P1.2/TACAP
INT2			D-3	3(9)	P1.3/TD1OUT/ TD1PWM P4.0/ SEG12 P4.1/SEG13
INT3				4(10)	P4.2/SEG14 P4.3/ SEG15
INT4				37(41)	
INT5			H-4	38(42)	
INT6				39(1)	
INT7				40(2)	
AVREF	A/D converter reference voltage.	—	—	23(27)	—
nRESET	System reset pin with a pull-up resistor.	I	—	12(18)	B

Note: Parentheses indicate pin numbers for the 42-pin SDIP package.

Table 1. Pin Descriptions, 44-Pin Device (Continued)

Pin Name	Pin Description	Pin Type	Circuit Type	Pin No.	Shared Functions
XIN XOUT	Main oscillator pins.	—	—	8(14) 7(13)	—
X _{TIN} X _{TOUT}	Crystal oscillator pins for sub clock.	—	—	10(16) 11(17)	P1.6 P1.7
TEST	Test pin: it must be connected to V _{SS}	I	—	9(15)	—
V _{DD}	Power supply input pins.	—	—	5(11)	—
V _{SS}	Ground pins.	—	—	6(12)	—
AV _{SS}	Ground pin.	—	—	24(28)	—

Note: Parentheses indicate pin numbers for the 42-pin SDIP package.

Pin Circuits

Figure 4 shows the Type A pin circuit.

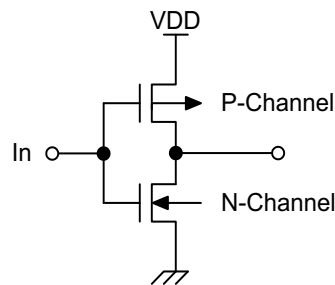


Figure 4. Pin Circuit Type A

Figure 5 shows the Type B pin circuit .

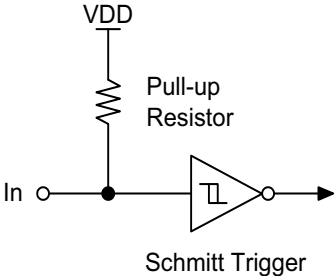


Figure 5. Pin Circuit Type B

Figure 6 shows the Type C Pin Circuit.

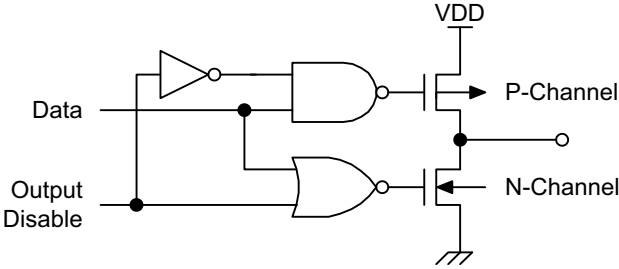


Figure 6. Pin Circuit Type C

Figure 7 shows the Type D-2 pin circuit for ports 1.6 to 1.7.

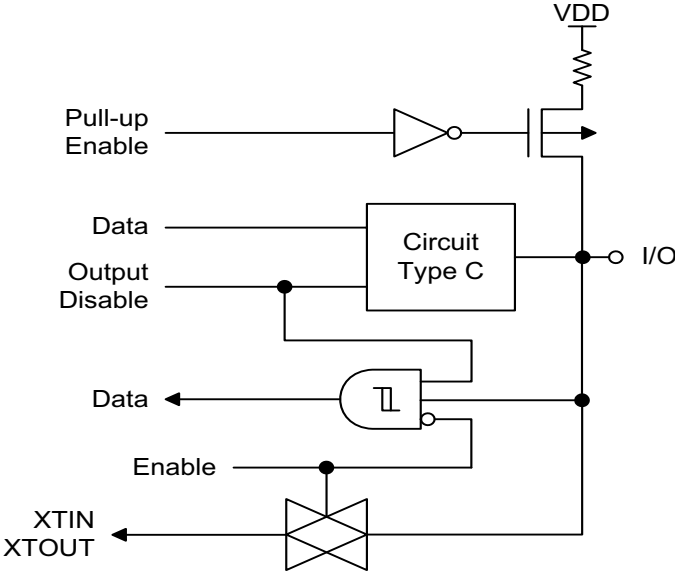


Figure 7. Pin Circuit Type D-2

Figure 8 shows the Type D-3 pin circuit for P1.2–P1.3 and P2.0–P2.1.

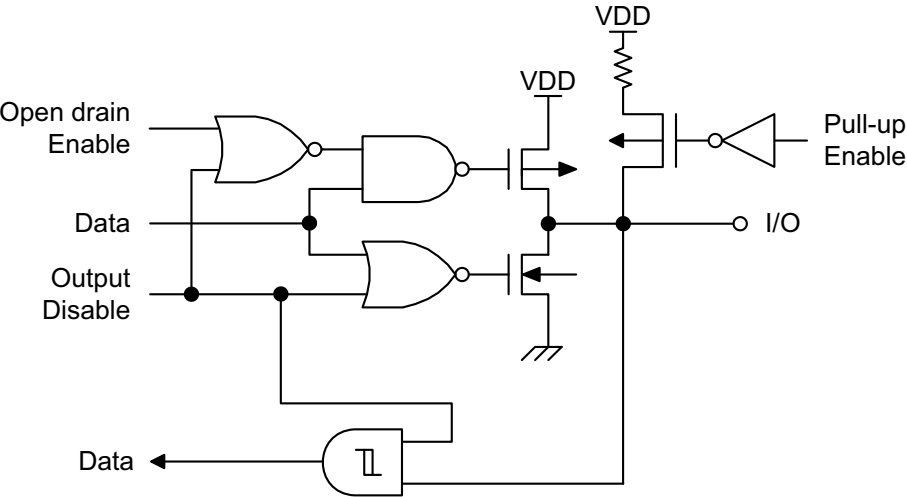


Figure 8. Pin Circuit Type D-3

Figure 9 shows the Type F-1 Pin Circuit for P1.4–P1.5.

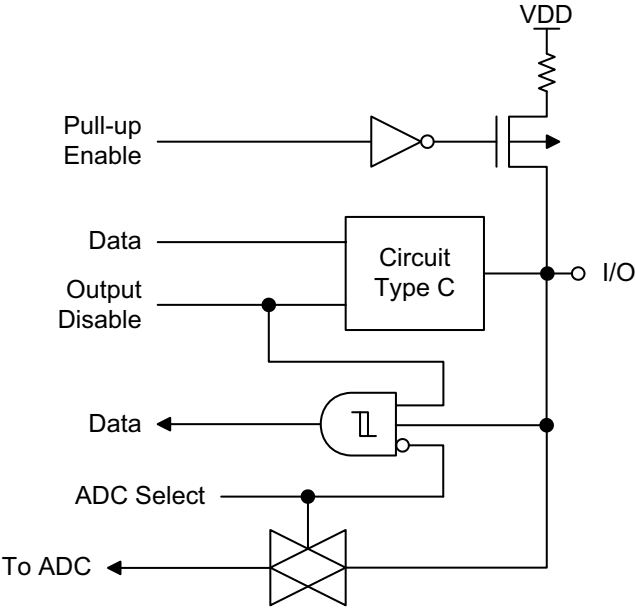


Figure 9. Pin Circuit Type F-1

Figure 10 shows the Type F-2 pin circuit for P2.2 and P2.3.

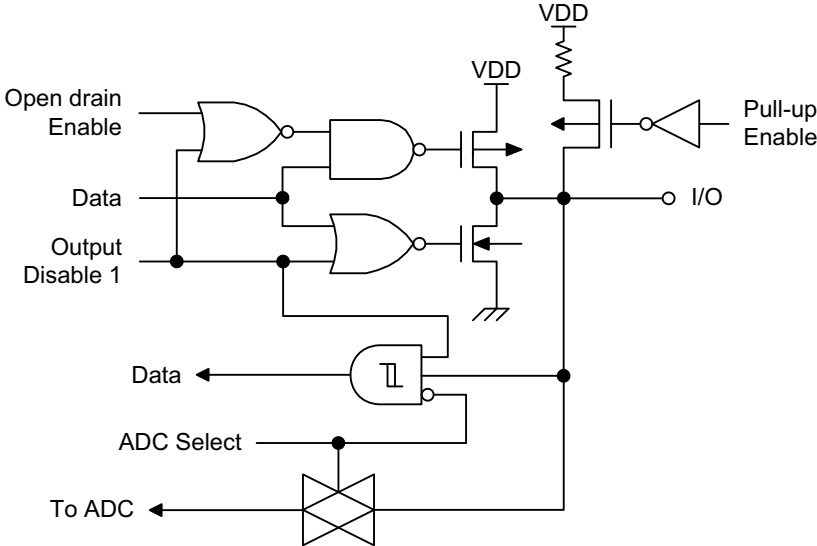


Figure 10. Pin Circuit Type F-2

Figure 11 shows the Type H-1 pin circuit.

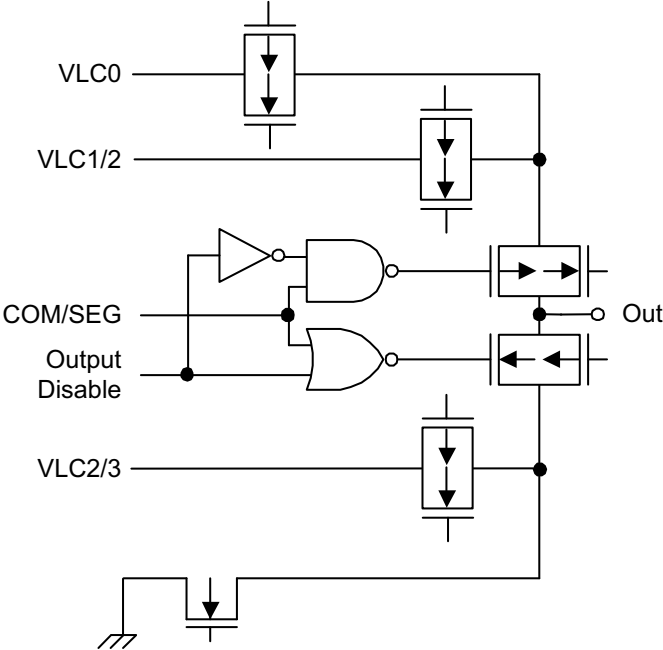


Figure 11. Pin Circuit Type H-1

Figure 12 shows the Type H-2 pin circuit for P0.0–P0.3.

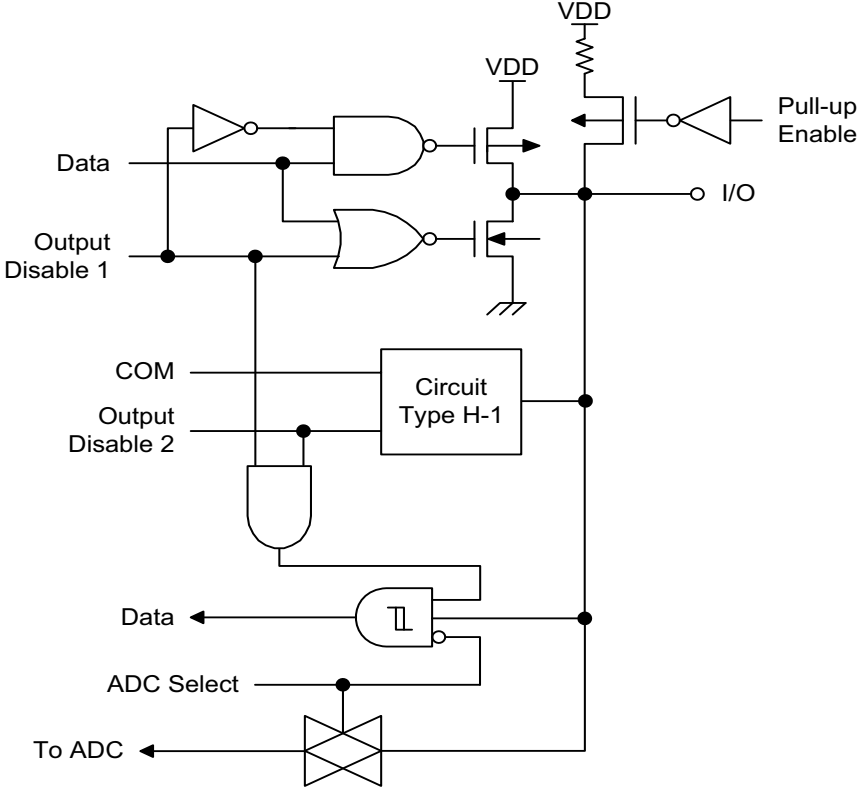


Figure 12. Pin Circuit Type H-2

Figure 13 shows the Type H-2 pin circuit for P1.0–P1.1, P2.4–P2.7, P3, and P4.

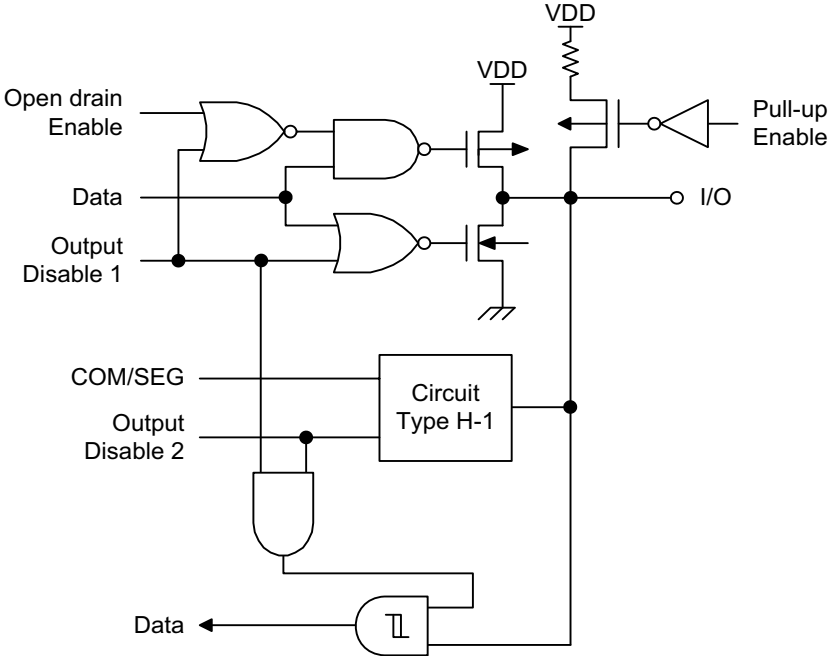


Figure 13. Pin Circuit Type H-4

Address Space

The S3F8S5A microcontroller features two types of address space:

- Internal program ROM
- Internal register file

A 16-bit address bus supports program memory operations. A separate 8-bit register bus carries addresses and data between the CPU and the register file.

The S3F8S5A features 48KB of internal Flash ROM. The 256-byte physical register space is expanded into an addressable area of 320 bytes using addressing modes.

A 22-byte LCD display register file is implemented.

Program Memory

Program memory (ROM) stores program code or table data. The S3F8S5A MCU features 48KB internal Flash program memory.

The first 256 bytes of the ROM space, 0h–0FFh, are reserved for interrupt vector addresses. Unused locations in this address range can be used as normal program memory. If you use the vector address area to store program code, be careful not to overwrite the vector addresses stored in these locations.

The ROM address at which program execution starts after a reset is 0100h.

The reset address of ROM can be changed by a smart option only in the S3F8S5A (full-Flash device). Refer to the [Embedded Flash Memory Interface](#) chapter on page 334 to learn more.

The program memory address space is shown in Figure 14.

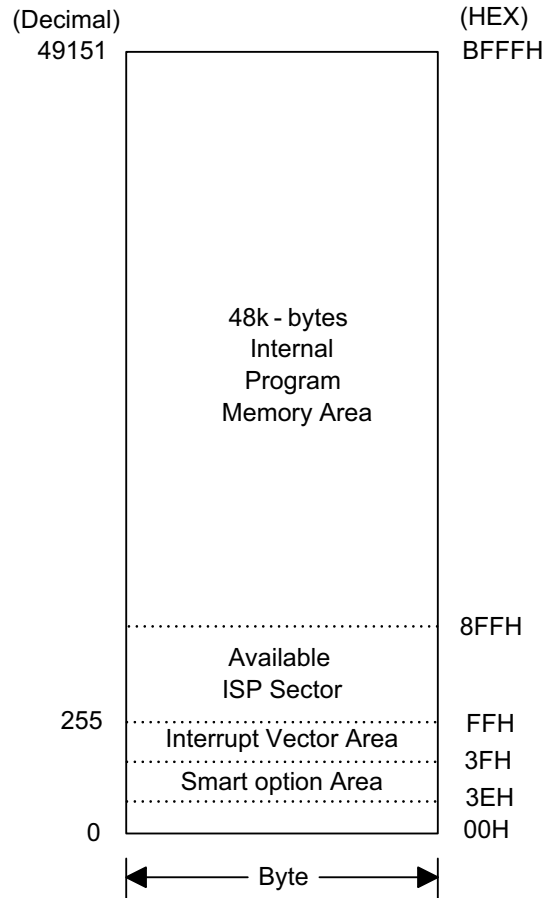


Figure 14. Program Memory Address Space

Smart Option

The *Smart Option*, diagrammed in Figure 15, is the ROM option for the start condition of the chip. The ROM address used for the smart option ranges from 003Ch to 003Fh. The S3F8S5A MCU uses only addresses in the range 003Eh to 003Fh.

When any values are written in the Smart Option area (i.e., 003Ch–003Fh) by an LDC instruction, the data in the area may be changed, but the Smart Option is not affected. Smart Option data should be written in this Smart Option area using an OTP/MTP programming tool.

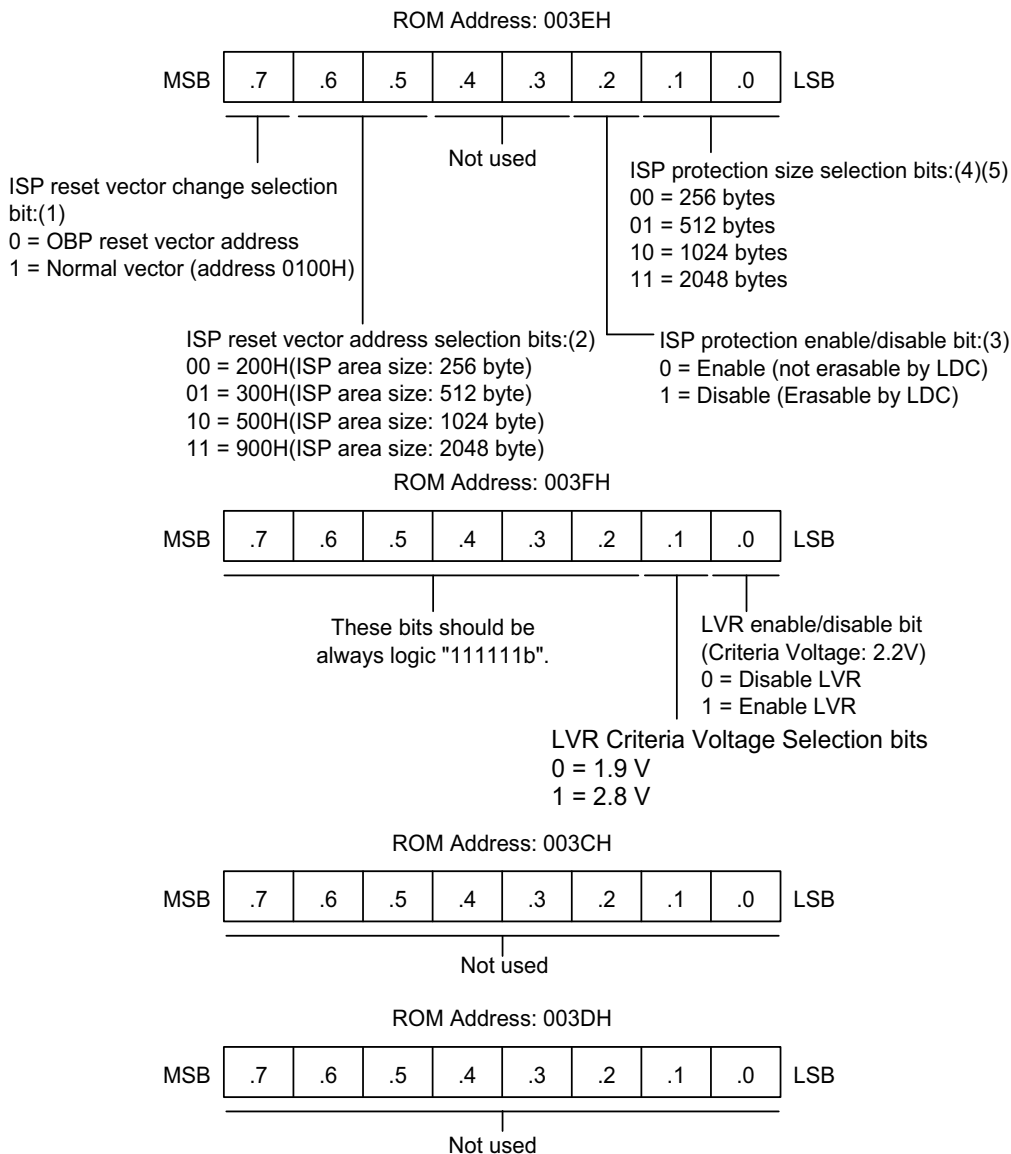


Figure 15. Smart Option

- **Notes:**
1. In Figure 15, by setting ISP reset vector change selection bit (3E . 7) to 0, the ISP area becomes available. If this bit is 1, 3Eh . 6 and 3Eh . 5 are rendered meaningless.
 2. If the ISP reset vector change selection bit (3Eh . 7) is 0, the user must change the ISP reset vector address from 0100h to an address for which the user wants to set a reset address (i.e., 0200h, 0300h, 0500h, or 0900h). If the reset vector address is 0200h,

the ISP area can be assigned from 0100h to 01FFh (an area of 256 bytes). If 0300h, the ISP area can be assigned from 0100h to 02FFh (512 bytes). If 0500h, the ISP area can be assigned from 0100h to 04FFh (1024 bytes). If 0900h, the ISP area can be assigned from 0100h to 08FFh (2048 bytes).

3. If the ISP protection enable/disable bit is 0, user cannot erase or program the ISP area selected by 3Eh.1 and 3Eh.0 in Flash memory.
 4. The user can select a suitable ISP protection size using 3Eh.1 and 3Eh.0. If the ISP protection enable/disable bit (3Eh.2) is 1, 3Eh.1 and 3Eh.0 are rendered meaningless.
 5. After selecting the ISP reset vector address when selecting the ISP protection size, do not select a value greater than the ISP area size.
-

Register Architecture

In the S3F8S5A implementation, the upper 64-byte area of register files is expanded to two 64-byte areas, called *Set1* and *Set2*. The upper 32-byte area of *Set1* is further expanded to two 32-byte register banks (Bank0 and Bank1), and the lower 32-byte area is a single 32-byte common area.

In the S3F8S5A MCU, the total number of addressable 8-bit registers is 1131. Of these 1131 registers, 13 bytes are designated for the CPU and system control registers, 78 bytes are designated for the peripheral control and data registers, 16 bytes are used as shared working registers, and 1024 registers are designated for general-purpose use in Page 0–Page 1 (including 22 bytes for LCD display registers).

Set1 register locations can always be set, regardless of which of the ten register pages is currently selected. A *Set1* location, however, can only be addressed using register addressing modes.

The extension of register space into separately addressable areas (sets, banks, and pages) is supported by multiple addressing mode restrictions: the select bank instructions, SB0 and SB1, and the register page pointer (PP).

Specific register types and the area (in bytes) that they occupy in the register file are summarized in Table 2.

Table 2. S3F8S5A Register Types

Register Type	Number of Bytes
General-purpose registers (including the 16-byte common working register area, four 192-byte prime register areas (including LCD data registers), and four 64-byte Set2 areas.	1040
CPU and system control registers.	13
Mapped clock, peripheral, I/O control, and data registers.	78
Total addressable bytes.	1131

Figure 16 shows the organization of the internal register file.

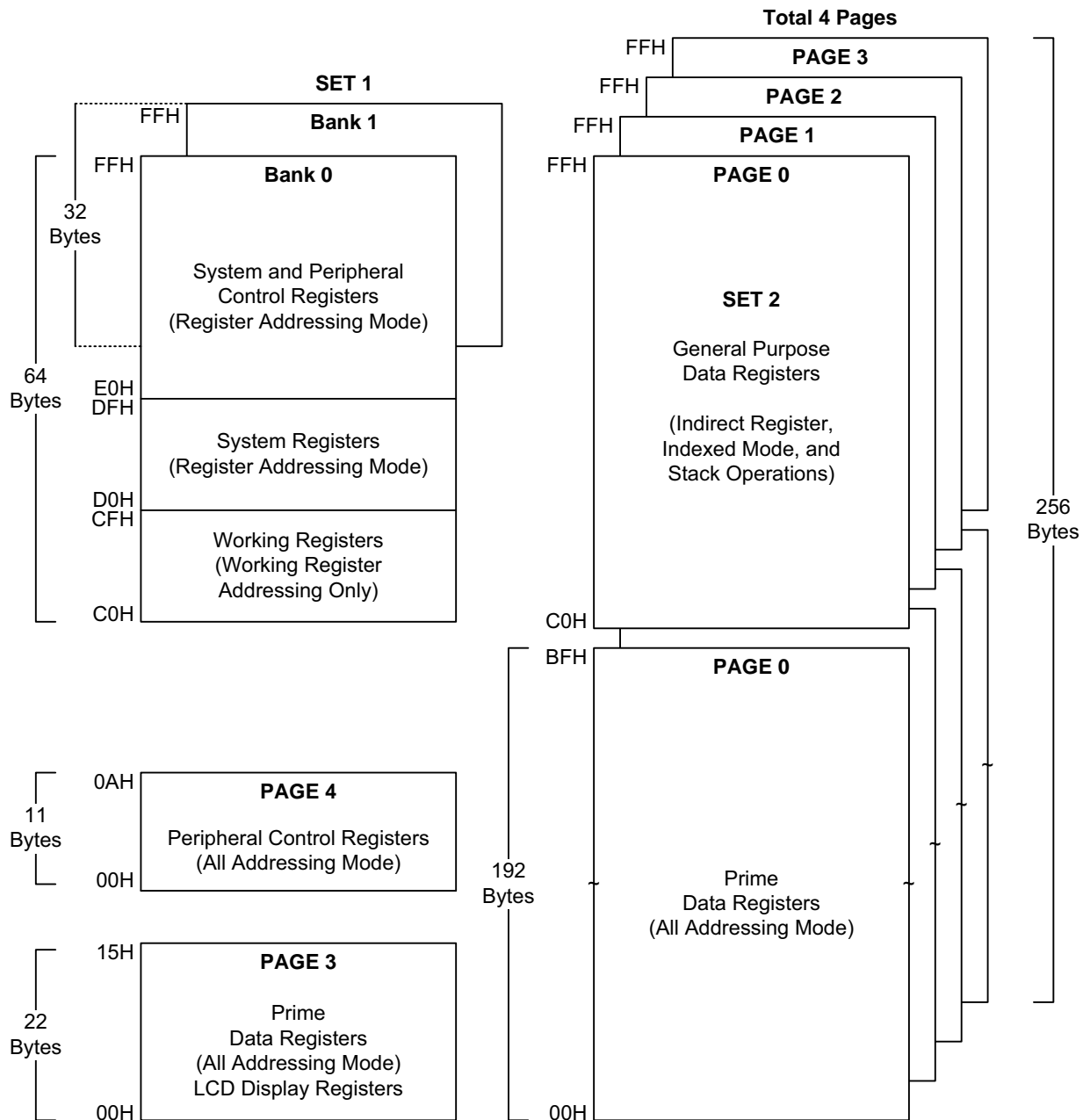


Figure 16. Internal Register File Organization

Register Page Pointer

The S3F8 Series architecture supports the logical expansion of the physical 256-byte internal register file (using an 8-bit data bus) into as many as 16 separately-addressable register pages. Page addressing is controlled by the register page pointer (PP; Set1, Bank0, DFh). In the S3F8S5A microcontroller, a paged register file expansion is implemented for LCD data registers, and the register page pointer must be changed to address other pages.

After a reset, the page pointer's source value (i.e., the lower nibble) and the destination value (the upper nibble) are always 0000, automatically. Therefore, the S3F8S5A MCU always selects Page 0 as the source and destination page for register addressing.

The contents of the Register Page Pointer (PP) Register are described in Table 3.

Table 3. Register Page Pointer (PP; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	DFh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:4]	Destination Register Page Selection Bits¹ 0000: Destination: Page 0. 0001: Destination: Page 1. 0010: Destination: Page 2. 0011: Destination: Page 3. 0100: Destination: Page 4. 0101–1111: Reserved.
[3:0]	Source Register Page Selection Bits² 0000: Destination: Page 0. 0001: Destination: Page 1. 0010: Destination: Page 2. 0011: Destination: Page 3. 0100: Destination: Page 4. 0101–1111: Reserved.

Notes:

1. In the S3F8S5A microcontroller, the internal register file is configured as three pages (pages 0–4).
2. Pages 0–3 are used for the general purpose register file; Page 3 addresses 00h–15h are also used for the LCD Data Register.

-
- **Notes:** In Table 3, the internal register file is configured as twelve pages (i.e., pages 0–4). Page 3 includes the LCD Data Register (300h–315h).
-

The following example indicates how to use the Page Pointer to clear the contents of RAM (i.e., Page 0, Page 1).

```

                                LD    PP,#00h    ; Destination ← 0, Source ← 0
                                SRP    #0C0H
                                LD    R0,#0FFH    ; Page 0 RAM clear starts
RAMCL0                          CLR    @R0
                                DJNZ  R0,RAMCL0
                                CLR    @R0        ; R0 = 00H LD PP,#10H ; Destination ←
                                                ; 1, Source ← 0
                                LD    R0,#0FFH    ; Page 1 RAM clear starts
RAMCL1                          CLR    @R0
                                DJNZ  R0,RAMCL1
                                CLR    @R0        ; R0 = 00h

```

-
- **Note:** To learn more about the DJNZ instruction, see [page 125](#).
-

Register Set1

The term *Set1* refers to the upper 64 bytes of the register file, locations C0h–FFh.

The upper 32-byte area of this 64-byte space (E0h–FFh) is divided into two 32-byte register banks, Bank0 and Bank1. The Set Register's SB0 or SB1 bank instructions are used to address one bank or the other. A hardware reset operation always selects Bank0 addressing.

The upper two 32-byte areas of Set1 (E0h–FFh), Bank0 and Bank1, contain 68 mapped system and peripheral control registers. The lower 32-byte area contains 16 system registers (D0h–DFh) and a 16-byte common working register area (C0h–CFh). Use the common working register area as a *scratch* area for data operations being performed in other areas of the register file.

Registers in the Set1 location are directly accessible at all times using Register Addressing Mode. The 16-byte working register area can only be accessed using working register addressing. To learn more about working register addressing, see the [Addressing Modes](#) chapter on page 43.

Register Set2

The same 64-byte physical space that is used for Set1 location C0h–FFh is logically duplicated to add another 64 bytes of register space. This expanded area of the register file is called Set2. In the S3F8S5A MCU, the Set2 C0h–FFh address range is accessible on pages 0–3.

The logical division of Set1 and Set2 is maintained by means of addressing mode restrictions: Use only Register Addressing Mode to access Set1 locations; to access registers in Set2, you must use Register Indirect Addressing Mode or Indexed Addressing Mode. The Set2 register area of Page 0 is commonly used for stack operations.

Prime Register Space

The lower 192 bytes of the S3F8S5A MCU's 256-byte register pages (00h–BFh) is called the *prime register space* or, more simply, the *prime area*. Prime registers can be accessed using any of the seven addressing modes (to learn more, see the [Addressing Modes](#) chapter on page 43).

The prime register area on Page 0 is immediately addressable following a reset. To address the prime registers on pages 0 or 1, you must set the register page pointer (PP) to the appropriate source and destination values.

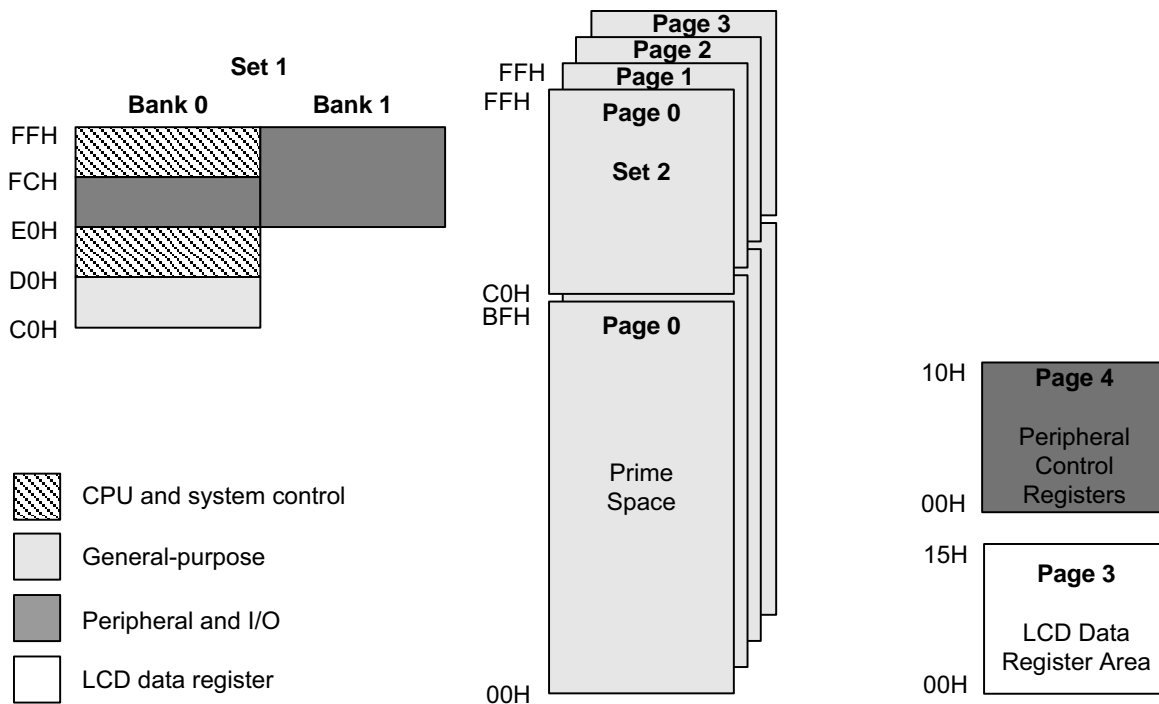


Figure 17. Set1, Set2, and Prime Area Register, and LCD Data Register Map

Working Registers

Instructions can access specific 8-bit registers or 16-bit register pairs using either 4-bit or 8-bit address fields. When 4-bit working register addressing is used, the 256-byte register file can be seen by the programmer as consisting of thirty-two 8-byte register groups, or *slices*. Each slice consists of eight 8-bit registers.

When using the two 8-bit register pointers, RP1 and RP0, two working register slices can be selected at any time to form a 16-byte working register block. When using these register pointers, you can move this 16-byte register block anywhere in the addressable register file, except for the Set2 area.

The terms *slice* and *block* are used in this document to help readers visualize the size and relative locations of selected working register spaces, as follows:

- One working register *slice* is 8 bytes (eight 8-bit working registers; R0–R7 or R8–R15)
- One working register *block* is 16 bytes (sixteen 8-bit working registers; R0–R15)

All of the registers in an 8-byte working register slice have the same binary value for their five most significant address bits, thereby making it possible for each register pointer to point to one of the 24 slices in the register file. The base addresses for the two selected 8-byte register slices are contained in register pointers RP0 and RP1.

After a reset, RP0 and RP1 always point to the 16-byte common area in Set1 (C0h–CFh). Figure 18 illustrates the 8-byte working register areas (i.e., slices).

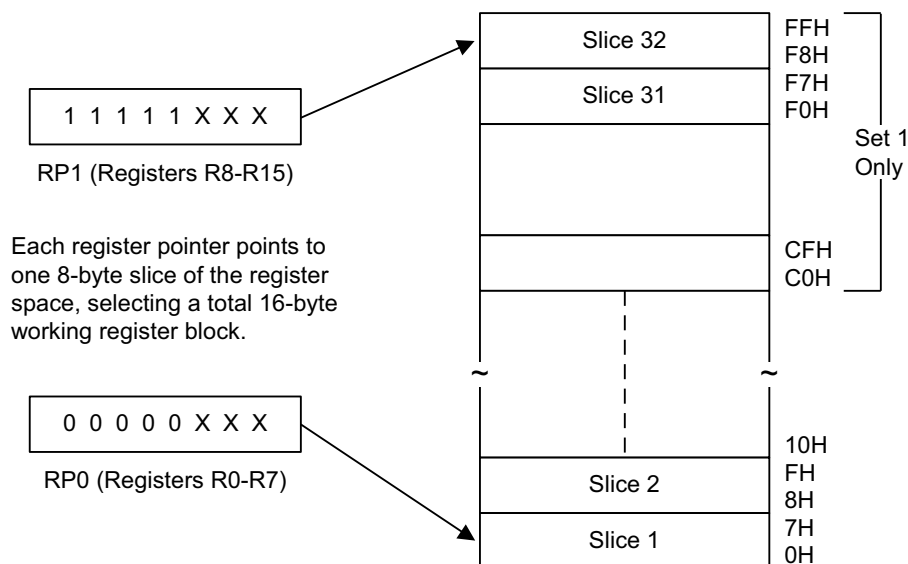


Figure 18. 8-Byte Working Register Areas

Using the Register Pointers

Register pointers RP0 and RP1, mapped to addresses D6h and D7h in Set1, are used to select two movable 8-byte working register slices in the register file. After a reset, they point to the working register common area; RP0 points to addresses C0h–C7h, and RP1 points to addresses C8h–CFh.

To change a register pointer value, load a new value to RP0 and/or RP1 using an SRP or LD instruction; see Figures 19 and 20.

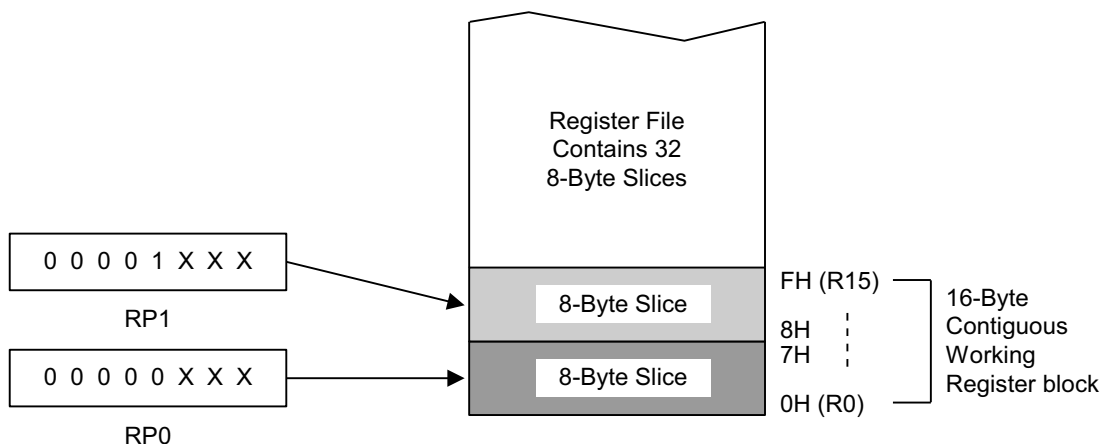


Figure 19. Contiguous 16-Byte Working Register Block

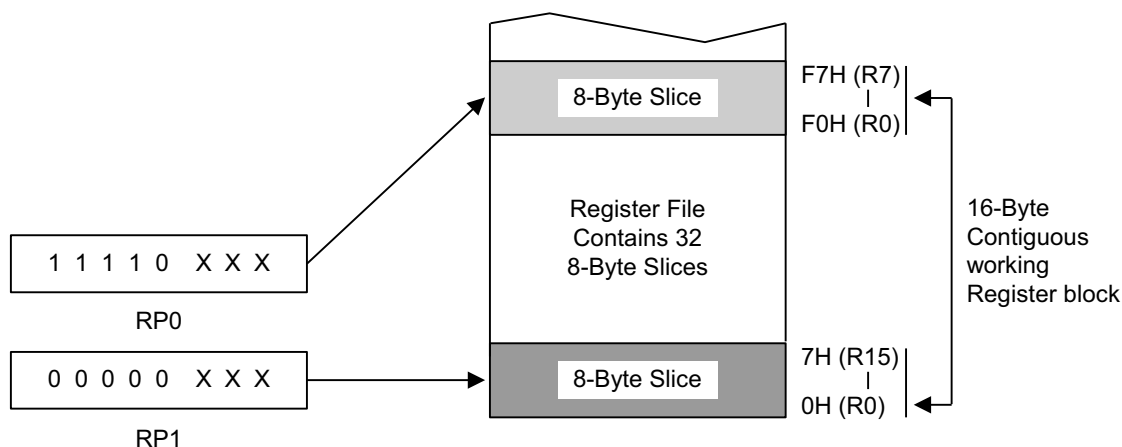


Figure 20. Noncontiguous 16-Byte Working Register Block

With working register addressing, you can only access those two 8-bit slices of the register file that are currently pointed to by RP0 and RP1. You cannot, however, use the register pointers to select a working register space in Set2, C0h–FFh, because these locations can be accessed only using the Indirect Register or Indexed addressing modes.

The selected 16-byte working register block usually consists of two contiguous 8-byte slices. As a general programming guideline, Zilog recommends that RP0 point to the lower slice, and that RP1 point to the upper slice; see Figure 19. In some cases, it may be

necessary to define working register areas in different (noncontiguous) areas of the register file. In Figure 20, RP0 points to the upper slice, and RP1 to the lower slice.

Because a register pointer can point to either of the two 8-byte slices in the working register block, the working register area can be flexibly defined to support program requirements.

Setting the Register Pointers

```
SRP      #70h          ; RP0 ← 70h, RP1 ← 78h
SRP1     #48h          ; RP0 ← no change, RP1 ← 48h
SRP0     #0A0h         ; RP0 ← A0h, RP1 ← no change
CLR      RP0           ; RP0 ← 00h, RP1 ← no change
LD       RP1, #0F8h    ; RP0 ← no change, RP1 ← 0F8h
```

Using Register Pointers to Calculate the Sum of a Series of Registers

Calculate the sum of registers 80h to 85h using the register pointer. The register addresses 80h through 85h contains the values 10h, 11h, 12h, 13h, 14h, and 15h, respectively:

```
SRP0     #80h          ; RP0 ← 80h
ADD      R0,R1         ; R0 ← R0 + R1
ADC      R0,R2         ; R0 ← R0 + R2 + C
ADC      R0,R3         ; R0 ← R0 + R3 + C
ADC      R0,R4         ; R0 ← R0 + R4 + C
ADC      R0,R5         ; R0 ← R0 + R5 + C
```

The sum of these six registers, 6Fh, is located in the R0 Register (80h). The instruction string used in this example takes 12 bytes of instruction code, and its execution time is 36 cycles. If the register pointer is not used to calculate the sum of these registers, the following instruction sequence must be used:

```
ADD      80h,81h ; 80h ← (80h) + (81h)
ADC      80h,82h ; 80h ← (80h) + (82h) + C
ADC      80h,83h ; 80h ← (80h) + (83h) + C
ADC      80h,84h ; 80h ← (80h) + (84h) + C
ADC      80h,85h ; 80h ← (80h) + (85h) + C
```

As a result, the sum of the six registers is also located in register 80h. However, this instruction string takes 15 bytes of instruction code rather than 12 bytes, and its execution time is 50 cycles rather than 36 cycles.

Register Pointer Registers

The contents of the Register Pointer 0 (RP0) and Register Pointer 1 (RP1) registers are described in Tables 4 and 5.

Table 4. Register Pointer 0 (RP0; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	1	1	0	0	0	–	–	–
R/W	R/W	R/W	R/W	R/W	R/W	–	–	–
Address	D6h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:3]	Register Pointer 0 Address Value Register pointer 0 can independently point to one of the 256-byte working register areas in the register file. Using register pointers RP0 and RP1, select two 8-byte register slices at one time as the active working register space. After a reset, RP0 points to C0h in register Set1, selecting the 8-byte working register slice C0h–C7h.
[2:0]	Reserved

Table 5. Register Pointer 1 (RP1; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	1	1	0	0	1	–	–	–
R/W	R/W	R/W	R/W	R/W	R/W	–	–	–
Address	D7h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:3]	Register Pointer 1 Address Value Register pointer 1 can independently point to one of the 256-byte working register areas in the register file. Using register pointers RP0 and RP1, select two 8-byte register slices at one time as the active working register space. After a reset, RP1 points to C8h in register Set1, selecting the 8-byte working register slice C8h–CFh.
[2:0]	Reserved

Register Addressing

The S3F8 Series register architecture provides an efficient method of working register addressing that takes full advantage of shorter instruction formats to reduce execution time.

With Register (R) Addressing Mode, in which an operand value is contained in a specific register or register pair, you can access all locations in the register file except for Set2.

With working register addressing, use a register pointer to specify an 8-byte working register space in the register file and an 8-bit register within that space.

Registers are addressed either as a single 8-bit register or as a paired 16-bit register space. In a 16-bit register pair, the address of the first 8-bit register is always an even number and the address of the next register is always an odd number. The most significant byte of the 16-bit data is always stored in the even-numbered register; the least significant byte is always stored in the next (+ 1) odd-numbered register.

Working register addressing differs from register addressing because it uses a register pointer to identify a specific 8-byte working register space in the internal register file, and a specific 8-bit register within that space; see Figures 21 and 22.

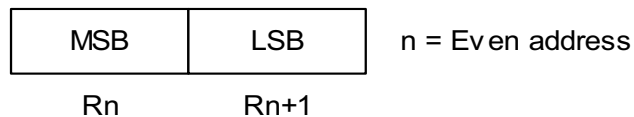


Figure 21. 16-Bit Register Pair

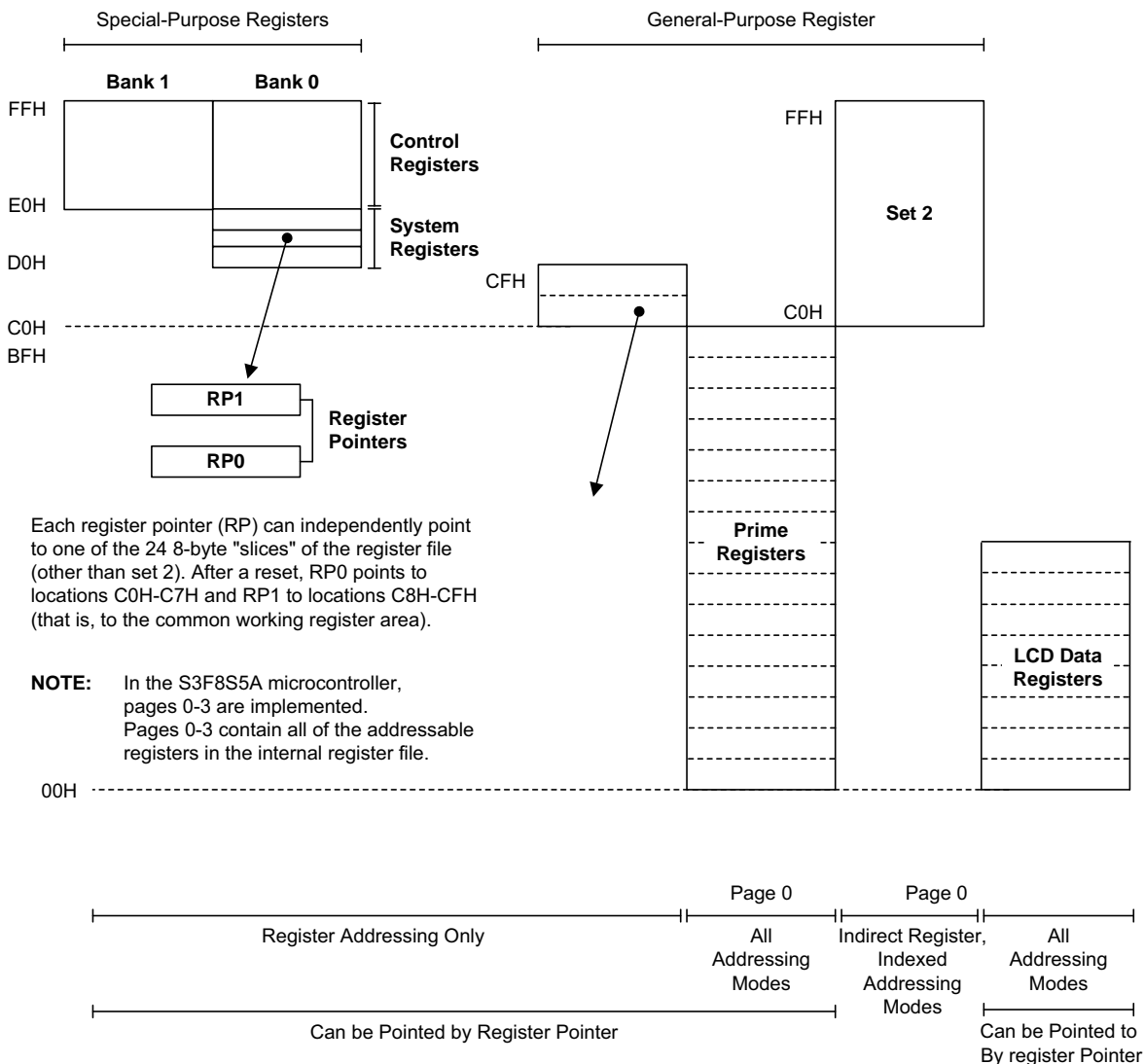


Figure 22. Register File Addressing

Common Working Register Area

After a reset, register pointers RP0 and RP1 automatically select two 8-byte register slices in Set1, locations C0h to CFh, as the active 16-byte working register block, as shown below.

- RP0 → C0h–C7h
- RP1 → C8h–CFh

This 16-byte address range is called the *common working area*. Essentially, locations in this area can be used as working registers by operations that address any location on any page in the register file. Typically, these working registers serve as temporary buffers for data operations. See Figure 23.

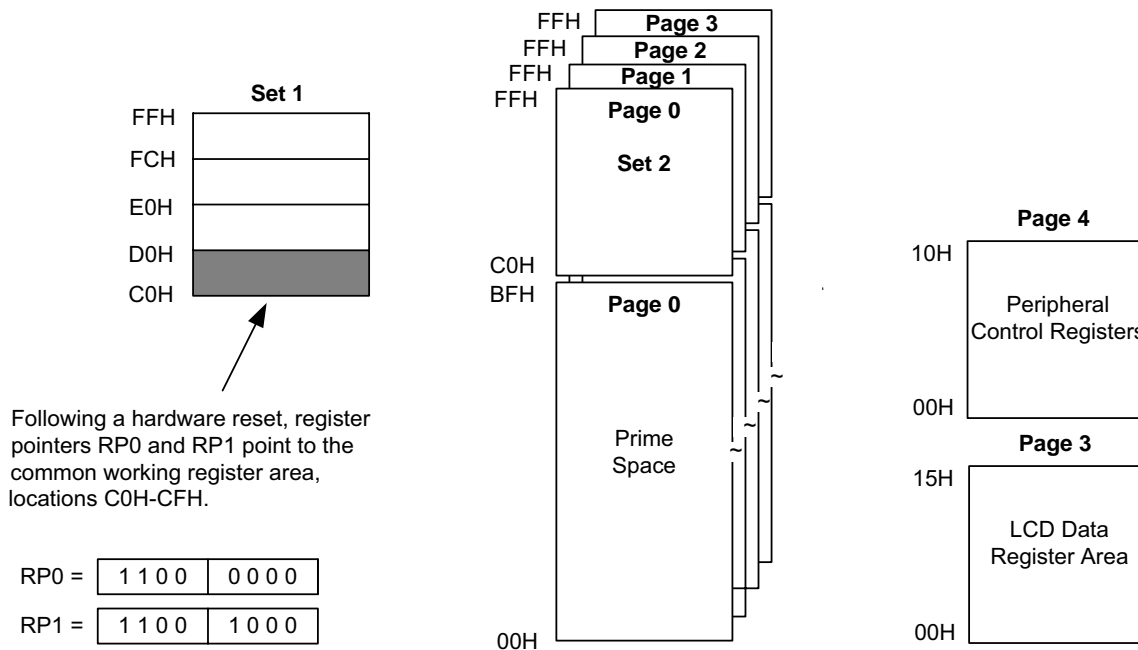


Figure 23. Common Working Register Area

Addressing the Common Working Register Area

As the following two examples show, you should access working registers in the common area, locations C0h to CFh, using working Register Addressing Mode only.

Example 1

```
LD      0C2h, 40h    ; Invalid addressing mode!
```

Use working register addressing instead:

```
SRP     #0C0h
LD      R2, 40h     ; R2 (C2h) ← the value in location 40h
```

Example 2

```
ADD     0C3h, #45h  ; Invalid addressing mode!
```

Use working register addressing instead:

```
SRP     #0C0h
ADD     R3, #45h    ; R3 (C3h) ← R3 + 45h
```


4-Bit Working Register Addressing

Each register pointer defines a movable 8-byte slice of working register space. The address information stored in a register pointer serves as an addressing window that makes it possible for instructions to access working registers very efficiently using short 4-bit addresses. When an instruction addresses a location in the selected working register area, the address bits are concatenated in the following way to form a complete 8-bit address:

- The high-order bit of the 4-bit address selects one of the register pointers (i.e., 0 selects RP0, 1 selects RP1)
- The five high-order bits in the register pointer select an 8-byte slice of the register space.
- The three low-order bits of the 4-bit address select one of the eight registers in the slice

As shown in Figure 24, the result of this operation is that the five high-order bits from the register pointer are concatenated with the three low-order bits from the instruction address to form the complete address. As long as the address stored in the register pointer remains unchanged, the three bits from the address will always point to an address in the same 8-byte register slice.

Figure 25 shows a typical example of 4-bit working register addressing. The high-order bit of the instruction INC-R6 is 0, which selects RP0. The five high-order bits stored in RP0 (01110b) are concatenated with the three low-order bits of the instruction's 4-bit address (110b) to produce the register address 76h (01110110b).

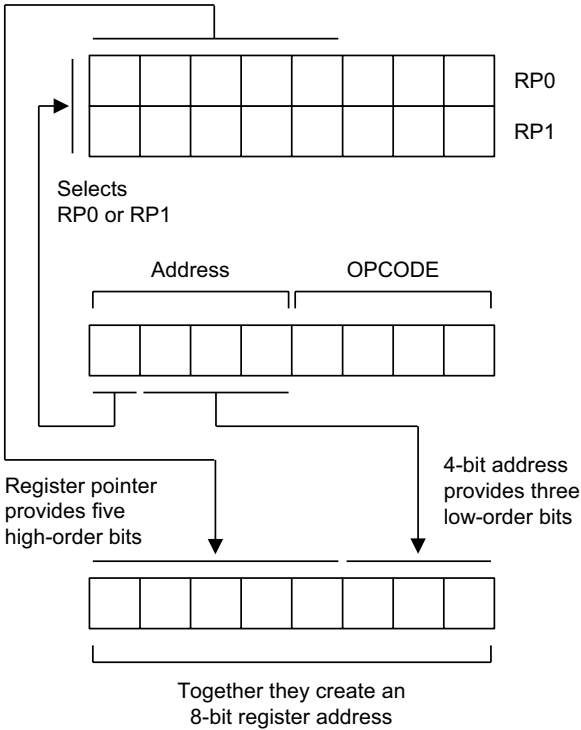


Figure 24. 4-Bit Working Register Addressing

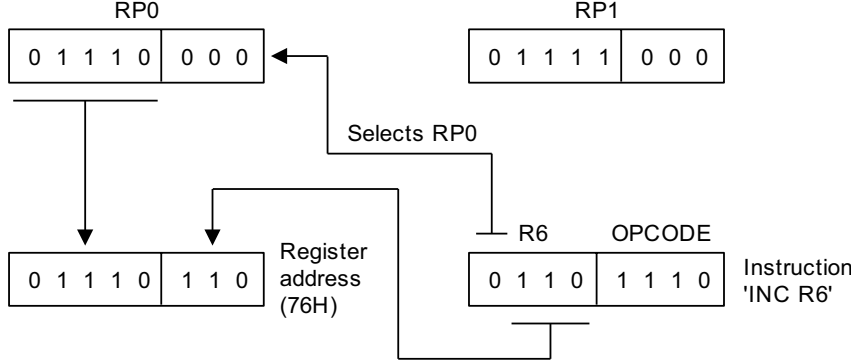


Figure 25. 4-Bit Working Register Addressing Example

8-Bit Working Register Addressing

Use 8-bit working register addressing to access registers in a selected working register area. To initiate 8-bit working register addressing, the upper four bits of the instruction address must contain the 4-bit value, 1100b. This value indicates that the remaining four bits have the same effect as 4-bit working register addressing.

As shown in Figure 26, the lower nibble of the 8-bit address is concatenated in much the same way as for 4-bit addressing: bit 3 selects either RP0 or RP1, which then supplies the five high-order bits of the final address. The three low-order bits of the complete address are provided by the original instruction.

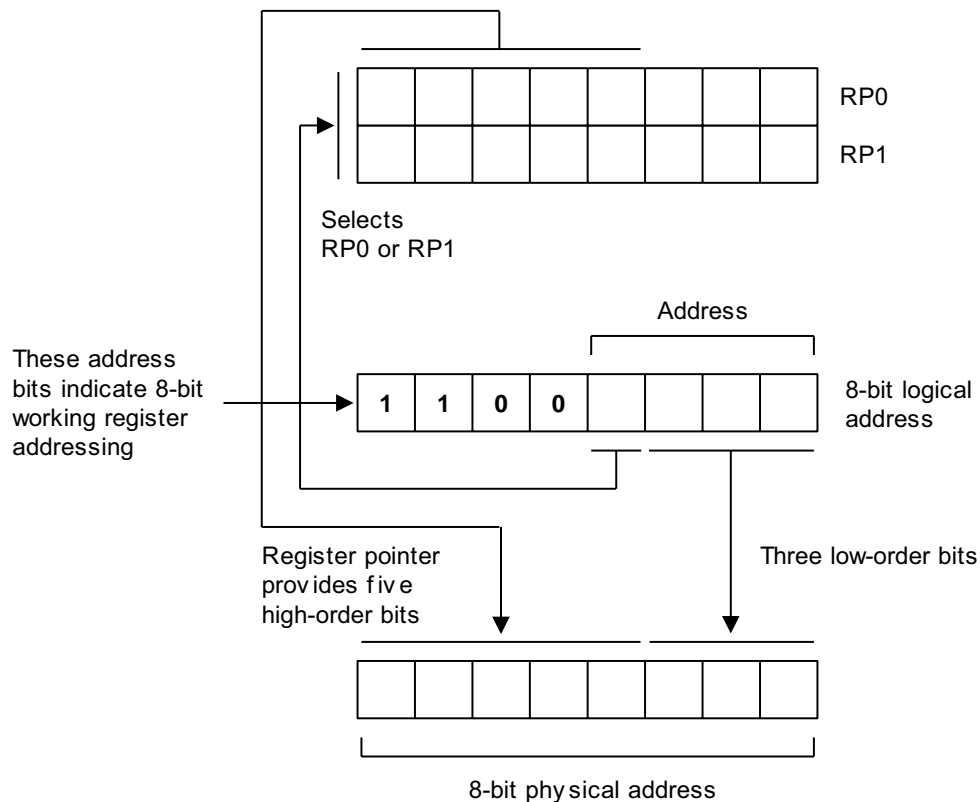


Figure 26. 8-Bit Working Register Addressing

Figure 27 shows an example of 8-bit working register addressing. The four high-order bits of the instruction address (1100b) specify 8-bit working register addressing. Bit 4 (1) selects RP1, and the five high-order bits in RP1 (10101b) become the five high-order bits of the register address. The three low-order bits of the register address (011) are provided by the three low-order bits of the 8-bit instruction address. The five-address bits from RP1

and the three address bits from the instruction are concatenated to form the complete register address, 0ABh (10101011b).

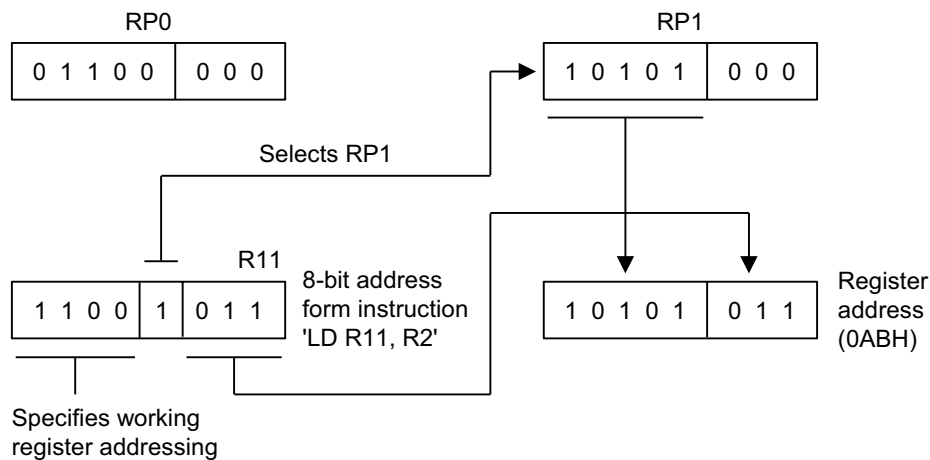


Figure 27. 8-Bit Working Register Addressing Example

System and User Stack

S3F8 Series microcontrollers use the system stack for subroutine calls and returns and to store data. The PUSH and POP instructions are used to control system stack operations. The S3F8S5A architecture supports stack operations in the internal register file.

Stack Operations

Return addresses for procedure calls, interrupts, and data are stored on the stack. The contents of the PC are saved to stack by a CALL instruction and restored by the RET instruction. When an interrupt occurs, the contents of the PC and the Flags registers are pushed to the stack. The IRET instruction then pops these values back to their original locations. The stack address value is always decreased by one before a push operation and increased by one after a pop operation. The stack pointer (SP) always points to the stack frame stored on the top of the stack, as shown in Figure 28.

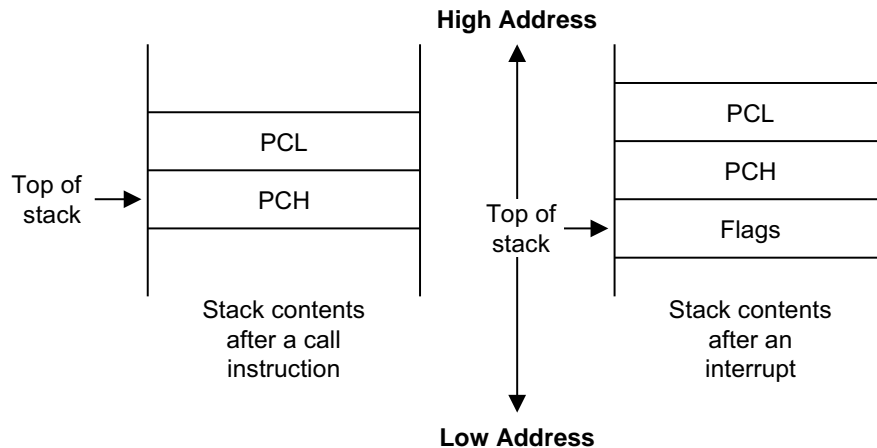


Figure 28. Stack Operations

User-Defined Stacks

Stacks in the internal register file can be defined as data storage locations. The PUSHUI, PUSHUD, POPUI, and POPUD instructions support user-defined stack operations.

Stack Pointers

Register locations D8h and D9h contain the 8-bit stack pointer (SPL) that is used for system stack operations. The most significant byte of the SP address, SP15–SP8, is stored in the SPH Register (D8h), and the least significant byte, SP7–SP0, is stored in the SPL Register (D9h). After a reset, the SP value is undetermined.

Because only internal memory space is implemented in the S3F8S5A MCU, the SPL must be initialized to an 8-bit value in the range 00h–FFh. The SPH Register is not required and can be used as a general-purpose register, if necessary.

When the SPL Register contains the only stack pointer value (i.e., when it points to a system stack in the register file), you can use the SPH Register as a general-purpose data register. However, if an overflow or underflow condition occurs as a result of increasing or decreasing the stack address value in the SPL Register during normal stack operations, the value in the SPL Register will overflow (or underflow) to the SPH Register, thereby overwriting any other data that is currently stored there. To avoid overwriting data in the SPH Register, initialize the SPL value to FFh instead of 00h.

The contents of the Stack Pointer High Byte (SPH) and Stack Pointer Low Byte (SPL) registers are described in Tables 6 and 7.

Table 6. Stack Pointer High Byte Register (SPH; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W	R/W							
Address	D8h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	<p>Stack Pointer Address High Byte</p> <p>The high-byte stack pointer value is the upper eight bits of the 16-bit stack pointer address (SP15–SP8). The lower byte of the stack pointer value is located in register SPL (D9H). The SP value is undefined following a reset.</p>

Table 7. Stack Pointer Low Byte Register (SPL; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W	R/W							
Address	D9h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	<p>Stack Pointer Address Low Byte</p> <p>The low-byte stack pointer value is the lower eight bits of the 16-bit stack pointer address (SP7–SP0). The upper byte of the stack pointer value is located in register SPH (D8H). The SP value is undefined following a reset.</p>

The following example shows how to perform stack operations in the internal register file using the PUSH and POP instructions.

Standard Stack Operations Using PUSH and POP

```
LD      SPL, #0FFh ; SPL ← FFh; (Normally, the SPL is set to
                    ; 0FFh by the initialization
```

```
                                ; routine)
•
•
•
PUSH    PP                ; Stack address 0FEh ← PP
PUSH    RP0               ; Stack address 0FDh ← RP0
PUSH    RP1               ; Stack address 0FCh ← RP1
PUSH    R3                ; Stack address 0FBh ← R3
•
•
•
POP     R3                ; R3 ← Stack address 0FBh
POP     RP1               ; RP1 ← Stack address 0FCh
POP     RP0               ; RP0 ← Stack address 0FDh
POP     PP                ; PP ← Stack address 0FEh
```

Addressing Modes

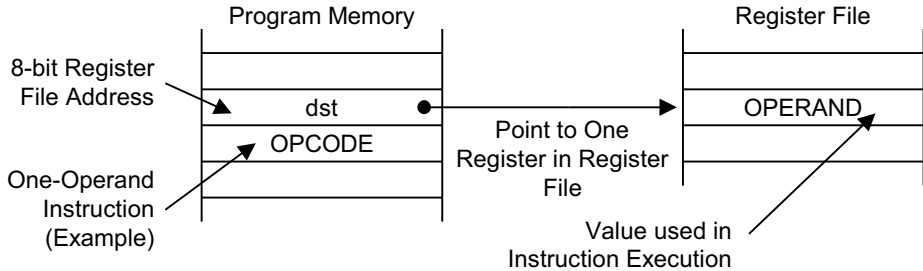
The program counter is used to fetch instructions that are stored in program memory for execution. Instructions indicate the operation to be performed and the data to be operated on. Addressing Mode is the method used to determine the location of the data operand. The operands specified in instructions may be condition codes, immediate data, or a location in the register file, program memory, or data memory.

The S3F8 Series instruction set supports the following seven explicit addressing modes; not all of these addressing modes are available for each instruction.

- Register (R)
- Indirect Register (IR)
- Indexed (X)
- Direct Address (DA)
- Indirect Address (IA)
- Relative Address (RA)
- Immediate (IM)

Register Addressing Mode

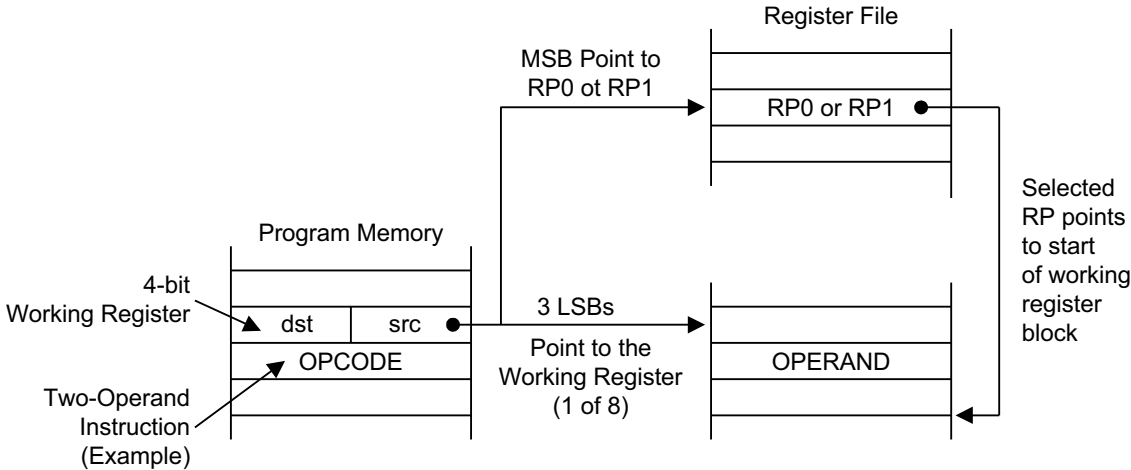
In Register Addressing Mode (R), the operand is the content of a specified register or register pair; see Figure 29. Working register addressing differs from register addressing because it uses a register pointer to specify an 8-byte working register space in the register file and an 8-bit register within that space; see Figure 30.



Sample Instruction:

DEC CNTR ; Where CNTR is the label of an 8-bit register address

Figure 29. Register Addressing



Sample Instruction:

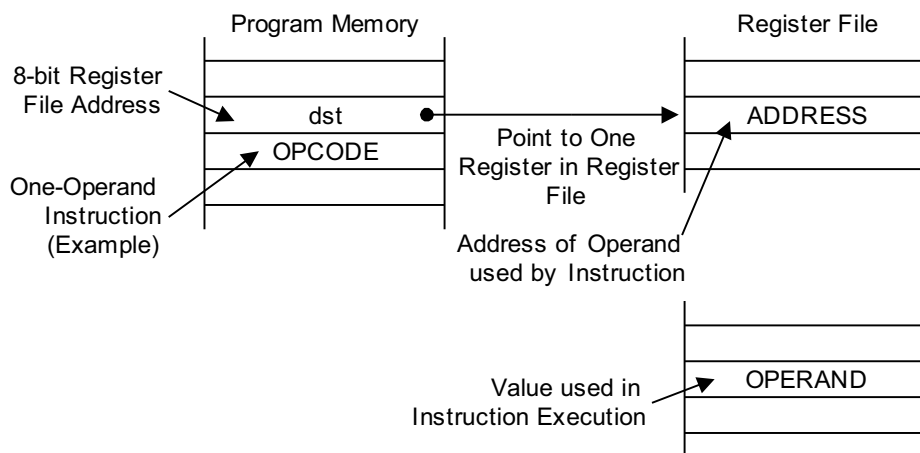
ADD R1, R2 ; Where R1 and R2 are registers in the currently selected working register area.

Figure 30. Working Register Addressing

Indirect Register Addressing Mode

In Indirect Register (IR) Addressing Mode, the contents of the specified register or register pair represent the address of the operand. Depending on the instruction used, the actual address may point to a register in the register file, to program memory (ROM), or to an external memory space, if implemented; see Figures 31 through 34.

Use any 8-bit register to indirectly address another register. Any 16-bit register pair can be used to indirectly address another memory location. Remember, however, that locations C0h–FFh in Set1 cannot be accessed using Indirect Register Addressing Mode.



Sample Instruction:

RL @SHIFT ; Where SHIFT is the label of an 8-bit register address

Figure 31. Indirect Register Addressing to Register File

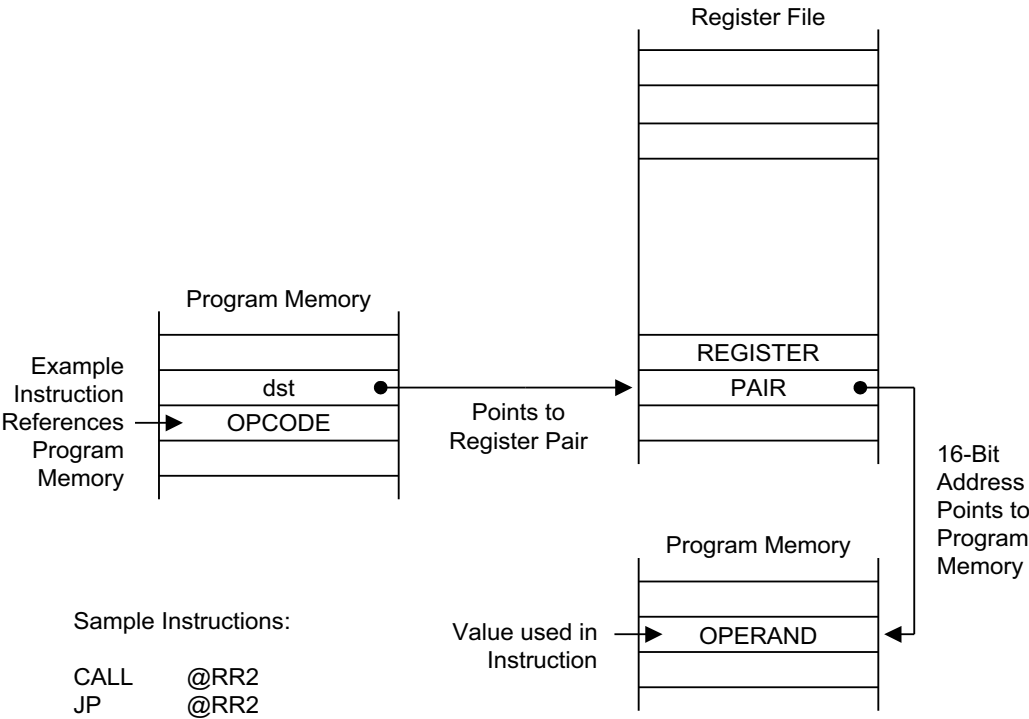


Figure 32. Indirect Register Addressing to Program Memory

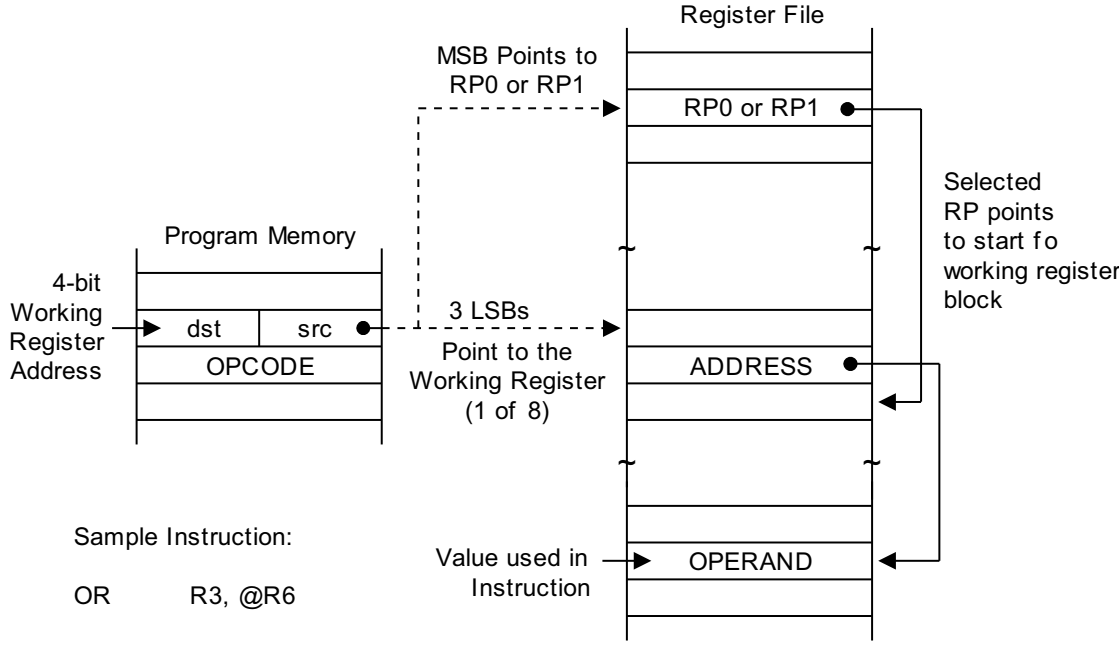
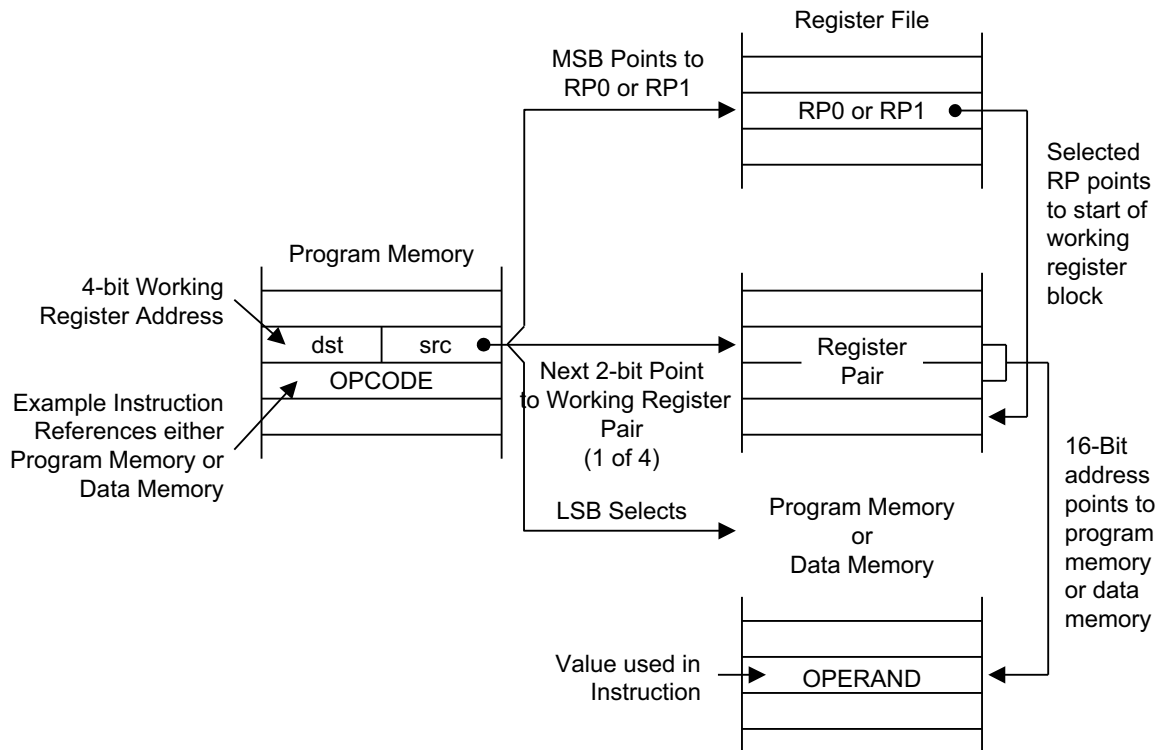


Figure 33. Indirect Working Register Addressing to Register File



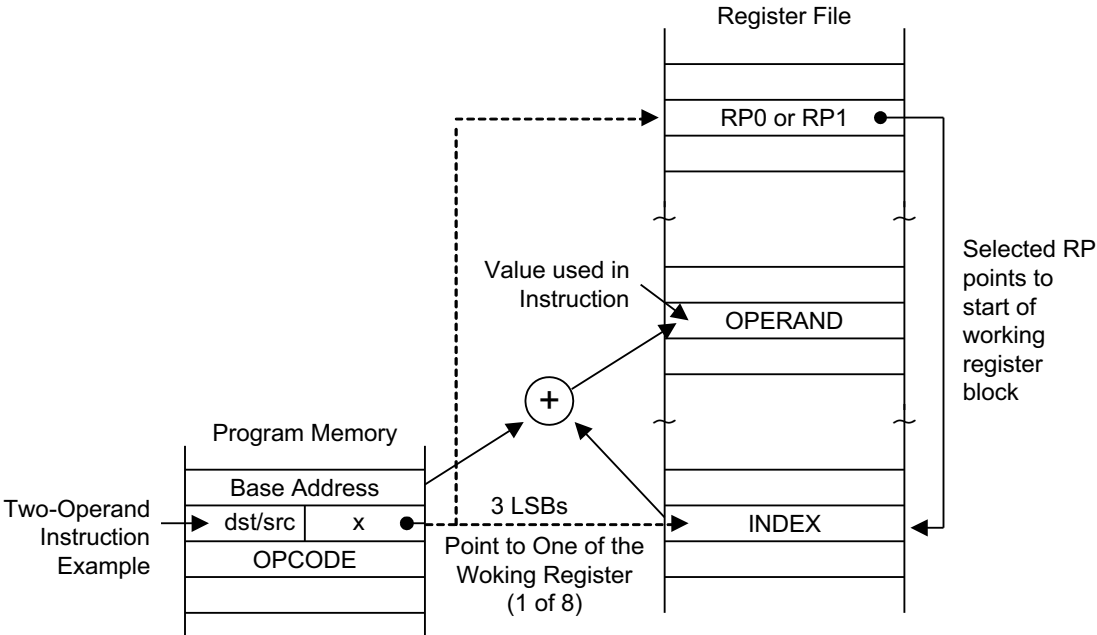
Sample Instructions:

```
LCD    R5,@RR6; Program memory access
LDE    R3,@RR14 ; External data memory access
LDE    @RR4, R8 ; External data memory access
```

Figure 34. Indirect Working Register Addressing to Program or Data Memory

Indexed Addressing Mode

Indexed (X) Addressing Mode adds an offset value to a base address during instruction execution to calculate the effective operand address; see Figure 35. Use Indexed Addressing Mode to access locations in the internal register file or in external memory (if implemented). You cannot, however, access locations C0h–FFh in Set1 using indexed addressing.

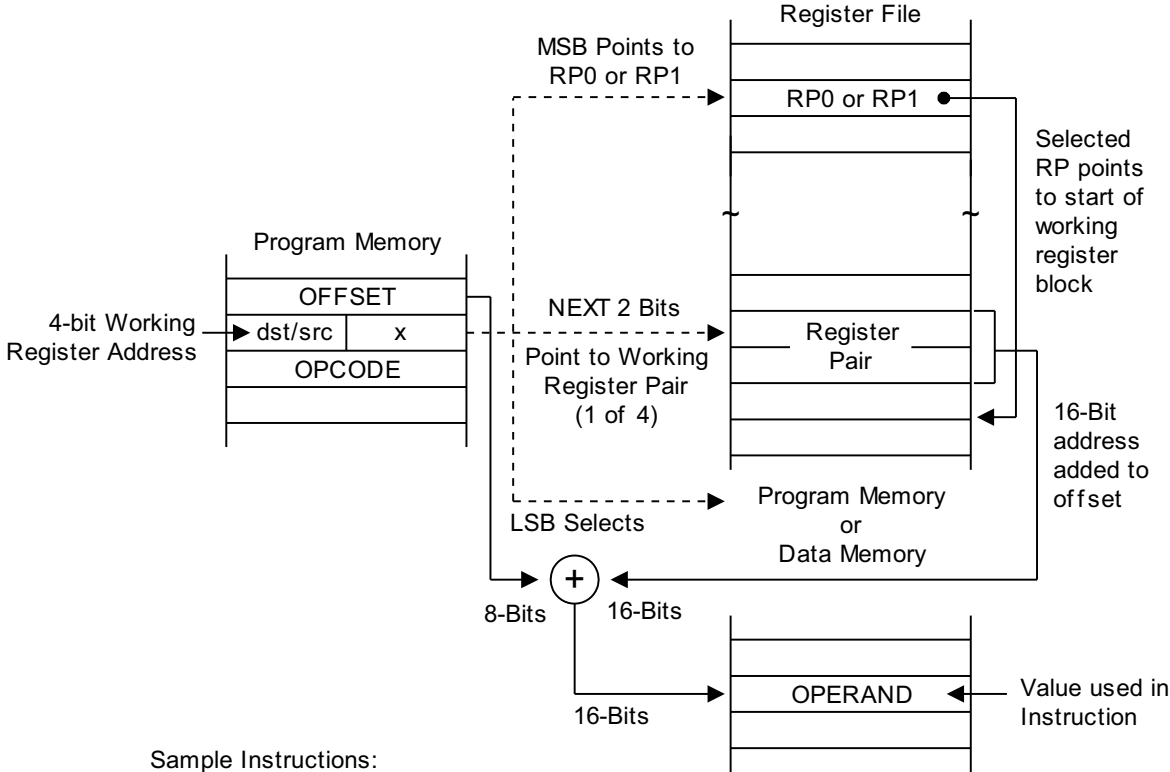


Sample Instruction:

```
LD R0, #BASE[R1] ; Where BASE is an 8-bit immediate value
```

Figure 35. Indexed Addressing to Register File

In short offset Indexed Addressing Mode, the 8-bit displacement is treated as a signed integer in the range -128 to +127. This displacement applies to external memory accesses only; see Figure 36.



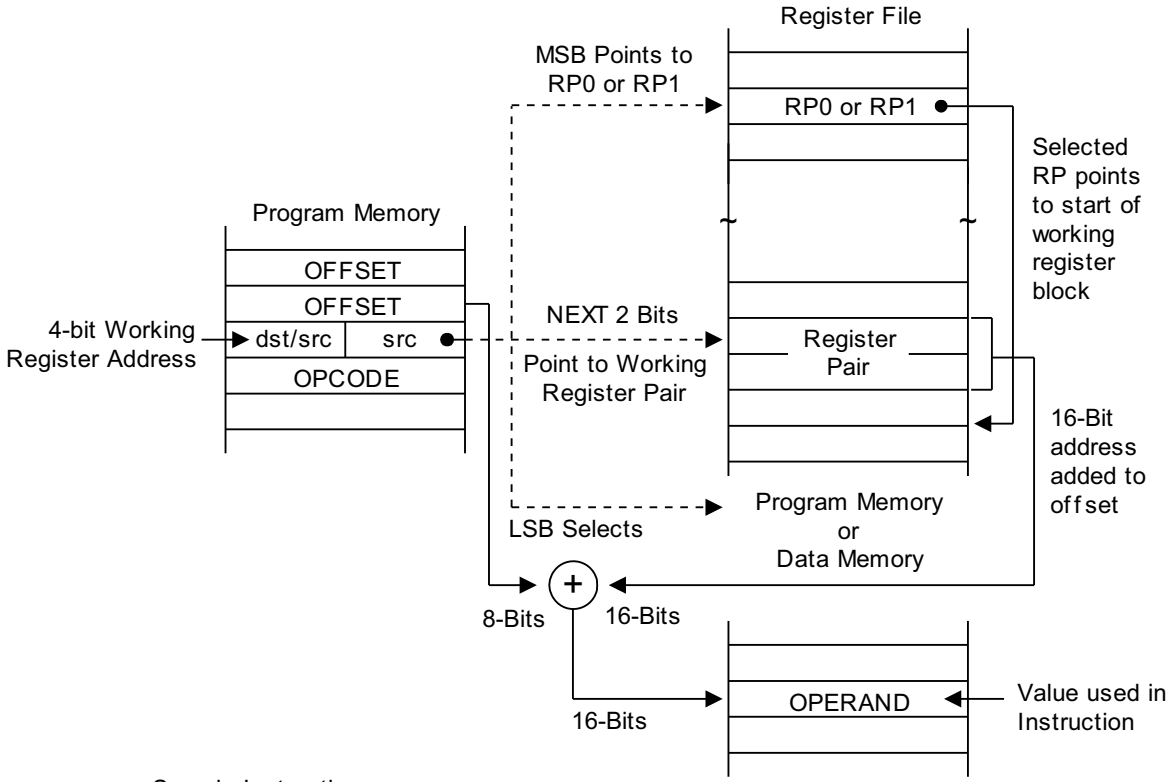
Sample Instructions:

```

LDC    R4, #04H[RR2]    ; The values in the program address (RR2 + 04H)
                        ; are loaded into register R4.
LDE    R4,#04H[RR2]    ; Identical operation to LDC example, except that
                        ; external program memory is accessed.
    
```

Figure 36. Indexed Addressing to Program or Data Memory with Short Offset

For register file addressing, an 8-bit base address provided by the instruction is added to an 8-bit offset contained in a working register. For external memory accesses, the base address is stored in the working register pair designated in the instruction. The 8-bit or 16-bit offset provided in the instruction is then added to the base address; see Figure 37.



Sample Instructions:

- LDC R4, #1000H[RR2] ; The values in the program address (RR2 + 1000H) are loaded into register R4.
- LDE R4, #1000H[RR2] ; Identical operation to LDC example, except that external program memory is accessed.

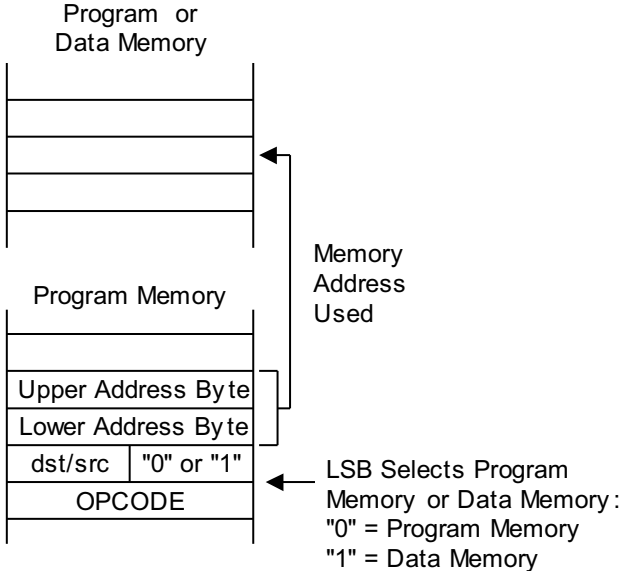
Figure 37. Indexed Addressing to Program or Data Memory

The only instruction that supports Indexed Addressing Mode for the internal register file is the Load instruction (LD). The LDC and LDE instructions support Indexed Addressing Mode for internal program memory and for external data memory (if implemented).

Direct Address Mode

In Direct Address (DA) Mode, the instruction provides the operand’s 16-bit memory address. Jump (JP) and Call (CALL) instructions use this addressing mode to specify the 16-bit destination address that is loaded into the PC whenever a JP or CALL instruction is executed.

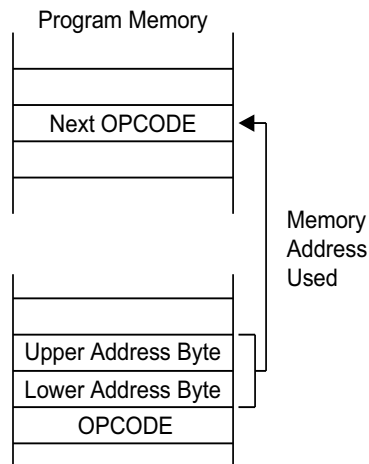
The LDC and LDE instructions can use Direct Address Mode to specify the source or destination address for Load operations to program memory (LDC) or to external data memory (LDE), if implemented. See Figures 38 and 39.



Sample Instructions:

- LDC R5,1234H ; The values in the program address (1234H) are loaded into register R5.
- LDE R5,1234H ; Identical operation to LDC example, except that external program memory is accessed.

Figure 38. Direct Addressing for Load Instructions



Sample Instructions:

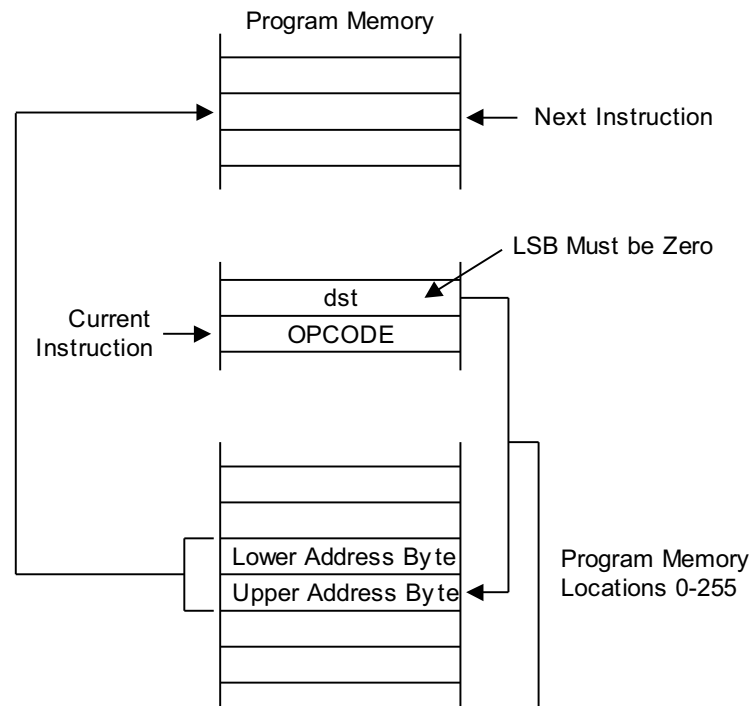
JP C, JOB1 ; Where JOB1 is a 16-bit immediate address
CALL DISPLAY ; Where DISPLAY is a 16-bit immediate address

Figure 39. Direct Addressing for Call and Jump Instructions

Indirect Address Mode

In Indirect Address (IA) Mode, the instruction specifies an address located in the lowest 256 bytes of program memory. The selected pair of memory locations contains the actual address of the next instruction to be executed. Only the CALL instruction can use Indirect Address Mode.

Because Indirect Address Mode assumes that the operand is located in the lowest 256 bytes of program memory, only an 8-bit address is supplied in the instruction; the upper bytes of the destination address are assumed to be all zeros. See Figure 40.



Sample Instruction:

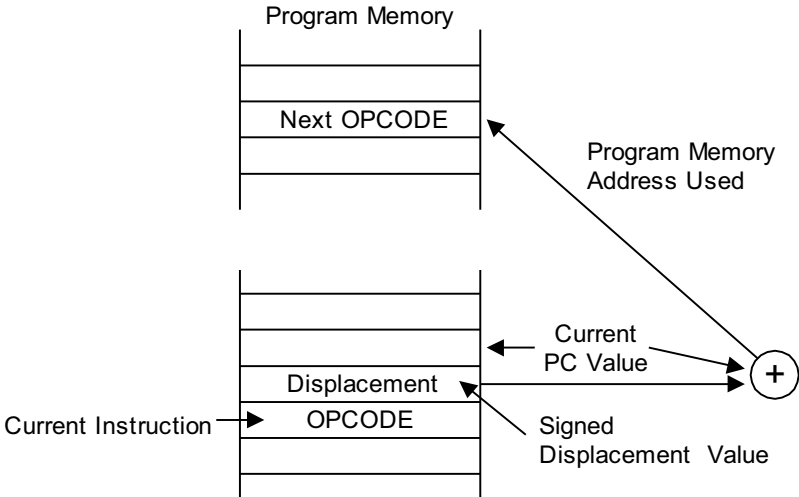
```
CALL #40h ; The 16-bit value in program memory addresses 40h
           and 41h is the subroutine start address.
```

Figure 40. Indirect Addressing

Relative Address Mode

In Relative Address (RA) Mode, a two's-complement signed displacement between -128 and $+127$ is specified in the instruction. This displacement value is then added to the current PC value. The result is the address of the next instruction to be executed. Before this addition occurs, the PC contains the address of the instruction immediately following the current instruction.

Several program control instructions use Relative Address Mode to perform conditional jumps. The instructions that support RA addressing are BTJRF, BTJRT, DJNZ, CPIJE, CPIJNE, and JR. See Figure 41.



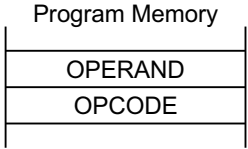
Sample Instructions:

```
JR    ULT,$+OFFSET    ; Where OFFSET is a value in the range +127 to -128
```

Figure 41. Relative Addressing

Immediate Mode

In Immediate (IM) Addressing Mode, the operand value used in the instruction is the value supplied in the operand field itself. The operand may be one byte or one word in length, depending on the instruction used. Immediate Addressing Mode is useful for loading constant values into registers. See Figure 42.



(The Operand value is in the instruction)

Sample Instruction:

```
LD    R0,#0AAH
```

Figure 42. Immediate Addressing

Control Registers

This chapter describes the S3F8S5A MCU's control registers. Data and counter registers are not described in this chapter; information about all registers used by a specific peripheral is presented in corresponding chapters.

Table 8 identifies the names, mnemonics, decimal and hex equivalents, and read/write settings of the Set1, Bank0 mapped registers; click to the linked page to review the contents of each. The hardware reset value for each mapped register is described in the [Reset and Power-Down](#) chapter on page 194.

Table 8. Set1 Registers

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
Basic Timer Control	230	BTCON	211	D3h	RW
System Clock Control	190	CLKCON	212	D4h	RW
Flags	86	FLAGS	213	D5h	RW
Register Pointer 0	32	RP0	214	D6h	RW
Register Pointer 1	32	RP1	215	D7h	RW
Stack Pointer High Byte	41	SPH	216	D8h	RW
Stack Pointer Low Byte	41	SPL	217	D9h	RW
Instruction Pointer High Byte	79	IPH	218	DAh	RW
Instruction Pointer Low Byte	80	IPL	219	DBh	RW
Interrupt Request	74	IRQ	220	DCh	R
Interrupt Mask	71	IMR	221	DDh	RW
System Mode	70	SYM	222	DEh	RW
Register Page Pointer	25	PP	223	DFh	RW

Table 9 identifies the names, mnemonics, decimal and hex equivalents, and read/write settings of the Page 4 registers.

Table 9. Page 4 Registers

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
Reset Source Indicating	200	RESETID	0	00h	RW
Timer D0 Control	251	TD0CON	1	01h	RW
Timer D0 Counter High Byte	–	TD0CNTH	2	02h	R
Timer D0 Counter Low Byte	–	TD0CNTL	3	03h	R
Timer D0 Data High Byte	–	TD0DATAH	4	04h	RW

Table 9. Page 4 Registers (Continued)

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
Timer D0 Data Low Byte	–	TD0DATAL	5	05h	RW
Timer D1 Control	258	TD1CON	10	0Ah	RW
Timer D1 Counter High Byte	–	TD1CNTH	6	06h	R
Timer D1 Counter Low Byte	–	TD1CNTL	7	07h	R
Timer D1 Data High Byte	–	TD1DATAH	8	08h	RW
Timer D1 Data Low Byte	–	TD1DATAL	9	09h	RW

Table 10. Set1, Bank0 Registers

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
A/D Converter Data High Byte	282	ADDATAH	208	D0h	R
A/D Converter Data Low Byte	282	ADDATAL	209	D1h	R
A/D Converter Control	281	ADCON	210	D2h	RW
Timer A Counter	–	TACNT	224	E0h	R
Timer A Data	–	TADATA	225	E1h	RW
Timer A Control	234	TACON	226	E2h	RW
Timer B Control	240	TBCON	227	E3h	RW
Timer B Data High Byte	–	TBDATAH	228	E4h	RW
Timer B Data Low Byte	–	TBDATAL	229	E5h	RW
Timer B Clock Selection	241	TBCLKS	230	E6h	RW
SIO Control	286	SIOCON	231	E7h	RW
SIO Data	–	SIODATA	232	E8h	RW
SIO prescaler	287	SIOPS	233	E9h	RW
Timer C Counter	–	TCCNT	234	EAh	R
Timer C Data	–	TCDATA	235	EBh	RW
Timer C Control	248	TCCON	236	ECh	RW
STOP Control	192	STPCON	237	EDh	RW
UART 0 Control High Byte	291	UART0CONH	238	EEh	RW
UART 0 Control Low Byte	294	UART0CONL	239	EFh	RW
UART 0 Data	295	UDATA0	240	F0h	RW
UART 0 Baud Rate Data	295	BRDATA0	241	F1h	RW
UART 1 Control High Byte	308	UART1CONH	242	F2h	RW
UART 1 Control Low Byte	310	UART1CONL	243	F3h	RW

Table 10. Set1, Bank0 Registers (Continued)

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
UART 1 Data	311	UDATA1	244	F4h	RW
UART 1 Baud Rate Data	311	BRDATA1	245	F5h	RW
Flash Memory Sector Address High Byte	337	FMSECH	246	F6h	RW
Flash Memory Sector Address Low Byte	338	FMSECL	247	F7h	RW
Flash Memory User Programming Enable	336	FMUSR	248	F8h	RW
Flash Memory Control	335	FMCON	249	F9h	RW
Oscillator Control	191	OSCCON	250	FAh	RW
Interrupt Pending	76	INTPND	251	FBh	RW
Location FCH is not mapped.					
Basic Timer Counter	–	BTCNT	253	FDh	R
Location FEH is not mapped.					
Interrupt Priority	73	IPR	255	FFh	RW

Table 11. Set1, Bank1 Registers

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
Port 0 Control	205	P0CON	208	D0h	RW
Port 0 Pull-up Resistor Enable	206	P0PUR	209	D1h	RW
Port 1 n-Channel Open-Drain Mode	213	PNE1	210	D2h	RW
Port 1 Control High Byte	208	P1CONH	224	E0h	RW
Port 1 Control Low Byte	209	P1CONL	225	E1h	RW
Port 1 Pull-up Resistor Enable	212	P1PUR	226	E2h	RW
Port 1 Interrupt Control	210	P1INT	227	E3h	RW
Port 1 Interrupt Pending	211	P1PND	228	E4h	RW
Port 2 n-Channel Open-Drain Mode	217	PNE2	229	E5h	RW
Port 2 Control High Byte	214	P2CONH	230	E6h	RW
Port 2 Control Low Byte	215	P2CONL	231	E7h	RW
Port 2 Pull-up Resistor Enable	216	P2PUR	232	E8h	RW
Port 3 n-Channel Open-Drain Mode	223	PNE3	233	E9h	RW
Port 3 Control High Byte	219	P3CONH	234	EAh	RW
Port 3 Control (Mid Byte)	220	P3CONM	235	EBh	RW

Table 11. Set1, Bank1 Registers (Continued)

Register Name	Page #	Mnemonic	Decimal	Hex	R/W
Port 3 Control Low Byte	221	P3CONL	236	ECh	RW
Port 3 Pull-up Resistor Enable	222	P3PUR	237	EDh	RW
Port 4 Control High Byte	224	P4CONH	238	EEh	RW
Port 4 Control Low Byte	225	P4CONL	239	EFh	RW
Port 0 Data	–	P0	240	F0h	RW
Port 1 Data	–	P1	241	F1h	RW
Port 2 Data	–	P2	242	F2h	RW
Port 3 Data	–	P3	243	F3h	RW
Port 4 Data	–	P4	244	F4h	RW
Port 4 Pull-up Resistor Enable	228	P4PUR	245	F5h	RW
Port 4 Interrupt Control	226	P4INT	246	F6h	RW
Port 4 Interrupt Pending	227	P4PND	247	F7h	RW
Pattern Generation Control	324	PGCON	248	F8h	RW
Pattern Generation Data	–	PGDATA	249	F9h	RW
LCD Control	266	LCON	250	FAh	RW
PWM Control	330	PWMCON	251	FBh	RW
PWM Data High Byte	–	PWMDATAH	252	FCh	RW
PWM Data Low Byte	–	PWMDATAL	253	FDh	RW
Watch Timer Control	265	WTCON	254	FEh	RW
Location FFh is not mapped.					

Interrupt Structure

The S3F8 Series interrupt structure has three basic components: levels, vectors, and sources. The SAM88 RC CPU recognizes up to eight interrupt levels and supports up to 128 interrupt vectors. When a specific interrupt level has more than one vector address, the vector priorities are established in hardware. A vector address can be assigned to one or more sources.

Levels

Interrupt levels are the main unit for interrupt priority assignment and recognition. All peripherals and I/O blocks can issue interrupt requests. In other words, peripheral and I/O operations are interrupt-driven. There are eight possible interrupt levels: IRQ0–IRQ7, also called *Level 0–Level 7*. Each interrupt level directly corresponds to an interrupt request number (IRQn). The total number of interrupt levels used in the interrupt structure varies from device to device. The S3F8S5A MCU's interrupt structure recognizes eight interrupt levels.

The interrupt level numbers 0 through 7 do not necessarily indicate the relative priority of the levels; they are simply identifiers for the interrupt levels that are recognized by the CPU. The relative priority of different interrupt levels is determined by settings in the Interrupt Priority (IPR) Register. Interrupt group and subgroup logic controlled by IPR Register settings lets you define more complex priority relationships between different levels.

Vectors

Each interrupt level can have one or more interrupt vectors, or it may have no vector address assigned at all. The maximum number of vectors that can be supported for a given level is 128. (The actual number of vectors used for S3F8 Series devices is always much smaller.) If an interrupt level has more than one vector address, the vector priorities are set in hardware. The S3F8S5A MCU uses 22 vectors.

Sources

A source is any peripheral that generates an interrupt. For example, a source can be an external pin or a counter overflow. Each vector can have several interrupt sources. In the S3F8S5A MCU's interrupt structure, there are 22 possible interrupt sources.

When a service routine starts, the respective pending bit is either cleared automatically by hardware or must be cleared manually by program software. The characteristics of the source's pending mechanism determine which method is used to clear its respective pending bit.

Interrupt Types

The three components of the S3F8 Series interrupt structure described previously – levels, vectors, and sources – are combined to determine the interrupt structure of an individual device and to make full use of its available interrupt logic. There are three possible combinations of interrupt structure components, called interrupt types 1, 2, and 3. These three types differ in the number of vectors and interrupt sources assigned to each level, as follows.

- Type 1: 1 level (IRQ_n)+1 vector (V₁)+one source (S₁)
- Type 2: 1 level (IRQ_n)+1 vector (V₁)+multiple sources (S₁–S_n)
- Type 3: 1 level (IRQ_n)+multiple vectors (V₁–V_n)+multiple sources (S₁–S_n, S_{n+1}–S_{n+m})

In the S3F8S5A microcontroller, all three interrupt types are implemented; see Figure 43.

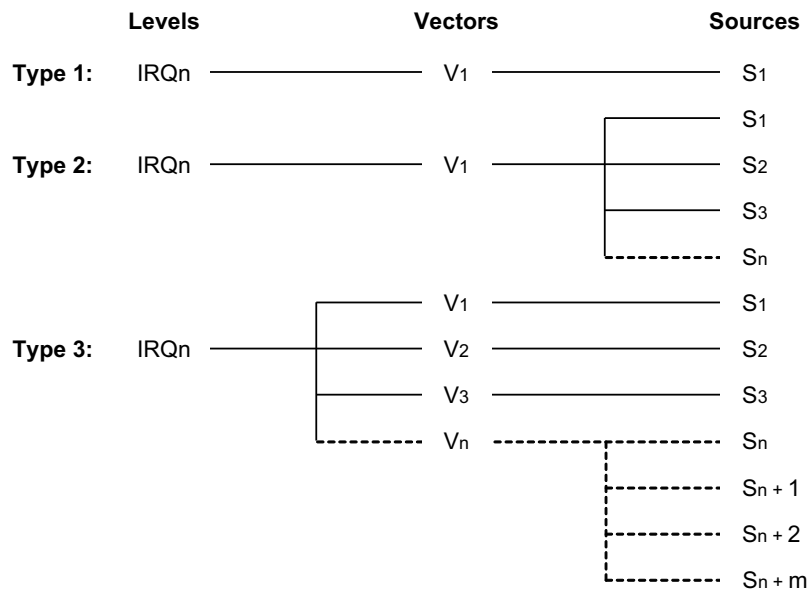


Figure 43. S3F8 Series Interrupt Types

► **Note:** In Figure 43, the number of S_n and V_n values is expandable. In the S3F8S5A implementation, interrupt types 1 and 3 are used.

S3F8S5A Interrupt Structure

The S3F8S5A microcontroller supports 22 interrupt sources. All 2 of the interrupt sources have a corresponding interrupt vector address. Eight interrupt levels are recognized by the CPU in this device-specific interrupt structure, as shown in Figure 44.

When multiple interrupt levels are active, the Interrupt Priority (IPR) Register determines the order in which contending interrupts are to be serviced. If multiple interrupts occur within the same interrupt level, the interrupt with the lowest vector address is usually processed first (The relative priorities of multiple interrupts within a single level are fixed in hardware).

When the CPU grants an interrupt request, interrupt processing starts: All other interrupts are disabled and the program counter value and status flags are pushed to stack. The starting address of the service routine is fetched from the appropriate vector address (plus the next 8-bit value to concatenate the full 16-bit address) and the service routine is executed.

Levels	Vectors	Sources	Reset/Clear
nRESET	100H	Basic Timer Overflow	H/W
IRQ0	CEH	Timer A Match/Capture	S/W
	D0H	Timer A Overflow	H/W, S/W
IRQ1	D2H	Timer B Match	H/W
IRQ2	D4H	Timer C Match/Overflow	H/W, S/W
	D6H	10-bit PWM overflow	H/W, S/W
IRQ3	D8H	Timer D0 Match/Capture	S/W
	DAH	Timer D0 Overflow	H/W, S/W
	DCH	Timer D1 Match/Capture	S/W
	DEH	Timer D1 Overflow	H/W, S/W
IRQ4	E4H	SIO Interrupt	S/W
	E6H	Watch Timer Overflow	S/W
IRQ5	E8H	UART 0 Data Transmit	S/W
	EAH	UART 0 Data Receive	S/W
	ECH	UART 1 Data Transmit	S/W
	EEH	UART 1 Data Receive	S/W
IRQ6	F0H	P1.0 External Interrupt	S/W
	F2H	P1.1 External Interrupt	S/W
	F4H	P1.2 External Interrupt	S/W
	F6H	P1.3 External Interrupt	S/W
IRQ7	F8H	P4.0 External Interrupt	S/W
	FAH	P4.1 External Interrupt	S/W
	FCH	P4.2 External Interrupt	S/W
	FEH	P4.3 External Interrupt	S/W

Figure 44. S3F8S5A Interrupt Structure

- **Notes:** 1. In Figure 44, within a given interrupt level, the low vector address has high priority. For example, within the IRQ0 level, CEh has higher priority than D0h. Priorities within each level are set at the factory.
- 2. External interrupts are triggered by a rising or falling edge, depending on the corresponding control register setting.

Interrupt Vector Addresses

All interrupt vector addresses for the S3F8S5A interrupt structure are stored in the vector address area of the internal 48KB ROM, 0h–BFFFh; see Figure 45.

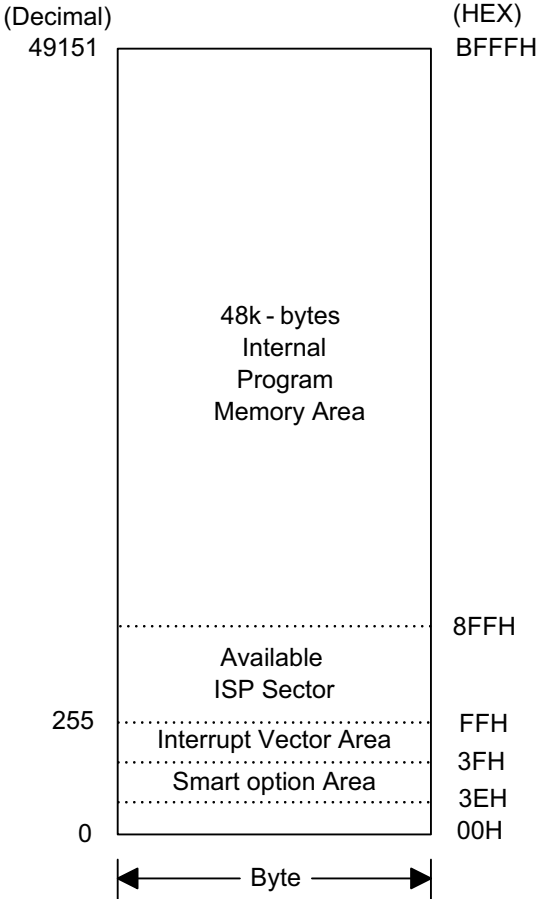


Figure 45. ROM Vector Address Area

Allocate unused locations in the vector address area as normal program memory. However, be careful not to overwrite any of the stored vector addresses, which are listed in Table 12.

Table 12. S3F8S5A Interrupt Vectors

Vector Address		Interrupt Source	Request		Reset/Clear	
Decimal Value	Hex Value		Interrupt Level	Priority in Level	Hardware	Software
256	100h	Basic Timer overflow	RESET	–	√	
206	CEh	Timer A match/capture	IRQ0	0	√	√
208	D0h	Timer A overflow	–	1	√	√
210	D2h	Timer B match	IRQ1	–	√	
212	D4h	Timer C match/overflow	IRQ2	0	√	√
214	D6h	10-bit PWM overflow	–	1	√	√
216	D8h	Timer D0 match/capture	IRQ3	0	√	√
218	DAh	Timer D0 overflow	–	1	√	√
220	DCh	Timer D1 match/capture	–	2	√	√
222	DEh	Timer D1 overflow	–	3	√	√
228	E4h	SIO interrupt	IRQ4	0	–	√
230	E6h	Watch timer overflow	–	1	–	√
232	E8h	UART 0 data transmit	IRQ5	0	–	√
234	EAh	UART 0 data receive	–	1	–	√
236	ECh	UART 1 data transmit	–	2	–	√
238	Eeh	UART 1 data receive	–	3	–	√
240	F0h	P1.0 external interrupt	IRQ6	0	–	√
242	F2h	P1.1 external interrupt	–	1	–	√
244	F4h	P1.2 external interrupt	–	2	–	√
246	F6h	P1.3 external interrupt	–	3	–	√
248	F8h	P4.0 external interrupt	IRQ7	0	–	√
250	FAh	P4.1 external interrupt	–	1	–	√
252	FCh	P4.2 external interrupt	–	2	–	√
254	FEh	P4.3 external interrupt	–	3	–	√

Note: Interrupt priorities are identified in inverse order: 0 is the highest priority, 1 is the next highest priority, etc. If two or more interrupts within the same level contend, the interrupt with the lowest vector address usually has priority over an interrupt with a higher vector address. Priorities within a given level are fixed in hardware.

Enable/Disable Interrupt Instructions

Executing the Enable Interrupt (EI) instruction globally enables the interrupt structure. All interrupts are then serviced as they occur, and according to the established priorities.

► **Note:** The system initialization routine that is executed following a reset must always contain an EI instruction to globally enable the interrupt structure.

During normal operation, the Disable Interrupt (DI) instruction can be executed at any time to globally disable interrupt processing. The EI and DI instructions change the value of bit 0 in the SYM Register.

System-Level Interrupt Control Registers

In addition to the control registers for specific interrupt sources, the following four system-level registers control interrupt processing.

- The Interrupt Mask (IMR) Register enables (unmasks) or disables (masks) interrupt levels
- The Interrupt Priority (IPR) Register controls the relative priorities of interrupt levels
- The Interrupt Request (IRQ) Register contains interrupt pending flags for each interrupt level (as opposed to each interrupt source)
- The System Mode (SYM) Register enables or disables global interrupt processing (SYM settings also enable fast interrupts and control the activity of external interface, if implemented)

A summary of these interrupt control registers is provided in Table 13.

Table 13. Interrupt Control Register Overview

Control Register	Mnemonic	R/W	Function Description
Interrupt Mask Register	IMR	R/W	Bit settings in the IMR Register enable or disable interrupt processing for each of the eight interrupt levels: IRQ0–IRQ7.
Interrupt Priority Register	IPR	R/W	Controls the relative processing priorities of the interrupt levels. The eight levels of the S3F8S5A MCU are organized into three groups: A, B and C. Group A is IRQ0 and IRQ1, group B is IRQ2, IRQ3, IRQ4 and group C is IRQ5, IRQ6 and IRQ7.

Note: Before an IMR Register value is changed, all interrupts must be disabled; Zilog recommends the DI instruction.

Table 13. Interrupt Control Register Overview (Continued)

Control Register	Mnemonic	R/W	Function Description
Interrupt Request Register	IRQ	R	This register contains a request pending bit for each interrupt level.
System Mode Register	SYM	R/W	A dynamic global interrupt processing enables/disables, fast interrupt processing, and external interface control (an external memory interface is not implemented in the S3F8S5A microcontroller).

Note: Before an IMR Register value is changed, all interrupts must be disabled; Zilog recommends the DI instruction.

Interrupt Processing Control Points

Interrupt processing can be controlled in either of two ways: either globally or by a specific interrupt level and source. The system-level control points in the interrupt structure are:

- Global interrupt enable and disable by EI and DI instructions or by a direct manipulation of SYM.0
- Interrupt-level enable/disable settings (IMR Register)
- Interrupt-level priority settings (IPR Register)
- Interrupt source enable/disable settings in the corresponding peripheral control registers

Figure 46 diagrams the functions of these combined interrupt processes.

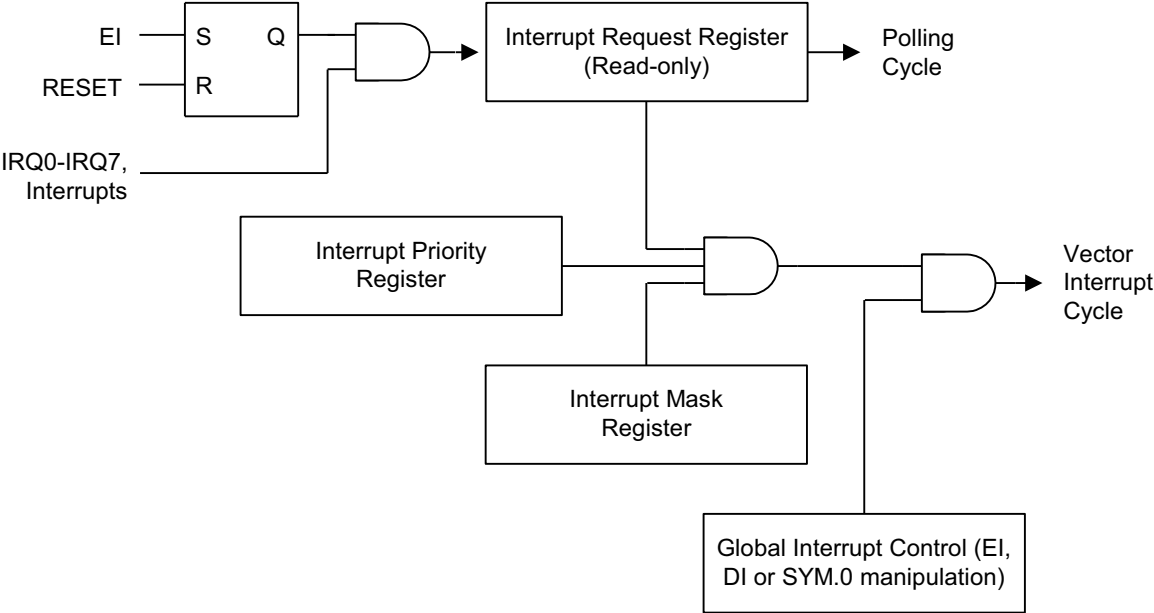


Figure 46. Interrupt Function Diagram

► **Note:** When writing the part of your application that handles the processing of interrupts, be sure to include the necessary register file address (register pointer) information.

Peripheral Interrupt Control Registers

For each interrupt source there is one or more corresponding peripheral control registers that let you control the interrupt generated by that peripheral; see Table 14.

Table 14. Vectored Interrupt Source Control and Data Registers*

Interrupt Source	Interrupt Level	Register(s)	Location(s) in Set1
Timer A match/capture	IRQ0	TACON	E2h, Bank0
Timer A overflow		TACNT	E0h, Bank0
		TADATA	E1h, Bank0
Timer B match	IRQ1	TBCON	E3h, Bank0
		TBCLKS	E6h, Bank0
		TBDATAH	E4h, Bank0
		TBDATAL	E5h, Bank0
Timer C match/overflow	IRQ2	TCCON	ECh, Bank0
10-bit PWM overflow		TCCNT	EAh, Bank0
		TCDATA	EBh, Bank0
		PWMCON	FBh, Bank1
		PWMDATAH	FCh, Bank1
		PWMDATAL	FDh, Bank1
Timer D0 match/capture	IRQ3	TD0CON	01h, Page 4
Timer D0 overflow		TD0CNTH	02h, Page 4
Timer D1 match/capture		TD0CNTL	03h, Page 4
Timer D1 overflow		TD0DATAH	04h, Page 4
		TD0DATAL	05h, Page 4
		TD1CON	0Ah, Page 4
		TD1CNTH	06h, Page 4
		TD1CNTL	07h, Page 4
		TD1DATAH	08h, Page 4
		TD1DATAL	09h, Page 4
SIO interrupt	IRQ4	SIOCON	E7h, Bank0
Watch timer overflow		SIODATA	E8h, Bank0
		SIOPS	E9h, Bank0
		WTCON	FEh, Bank1
UART 0 data transmit	IRQ5	UART0CONH	EEh, Bank0
UART 0 data receive		UART0CONL	EFh, Bank0
UART 1 data transmit		UDATA0, BRDATA0	F0h, F1h, Bank0
UART 1 data receive		UART1CONH	F2h, Bank0
		UART1CONL	F3h, Bank0
		UDATA1, BRDATA1	F4h, F5h, Bank0

Note: *If an interrupt is unmasked (i.e., at an enable interrupt level) in the IMR Register, the pending bit and enable bit of the interrupt should be written after a DI instruction is executed.

Table 14. Vectored Interrupt Source Control and Data Registers* (Continued)

Interrupt Source	Interrupt Level	Register(s)	Location(s) in Set1
P1.0 external interrupt	IRQ6	P1CONL	E1h, Bank1
P1.1 external interrupt		P1INT	E3h, Bank1
P1.2 external interrupt		P1PND	E4h, Bank1
P1.3 external interrupt			
P4.0 external interrupt	IRQ7	P4CONL	EFh, Bank1
P4.1 external interrupt		P4INT	F6h, Bank1
P4.2 external interrupt		P4PND	F7h, Bank1
P4.3 external interrupt			

Note: *If an interrupt is unmasked (i.e., at an enable interrupt level) in the IMR Register, the pending bit and enable bit of the interrupt should be written after a DI instruction is executed.

System Mode Register

The System Mode (SYM) Register (DEh, Set1; see Table 15) is used to globally enable and disable interrupt processing and to control fast interrupt processing.

A reset clears SYM.1 and SYM.0 to 0. The 3-bit value, SYM.4–SYM.2, is for fast interrupt level selection and undetermined values after reset.

The instructions EI and DI enable and disable global interrupt processing, respectively, by modifying the bit 0 value of the SYM Register. An Enable Interrupt (EI) instruction must be included in the initialization routine, which follows a reset operation to enable interrupt processing. Although you can manipulate SYM.0 directly to enable and disable interrupts during normal operation, Zilog recommends using the EI and DI instructions for this purpose.

-
- **Notes:**
1. For fast interrupt processing, select only one interrupt level at a time.
 2. Setting SYM.1 to 1 enables fast interrupt processing for the interrupt level currently selected by SYM.2–SYM.4.
 3. Following a reset, enable global interrupt processing by executing an EI instruction instead of writing a 1 to SYM.0).
-

Table 15. System Mode Register (SYM; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	0	–	–	x	x	x	0	0
R/W	R/W	–	–	R/W	R/W	R/W	R/W	R/W
Address	DEh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7]	Reserved
[6:5]	Reserved
[4:2]	Fast Interrupt Level Selection Bits¹ 000: IRQ0. 001: IRQ1. 010: IRQ2. 011: IRQ3. 100: IRQ4. 101: IRQ5. 110: IRQ6. 111: IRQ7.
[1]	Fast Interrupt Enable Bit² 0: Disable fast interrupt processing. 1: Enable fast interrupt processing.
[0]	Global Interrupt Enable Bit³ 0: Disable global interrupt processing. 1: Enable global interrupt processing.

Note:

1. You can select only one interrupt level at a time for fast interrupt processing.
2. Setting SYM.1 to 1 enables fast interrupt processing for the interrupt level currently selected by SYM.2–SYM.4.
3. Following a reset, you must enable global interrupt processing by executing an EI instruction (not by writing a 1 to SYM.0).

Interrupt Mask Register

The Interrupt Mask (IMR) Register (DDh, Set1; see Table 16) is used to enable or disable interrupt processing for individual interrupt levels. After a reset, all IMR bit values are undetermined and must therefore be written to their required settings by the initialization routine. Before changing values in the IMR Register, first disable all interrupts with the DI instruction.

Table 16. Interrupt Mask Register (IMR; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W	R/W							
Address	DDh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Interrupt Level 7 (IRQ7) Enable Bit; External Interrupts P4.0–P4.3 0: Disable (Mask). 1: Enable (Unmask).
[6]	Interrupt Level 6 (IRQ6) Enable Bit; External Interrupts P1.0–P1.3 0: Disable (Mask). 1: Enable (Unmask).
[5]	Interrupt Level 5 (IRQ5) Enable Bit; UART0/1 Transmit, UART0/1 Receive 0: Disable (Mask). 1: Enable (Unmask).
[4]	Interrupt Level 4 (IRQ4) Enable Bit; Watch Timer, SIO 0: Disable (Mask). 1: Enable (Unmask).
[3]	Interrupt Level 3 (IRQ3) Enable Bit; Timer D0/1 Match/Capture or Overflow 0: Disable (Mask). 1: Enable (Unmask).
[2]	Interrupt Level 2 (IRQ2) Enable Bit; Timer C Match/Overflow, 10-bit PWM Overflow Interrupt 0: Disable (Mask). 1: Enable (Unmask).
[1]	Interrupt Level 1 (IRQ1) Enable Bit; Timer B Match 0: Disable (Mask). 1: Enable (Unmask).
[0]	Interrupt Level 0 (IRQ0) Enable Bit; Timer A Match/Capture or Overflow 0: Disable (Mask). 1: Enable (Unmask).

Note: When an interrupt level is masked, any interrupt requests that may be issued are not recognized by the CPU.

Each IMR bit corresponds to a specific interrupt level: bit 1 to IRQ1, bit 2 to IRQ2, etc. When the IMR bit of an interrupt level is cleared to 0, interrupt processing for that level is disabled (masked). When setting a level's IMR bit to 1, interrupt processing for the level is enabled (not masked).

The IMR Register is mapped to register location DDh in Set1 and Bank0. Bit values can be read and written by instructions using the Register Addressing Mode.

► **Note:** Before the IMR Register is changed to any value, all interrupts must be disabled; Zilog recommends using the DI instruction.

Interrupt Priority Register

The interrupt priority register, IPR (FFh, Set1, Bank0; see Table 17), is used to set the relative priorities of the interrupt levels used in the microcontroller's interrupt structure. After a reset, all IPR bit values are undetermined and must therefore be written to their required settings by the initialization routine.

When more than one interrupt source is active, the source with the highest priority level is serviced first. If two sources belong to the same interrupt level, the source with the lower vector address usually has priority; this priority is fixed in hardware.

To support programming of the relative interrupt level priorities, interrupts are organized into groups and subgroups by the interrupt logic. These groups and subgroups are used only by IPR logic for the IPR Register priority definitions, as listed below and shown in Figure 47.

- Group A: IRQ0, IRQ1
- Group B: IRQ2, IRQ3, IRQ4
- Group C: IRQ5, IRQ6, IRQ7

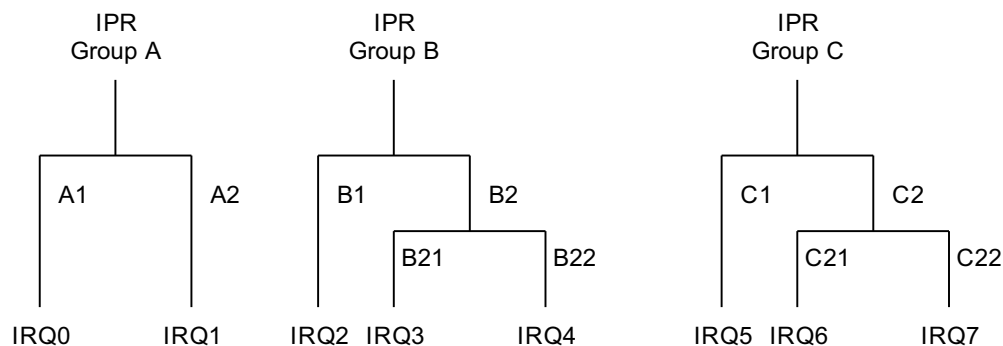


Figure 47. Interrupt Request Priority Groups

Table 17. Interrupt Priority Register (IPR; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W					R/W			
Address					FFh			
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7, 4, 1]	Priority Control Bits for Interrupt Groups A, B, and C 000: Group priority undefined 001: B > C > A. 010: A > B > C. 011: B > A > C. 100: C > A > B. 101: C > B > A. 110: A > C > B. 111: Group priority undefined.
[6]	Interrupt Subgroup C Priority Control Bit 0: IRQ6 > IRQ7. 1: IRQ7 > IRQ6.
[5]	Interrupt Group C Priority Control Bit 0: IRQ5 > (IRQ6, IRQ7). 1: (IRQ6, IRQ7) > IRQ5.
[3]	Interrupt Subgroup B Priority Control Bit* 0: IRQ3 > IRQ4. 1: IRQ4 > IRQ3.
[2]	Interrupt Group B Priority Control Bit* 0: IRQ2 > (IRQ3, IRQ4). 1: (IRQ3, IRQ4) > IRQ2.
[0]	Interrupt Group A Priority Control Bit 0: IRQ0 > IRQ1. 1: IRQ1 > IRQ0.

Note: Interrupt group A: IRQ0, IRQ1. Interrupt group B: IRQ2, IRQ3, IRQ4. Interrupt group C: IRQ5, IRQ6, IRQ7.

In the Interrupt Priority Register, IPR.7, IPR.4, and IPR.1 control the relative priority of interrupt groups A, B, and C. For example, a setting of 001b for these bits would select the group relationship B > C > A; a setting of 101b would select the relationship C > B > A.

The functions of the other IPR bit settings are:

- IPR.5 controls the relative priorities of group C interrupts.
- Interrupt Group C includes a subgroup to provide an additional priority relationship among the interrupt levels 5, 6, and 7. IPR.6 defines the Subgroup C relationship, and IPR.5 controls interrupt Group C.
- IPR.0 controls the relative priority setting of IRQ0 and IRQ1 interrupts.

Interrupt Request Register

Bit values in the Interrupt Request (IRQ) Register (DCh, Set1; see Table 18) can be polled to monitor interrupt request status for all levels in the microcontroller’s interrupt structure. Each bit corresponds to the interrupt level of the same number: bit 0 to IRQ0, bit 1 to IRQ1, etc. A 0 indicates that no interrupt request is currently being issued for that level; a 1 indicates that an interrupt request has been generated for that level.

IRQ bit values are read only-addressable using Register Addressing Mode. The contents of the IRQ Register can be read (tested) at any time using bit or byte addressing to determine the current interrupt request status of specific interrupt levels. After a reset, all IRQ status bits are cleared to 0.

IRQ Register values can be polled even if a DI instruction has been executed (i.e., if global interrupt processing is disabled). If an interrupt occurs while the interrupt structure is disabled, the CPU will not service it. You can, however, still detect the interrupt request by polling the IRQ Register. In this way, you can determine which events occurred while the interrupt structure is globally disabled.

Table 18. Interrupt Request Register (IPQ; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R							
Address	DCh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Level 7 (IRQ7) Request Pending Bit; External Interrupts P4.0–P4.3 0: Not pending. 1: Pending.
[6]	Level 6 (IRQ6) Request Pending Bit; External Interrupts P1.0–P1.3 0: Not pending. 1: Pending.

Bit	Description (Continued)
[5]	Level 5 (IRQ5) Request Pending Bit; UART0/1 Transmit, UART0/1 Receive 0: Not pending. 1: Pending.
[4]	Level 4 (IRQ4) Request Pending Bit; Watch Timer, SIO 0: Not pending. 1: Pending.
[3]	Level 3 (IRQ3) Request Pending Bit; Timer D0/1 Match/Capture or Overflow 0: Not pending. 1: Pending.
[2]	Level 2 (IRQ2) Request Pending Bit; Timer C Match/Overflow, 10-bit PWM Overflow Interrupt 0: Not pending. 1: Pending.
[1]	Level 1 (IRQ1) Request Pending Bit; Timer B Match 0: Not pending. 1: Pending.
[0]	Level 0 (IRQ0) Request Pending Bit; Timer A Match/Capture or Overflow 0: Not pending. 1: Pending.

Interrupt Pending Function Types

There are two types of interrupt pending bits: One type is automatically cleared by hardware after the interrupt service routine is acknowledged and executed; the other type must be cleared by the interrupt service routine.

Pending Bits Cleared Automatically by Hardware

For interrupt pending bits that are cleared automatically by hardware, interrupt logic sets the corresponding pending bit to 1 when a request occurs. It then issues an IRQ pulse to inform the CPU that an interrupt is waiting to be serviced. The CPU acknowledges the interrupt source by sending an IACK, executes the service routine, and clears the pending bit to 0. This type of pending bit is not mapped and cannot, therefore, be read or written by application software.

In the S3F8S5A MCU's interrupt structure, the Timer A overflow interrupt (IRQ0), the Timer B match interrupt (IRQ1), the Timer C overflow interrupt (IRQ2), and the Timer D0/D1 overflow interrupt (IRQ3) belong to this category of interrupts in which a pending condition is cleared automatically by hardware.

Pending Bits Cleared by the Service Routine

The second type of pending bit must be cleared by program software. The service routine must clear the appropriate pending bit before a return-from-interrupt subroutine (IRET) occurs; i.e., a 0 must be written to the corresponding pending bit location in the source's mode or control register.

In the following examples, a load instruction should be used to clear an interrupt pending bit.

Example 1

```
SB1
LD P03PND, #11111011b      ; Clear P3.5's interrupt pending bit
•
•
•
IRET
```

Example 2

```
SB0
LD INTPND, #11111101b      ; Clear Timer A match/capture
                             ; interrupt pending bit
•
•
•
IRET
```

The contents of the Interrupt Pending (INTPND) Register are described in Table 19. Before changing values in the IMR Register, first disable all interrupts with the DI instruction.

Table 19. Interrupt Pending Register (INTPND; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	–	0	0	0	0	0	0
R/W	R/W							
Address	DDh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Watch Timer Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[6]	Reserved.

Bit	Description (Continued)
[5]	Timer D1 Match/Capture Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[4]	Timer D1 Overflow Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[3]	Timer D0 Match/Capture Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[2]	Timer D0 Overflow Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[1]	Timer A Match/Capture Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).
[0]	Timer A Overflow Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).

Interrupt Source Polling Sequence

Interrupt request polling and servicing occurs via the following sequence:

1. A source generates an interrupt request by setting the interrupt request bit to 1.
2. The CPU polling procedure identifies a pending condition for that source.
3. The CPU checks the interrupt level of the source.
4. The CPU generates an interrupt acknowledge signal.
5. Interrupt logic determines the interrupt's vector address.
6. The service routine starts and the source's pending bit is cleared to 0 (by hardware or by software).
7. The CPU continues polling for interrupt requests.

Interrupt Service Routines

Before an interrupt request can be serviced, the following conditions must be met:

- Interrupt processing must be globally enabled (i.e., EI, SYM.0 = 1)
- The interrupt level must be enabled (IMR Register)

- The interrupt level must have the highest priority if more than one level is currently requesting service
- The interrupt must be enabled at the interrupt's source (i.e., the Peripheral Control Register)

When all of the above conditions are met, the interrupt request is acknowledged at the end of the instruction cycle. The CPU then initiates an interrupt machine cycle that completes the following processing sequence:

1. Reset (clear to 0) the interrupt enable bit in the SYM Register (SYM.0) to disable all subsequent interrupts.
2. Save the program counter (PC) and status flags to the system stack.
3. Branch to the interrupt vector to fetch the address of the service routine.
4. Pass control to the interrupt service routine.

When the interrupt service routine is completed, the CPU issues an Interrupt Return (IRET). This IRET restores the PC and status flags and sets SYM.0 to 1, allowing the CPU to process the next interrupt request.

Generating Interrupt Vector Addresses

The interrupt vector area in ROM (00h–FFh) contains the addresses of interrupt service routines that correspond to each level in the interrupt structure. Vectored interrupt processing observes the following sequence:

1. Push the program counter's low-byte value to the stack.
2. Push the program counter's high-byte value to the stack.
3. Push the Flags Register values to the stack.
4. Fetch the service routine's high-byte address from the vector location.
5. Fetch the service routine's low-byte address from the vector location.
6. Branch to the service routine specified by the concatenated 16-bit vector address.

► **Note:** A 16-bit vector address always begins at an even-numbered ROM address within the range 00h–FFh.

Nesting of Vectored Interrupts

It is possible to nest a higher-priority interrupt request while a lower-priority request is being serviced, as shown in the following sequence.

1. Push the current 8-bit Interrupt Mask (IMR) Register value to the stack (PUSH IMR).
2. Load the IMR Register with a new mask value that enables only the higher-priority interrupt.
3. Execute an EI instruction to enable interrupt processing (a higher-priority interrupt will be processed if it occurs).
4. When the lower-priority interrupt service routine ends, restore the IMR to its original value by returning the previous mask value from the stack (POP IMR).
5. Execute an IRET.

Depending on the application, the above procedure can be simplified to some extent.

Instruction Pointer

The Instruction Pointer (IP) is used by all S3F8 Series microcontrollers to control the optional high-speed interrupt processing feature called *fast interrupts*. The IP consists of register pair DAh and DBh. The IP Register names are IPH (high byte, IP15–IP8) and IPL (low byte, IP7–IP0).

The contents of the Instruction Pointer High Byte (IPH) and Instruction Pointer Low Byte (IPL) registers are described in Tables 20 and 21.

Table 20. Instruction Pointer High Byte Register (IPH; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W	R/W							
Address	DAh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	<p>Instruction Pointer Address (High Byte) The high-byte instruction pointer value is the upper eight bits of the 16-bit instruction pointer address (IP15–IP8). The lower byte of the IP address is located in the IPL Register (DBh).</p>

Table 21. Instruction Pointer Low Byte Register (IPL; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	x	x
R/W	R/W							
Address	DBh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7:0]	Instruction Pointer Address (Low Byte) The low-byte instruction pointer value is the lower eight bits of the 16-bit instruction pointer address (IP7–IP0). The upper byte of the IP address is located in the IPH Register (DAh).							

Fast Interrupt Processing

This feature lets you specify that an interrupt within a given level be completed in approximately six clock cycles instead of the usual 22 clock cycles. To select a specific interrupt level for fast interrupt processing, you write the appropriate 3-bit value to SYM.4–SYM.2. Then, to enable fast interrupt processing for the selected level, you set SYM.1 to 1.

Two other system registers support fast interrupts processing:

- The instruction pointer (IP) contains the starting address of the service routine (and is later used to swap the program counter values), and
- When a fast interrupt occurs, the contents of the Flags Register are stored in an unmapped, dedicated register called *Flags'* (a.k.a. Flags prime).

► **Note:** For the S3F8S5A microcontroller, the service routine for any one of the eight interrupt levels: IRQ0–IRQ7, can be selected for fast interrupt processing.

Procedure for Initiating Fast Interrupts

To initiate fast interrupt processing, follow these steps:

1. Load the start address of the service routine into the instruction pointer (IP).
2. Load the interrupt level number (IRQ_n) into the fast interrupt selection field (SYM.4–SYM.2).

3. Write a 1 to the fast interrupt enable bit in the SYM Register.

Fast Interrupt Service Routine

When an interrupt occurs in the level selected for fast interrupt processing, the following sequence of events occur:

1. The contents of the instruction pointer and the PC are swapped.
2. The Flags Register values are written to the Flags' (a.k.a. Flags prime) Register.
3. The fast interrupt status bit in the Flags Register is set.
4. The interrupt is serviced.
5. Assuming that the fast interrupt status bit is set, when the fast interrupt service routine ends, the instruction pointer and PC values are swapped back.
6. The content of Flags' is automatically copied back to the Flags Register.
7. The fast interrupt status bit in Flags is cleared automatically.

Relationship to Interrupt Pending Bit Types

As described previously, there are two types of interrupt pending bits; one is automatically cleared by hardware after the interrupt service routine is acknowledged and executed, and the other must be cleared by the application software's interrupt service routine. Fast interrupt processing can be selected for interrupts with either type of pending condition clear function – hardware or software.

Programming Guidelines

Be advised that the only way to enable/disable a fast interrupt is to set/clear the fast interrupt enable bit (SYM.1) in the SYM Register. Executing an EI or DI instruction globally enables or disables all interrupt processing, including fast interrupts. If you use fast interrupts, remember to load the IP with a new start address when the fast interrupt service routine ends.

Instruction Set

The SAM88 instruction set, which comprises 78 instructions, is specifically designed to support the large register files that are typical of most SAM88 microcontrollers.

The powerful data manipulation capabilities and features of the SAM88 instruction set include:

- A full complement of 8-bit arithmetic and logic operations, including multiply and divide
- No special I/O instructions (I/O control/data registers are mapped directly into the register file)
- Decimal adjustment included in binary-coded decimal (BCD) operations
- 16-bit (word) data can be incremented and decremented
- Flexible instructions for bit addressing, rotate, and shift operations

Data Types

The SAM88 CPU performs operations on bits, bytes, BCD digits, and two-byte words. Bits in the register file can be set, cleared, complemented, and tested. Bits within a byte are numbered from 7 to 0, where bit 0 is the least significant (right-most) bit.

Register Addressing

To access an individual register, an 8-bit address in the range 0–255 or the 4-bit address of a working register is specified. Paired registers can be used to construct 16-bit data or 16-bit program memory or data memory addresses. To learn more about register addressing, see the [Address Space](#) chapter on page 19.

Addressing Modes

There are seven explicit addressing modes: Register (R), Indirect Register (IR), Indexed (X), Direct (DA), Relative (RA), Immediate (IM) and Indirect (IA). To learn more about these addressing modes, see the [Addressing Modes](#) chapter on page 43.

Instruction Summary

All instructions are summarized by type, operand, and description in Table 22.

Table 22. Instruction Group Summary

Mnemonic	Operands	Instruction
Load Instructions		
CLR	dst	Clear
LD	dst,src	Load
LDB	dst,src	Load bit
LDE	dst,src	Load external data memory
LDC	dst,src	Load program memory
LDED	dst,src	Load external data memory and decrement
LDCD	dst,src	Load program memory and decrement
LDEI	dst,src	Load external data memory and increment
LDCI	dst,src	Load program memory and increment
LDEPD	dst,src	Load external data memory with predecrement
LDCPD	dst,src	Load program memory with predecrement
LDEPI	dst,src	Load external data memory with preincrement
LDCPI	dst,src	Load program memory with preincrement
LDW	dst,src	Load word
POP	dst	Pop from stack
POPUD	dst,src	Pop user stack (decrementing)
POPUI	dst,src	Pop user stack (incrementing)
PUSH	src	Push to stack
PUSHUD	dst,src	Push user stack (decrementing)
PUSHUI	dst,src	Push user stack (incrementing)
Arithmetic Instructions		
ADC	dst,src	Add with carry
ADD	dst,src	Add
CP	dst,src	Compare
DA	dst	Decimal adjust
DEC	dst	Decrement
DECW	dst	Decrement word
DIV	dst,src	Divide

Table 22. Instruction Group Summary (Continued)

Arithmetic Instructions (continued)		
INC	dst	Increment
INCW	dst	Increment word
MULT	dst,src	Multiply
SBC	dst,src	Subtract with carry
SUB	dst,src	Subtract
Logic Instructions		
AND	dst,src	Logical AND
COM	dst	Complement
OR	dst,src	Logical OR
XOR	dst,src	Logical exclusive OR
Mnemonic	Operands	Instruction
Program Control Instructions		
BTJRF	dst,src	Bit test and jump relative on false
BTJRT	dst,src	Bit test and jump relative on true
CALL	dst	Call procedure
CPIJE	dst,src	Compare, increment and jump on equal
CPIJNE	dst,src	Compare, increment and jump on non-equal
DJNZ	r,dst	Decrement register and jump on non-zero
ENTER	Enter	
EXIT	Exit	
IRET	Interrupt return	
JP	cc,dst	Jump on condition code
JP	dst	Jump unconditional
JR	cc,dst	Jump relative on condition code
NEXT	Next	
RET	Return	
WFI	Wait for interrupt	
Bit Manipulation Instructions		
BAND	dst,src	Bit AND
BCP	dst,src	Bit compare
BITC	dst	Bit complement
BITR	dst	Bit reset
BITS	dst	Bit set

Table 22. Instruction Group Summary (Continued)

Bit Manipulation Instructions (continued)		
BOR	dst,src	Bit OR
BXOR	dst,src	Bit XOR
TCM	dst,src	Test complement under mask
TM	dst,src	Test under mask
Rotate and Shift Instructions		
RL	dst	Rotate left
RLC	dst	Rotate left through carry
RR	dst	Rotate right
RRC	dst	Rotate right through carry
SRA	dst	Shift right arithmetic
SWAP	dst	Swap nibbles
CPU Control Instructions		
CCF		Complement carry flag
DI		Disable interrupts
EI		Enable interrupts
IDLE		Enter Idle mode
NOP		No operation
RCF		Reset carry flag
SB0		Set Bank0
SB1		Set Bank1
SCF		Set carry flag
SRP	src	Set register pointers
SRP0	src	Set register pointer 0
SRP1	src	Set register pointer 1
STOP		Enter Stop Mode

Flags Register

The Flags (FLAGS) Register, shown in Table 23, contains eight bits that describe the current status of CPU operations. Four of these bits, FLAGS.7–FLAGS.4, can be tested and used with conditional jump instructions; two others, FLAGS.3 and FLAGS.2, are used for BCD arithmetic.

The Flags Register also contains a bit to indicate the status of fast interrupt processing (FLAGS.1) and a bank address status bit (FLAGS.0) to indicate whether Bank0 or Bank1 is currently being addressed. The Flags Register can be set or reset by instructions as long as its outcome does not affect the flags (e.g., a Load instruction).

Logical and arithmetic instructions such as AND, OR, XOR, ADD, and SUB can affect the Flags Register. For example, the AND instruction updates the Zero, Sign, and Overflow flags based on the outcome of the AND instruction. If the AND instruction uses the Flags Register as the destination, then simultaneously, two writes will occur to the Flags Register, thereby producing an unpredictable result.

Table 23. Flags Register (FLAGS; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	x	x	x	x	x	x	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R	R/W
Address	D5h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Carry Flag Bit (C) 0: Operation does not generate a carry or borrow condition. 1: Operation generates a carry-out or borrow into high-order bit 7.
[6]	Zero Flag Bit (Z) 0: Operation result is a nonzero value. 1: Operation result is zero.
[5]	Sign Flag Bit (S) 0: Operation generates a positive number (MSB = 0). 1: Operation generates a negative number (MSB = 1).
[4]	Overflow Flag Bit (V) 0: Operation result is $\leq +127$ or -128 . 1: Operation result is $> +127$ or < -128 .
[3]	Decimal Adjust Flag Bit (D) 0: Add operation completed. 1: Subtraction operation completed.
[2]	Half-Carry Flag Bit (H) 0: No carry-out of bit 3 or no borrow into bit 3 by addition or subtraction. 1: Addition generated carry-out of bit 3 or subtraction generated borrow into bit 3.

Bit	Description (Continued)
[1]	Fast Interrupt Status Flag Bit (FIS) 0: Interrupt return (IRET) in progress when read. 1: Fast interrupt service routine in progress when read.
[0]	Bank Address Selection Flag Bit (BA) 0: Bank0 is selected. 1: Bank1 is selected.

Table 24 describes each of the flags managed by the Flags Register.

Table 24. Flag Descriptions

Flag	Description
C	Carry Flag (FLAGS.7) The C flag is set to 1 if the result from an arithmetic operation generates a carry-out from or a borrow to the bit 7 position (MSB). After rotate and shift operations, it contains the last value shifted out of the specified register. Program instructions can set, clear, or complement the carry flag.
Z	Zero Flag (FLAGS.6) For arithmetic and logic operations, the Z flag is set to 1 if the result of the operation is zero. For operations that test register bits, and for shift and rotate operations, the Z flag is set to 1 if the result is logic 0.
S	Sign Flag (FLAGS.5) Following the arithmetic, logic, rotate, or shift operations, the sign bit identifies the state of the MSB of the result. A logic 0 indicates a positive number and a logic 1 indicates a negative number.
V	Overflow Flag (FLAGS.4) The V flag is set to 1 when the result of a two's-complement operation is greater than +127 or less than -128. It is also cleared to 0 following logic operations.
D	Decimal Adjust Flag (FLAGS.3) The DA bit is used to specify what type of instruction is executed last during BCD operations, so that a subsequent decimal adjust operation can execute correctly. The DA bit is not usually accessed by programmers, and cannot be used as a test condition.
H	Half-Carry Flag (FLAGS.2) The H bit is set to 1 whenever an addition generates a carry-out of bit 3, or when a subtraction borrows out of bit 4. It is used by the Decimal Adjust (DA) instruction to convert the binary result of a previous addition or subtraction into the correct decimal (BCD) result. The H flag is seldom accessed directly by a program.

Table 24. Flag Descriptions (Continued)

Flag	Description
FIS	Fast Interrupt Status Flag (FLAGS.1) The FIS bit is set during a fast interrupt cycle and reset during the IRET following interrupt servicing. When set, it inhibits all interrupts and causes the fast interrupt return to be executed when the IRET instruction is executed.
BA	Bank Address Flag (FLAGS.0) The BA flag indicates which register bank in the Set1 area of the internal register file is currently selected, Bank0 or Bank1. The BA flag is cleared to 0 (select Bank0) when you execute the SB0 instruction and is set to 1 (select Bank1) when you execute the SB1 instruction.

Instruction Set Notation

Table 25 lists the conventions used for each of the flags managed by the Instruction Set. Symbols for the Instruction Set are listed in Table 26; conditions for these symbols are described in Table 27.

Table 25. Flag Notation Conventions

Flag	Description
C	Carry flag.
Z	Zero flag.
S	Sign flag.
V	Overflow flag.
D	Decimal-adjust flag.
H	Half-carry flag.
0	Cleared to logic 0.
1	Set to logic 1.
*	Set to cleared according to operation.
–	Value is unaffected.
x	Value is undefined.

Table 26. Instruction Set Symbols

Symbol	Description
dst	Destination operand.
src	Source operand.
@	Indirect register address prefix.

Table 26. Instruction Set Symbols (Continued)

Symbol	Description
PC	Program counter.
IP	Instruction pointer.
FLAGS	Flags register (D5h).
RP	Register pointer.
#	Immediate operand or register address prefix.
H	Hexadecimal number suffix.
D	Decimal number suffix.
B	Binary number suffix.
opc	Op code.

Table 27. Instruction Notation Conventions

Notation	Description	Actual Operand Range
cc	Condition code	See list of condition codes in Table 30 on page 93
r	Working register only	Rn (n = 0–15)
rb	Bit (b) of working register	Rn.b (n = 0–15, b = 0–7)
r0	Bit 0 (LSB) of working register	Rn (n = 0–15)
rr	Working register pair	RRp (p = 0, 2, 4, ..., 14)
R	Register or working register	reg or Rn (reg = 0–255, n = 0–15)
Rb	Bit (b) of register or working register	reg.b (reg = 0–255, b = 0–7)
RR	Register pair or working register pair	reg or RRp (reg = 0–254, even number only, in which p = 0, 2, ..., 14)
IA	Indirect Addressing Mode	addr (addr = 0–254, even number only)
Ir	Indirect working register only	@Rn (n = 0–15)
IR	Indirect register or indirect working register	@Rn or @reg (reg = 0–255, n = 0–15)
Irr	Indirect working register pair only	@RRp (p = 0, 2, ..., 14)
IRR	Indirect register pair or indirect working register pair	@RRp or @reg (reg = 0–254, even only, in which p = 0, 2, ..., 14)
X	Indexed Addressing Mode	#reg [Rn] (reg = 0–255, n = 0–15)
XS	Indexed (Short Offset) Addressing Mode	#addr [RRp] (addr = range –128 to +127, in which p = 0, 2, ..., 14)
xl	Indexed (Long Offset) Addressing Mode	#addr [RRp] (addr = range 0–65535, in which p = 0, 2, ..., 14)

Table 27. Instruction Notation Conventions (Continued)

Notation	Description	Actual Operand Range
da	Direct Addressing Mode	addr (addr = range 0–65535)
ra	Relative Addressing Mode	addr (addr = number in the range +127 to –128 that is an offset relative to the address of the next instruction)
im	Immediate Addressing Mode	#data (data = 0–255)
iml	Immediate (Long) Addressing Mode	#data (data = range 0–65535)

Op Code Maps

Tables 28 and 29 provide quick reference op code maps to addresses 0–7 and 8–F, respectively.

Table 28. Op Code Quick Reference (0–7)

		Op Code Map							
		Lower Nibble (Hex)							
		0	1	2	3	4	5	6	7
Upper Nibble (Hex)	0	DEC R1	DEC IR1	ADD r1, r2	ADD r1, lr2	ADD R2, R1	ADD IR2, R1	ADD R1, IM	BOR r0–Rb
	1	RLC R1	RLC IR1	ADC r1, r2	ADC r1, lr2	ADC R2, R1	ADC IR2, R1	ADC R1, IM	BCP r1.b, R2
	2	INC R1	INC IR1	SUB r1, r2	SUB r1, lr2	SUB R2, R1	SUB IR2, R1	SUB R1, IM	BXOR r0–Rb
	3	JP IRR1	SRP/0/1 IM	SBC r1, r2	SBC r1, lr2	SBC R2, R1	SBC IR2, R1	SBC R1, IM	BTJR r2.b, RA
	4	DA R1	DA IR1	OR r1, r2	OR r1, lr2	OR R2, R1	OR IR2, R1	OR R1, IM	LDB r0–Rb
	5	POP R1	POP IR1	AND r1, r2	AND r1, lr2	AND R2, R1	AND IR2, R1	AND R1, IM	BITC r1.b
	6	COM R1	COM IR1	TCM r1, r2	TCM r1, lr2	TCM R2, R1	TCM IR2, R1	TCM R1, IM	BAND r0–Rb
	7	PUSH R2	PUSH IR2	TM r1, r2	TM r1, lr2	TM R2, R1	TM IR2, R1	TM R1, IM	BIT r1.b
	8	DECW RR1	DECW IR1	PUSHUD IR1, R2	PUSHUI IR1, R2	MULT R2, RR1	MULT IR2, RR1	MULT IM, RR1	LD r1, x, r2
	9	RL R1	RL IR1	POPUD IR2, R1	POPUI IR2, R1	DIV R2, RR1	DIV IR2, RR1	DIV IM, RR1	LD r2, x, r1
	A	INCW RR1	INCW IR1	CP r1, r2	CP r1, lr2	CP R2, R1	CP IR2, R1	CP R1, IM	LDC r1, lrr2, xL
	B	CLR R1	CLR IR1	XOR r1, r2	XOR r1, lr2	XOR R2, R1	XOR IR2, R1	XOR R1, IM	LDC r2, lrr2, xL
	C	RRC R1	RRC IR1	CPIJE lr, r2, RA	LDC r1, lrr2	LDW RR2, RR1	LDW IR2, RR1	LDW RR1, IML	LD r1, lr2
	D	SRA R1	SRA IR1	CPIJNE lrr, r2, RA	LDC r2, lrr1	CALL IA1		LD IR1, IM	LD lr1, r2
	E	RR R1	RR IR1	LDCD r1, lrr2	LDCI r1, lrr2	LD R2, R1	LD R2, IR1	LD R1, IM	LDC r1, lrr2, xs
	F	SWAP R1	SWAP IR1	LDCPD r2, lrr1	LDCPI r2, lrr1	CALL IRR1	LD IR2, R1	CALL DA1	LDC r2, lrr1, xs

Table 29. Op Code Quick Reference (8–F)

Op Code Map									
Lower Nibble (Hex)									
	8	9	A	B	C	D	E	F	
	0	LD r1,R2	LD r2,R1	DJNZ r1,RA	JR cc, RA	LD r1,IM	JP cc, DA	INC r1	NEXT
	1	↓	↓	↓	↓	↓	↓	↓	ENTER
	2								EXIT
	3								WFI
	4								SB0
	5								SB1
	6								IDLE
Upper Nibble (Hex)	7	↓	↓	↓	↓	↓	↓	↓	STOP
	8								DI
	9								EI
	A								RET
	B								IRET
	C								RCF
	D	↓	↓	↓	↓	↓	↓	↓	SCF
	E								CCF
	F	LD r1, 2	LD r2, R1	DJNZ r1, RA	JR cc, RA	LD r1, IM	JP cc, DA	INC r1	NOP

Condition Codes

The op code of a conditional jump always contains a 4-bit field called the *condition code* (cc) that specifies under which conditions it is to execute the jump. For example, a conditional jump with a condition code of *equal* after a compare operation only jumps if the two operands are equal. The carry (C), zero (Z), sign (S), and overflow (V) flags are used to control the operation of conditional jump instructions.

These condition codes are listed in Table 30.

Table 30. Condition Codes¹

Mnemonic	Binary	Description	Flags Set
F	0000	Always false	–
T	1000	Always true	–
C ²	0111	Carry	C = 1
NC ²	1111	No carry	C = 0
Z ²	0110	Zero	Z = 1
NZ ²	1110	Not zero	Z = 0
PL	1101	Plus	S = 0
MI	0101	Minus	S = 1
OV	0100	Overflow	V = 1
NOV	1100	No overflow	V = 0
EQ ²	0110	Equal	Z = 1
NE ²	1110	Not equal	Z = 0
GE	1001	Greater than or equal	(S XOR V) = 0
LT	0001	Less than	(S XOR V) = 1
GT	1010	Greater than	(Z OR (S XOR V)) = 0
LE	0010	Less than or equal	(Z OR (S XOR V)) = 1
UGE ²	1111	Unsigned greater than or equal	C = 0
ULT ²	0111	Unsigned less than	C = 1
UGT	1011	Unsigned greater than	(C = 0 AND Z = 0) = 1
ULE	0011	Unsigned less than or equal	(C OR Z) = 1

Note:

1. For operations involving unsigned numbers, the special condition codes UGE, ULT, UGT, and ULE must be used.
2. Indicates condition codes that are related to two different mnemonics but which test the same flag. For example, Z and EQ are both true if the zero flag (Z) is set; however, after an ADD instruction, Z would probably be used; after a CP instruction, however, EQ would probably be used.

Instruction Descriptions

This section provides programming examples for each instruction in the SAM88 instruction set. Information is arranged in a consistent format for improved readability and for fast referencing.

The following information is included in each instruction description:

- Instruction name (mnemonic)
- Full instruction name
- Source/destination format of the instruction operand
- Shorthand notation of the instruction's operation
- Textual description of the instruction's effect
- Specific flag settings affected by the instruction
- The format of the instruction, its execution time, and addressing mode(s)
- Programming example(s) explaining how to use the instruction

Add with Carry

ADC dst, src

Operation $dst \leftarrow dst + src + c$

The source operand, along with the setting of the carry flag, is added to the destination operand and the sum is stored in the destination. The contents of the source are unaffected. Two's complement addition is performed. In multiple precision arithmetic, this instruction permits the carry from the addition of low-order operands to be carried into the addition of high-order operands.

- Flags**
- C** Set if there is a carry from the most significant bit of the result; cleared otherwise.
 - Z** Set if the result is 0; cleared otherwise.
 - S** Set if the result is negative; cleared otherwise.
 - V** Set if arithmetic overflow occurs, i.e., if both operands are of the same sign and the result is of the opposite sign; cleared otherwise.
 - D** Always cleared to 0.
 - H** Set if there is a carry from the most significant bit of the low-order four bits of the result; cleared otherwise.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	2	4	12	r	r
			6	13	r	lr
opc	src dst	3	6	14	R	R
			6	15	R	IR
opc	dst src	3	6	16	R	IM

Example Assume that R1 = 10h, R2 = 03h, C flag = 1, register 01h = 20h, register 02h = 03h, and register 03h = 0Ah.

ADC	R1, R2	→	R1 = 14h, R2 = 03h
ADC	R1, @R2	→	R1 = 1Bh, R2 = 03h
ADC	01h, 02h	→	Register 01h = 24h, register 02h = 03h
ADC	01h, @02h	→	Register 01h = 2Bh, register 02h = 03h
ADC	01h, #11h	→	Register 01h = 32h

In the first example, destination register R1 contains the value 10h, the carry flag is set to 1, and the source working register R2 contains the value 03h. The *ADC R1, R2* statement adds 03h and the carry flag value (1) to the destination value 10h, leaving 14h in register R1.

Add

ADD dst, src

Operation $dst \leftarrow dst + src$

The source operand is added to the destination operand and the sum is stored in the destination. The contents of the source are unaffected. Two's complement additions are performed.

- Flags**
- C** Set if there is a carry from the most significant bit of the result; cleared otherwise.
 - Z** Set if the result is 0; cleared otherwise.
 - S** Set if the result is negative; cleared otherwise.
 - V** Set if arithmetic overflow occurs, i.e., if both operands are of the same sign and the result is of the opposite sign; cleared otherwise.
 - D** Always cleared to 0.
 - H** Set if a carry from the low-order nibble occurred.

Format		Bytes	Cycles	Op Code (Hex)	dst	src
opc	dst src	2	4	02	r	r
			6	03	r	lr
opc	src dst	3	6	04	R	R
			6	05	R	IR
opc	dst src	3	6	06	R	IM

Example Assume that R1 = 12h, R2 = 03h, register 01h = 21h, register 02h = 03h, register 03h = 0Ah.

ADC	R1, R2	→	R1 = 15h, R2 = 03h
ADC	R1, @R2	→	R1 = 1Ch, R2 = 03h
ADC	01h, 02h	→	Register 01h = 24h, register 02h = 03h
ADC	01h, @02h	→	Register 01h = 2Bh, register 02h = 03h
ADC	01h, #25h	→	Register 01h = 46h

In the first example, destination working register R1 contains 12h and the source working register R2 contains 03h. The *ADD R1, R2* statement adds 03h to 12h, leaving the value 15h in register R1.

Logical AND

AND dst, src
Operation dst ← dst AND src

The source operand is logically ANDed with the destination operand. The result is stored in the destination. The AND operation results in a 1 bit being stored whenever the corresponding bits in the two operands are both logic 1s; otherwise a 0 bit value is stored. The contents of the source are unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always cleared to 0.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode	
	opc	dst src				dst	src
	opc	dst src	2	4	52	r	r
				6	53	r	lr
	opc	src dst	3	6	54	R	R
				6	55	R	IR
	opc	dst src	3	6	56	R	IM

Example Assume that R1 = 12h, R2 = 03h, register 01h = 21h, register 02h = 03h, register 03h = 0Ah.

AND	R1, R2	→	R1 = 02h, R2 = 03h
AND	R1, @R2	→	R1 = 02h, R2 = 03h
AND	01h, 02h	→	Register 01h = 01h, register 02h = 03h
AND	01h, @02h	→	Register 01h = 00h, register 02h = 03h
AND	01h, #25h	→	Register 01h = 21h

In the first example, destination working register R1 contains the value 12h and the source working register R2 contains 03h. The *AND R1, R2* statement logically ANDs the source operand 03h with the destination operand value 12h, leaving the value 02h in register R1.

Bit AND

BAND dst, src.b

BAND dst.b, src

Operation $\text{dst}(0) \leftarrow \text{dst}(0) \text{ AND } \text{src}(b)$
or
 $\text{dst}(b) \leftarrow \text{dst}(b) \text{ AND } \text{src}(0)$

The specified bit of the source (or the destination) is logically ANDed with the zero bit (LSB) of the destination (or source). The resultant bit is stored in the specified bit of the destination. No other bits of the destination are affected. The source is unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode	
						dst	src
opc	dst b 0	src	3	6	67	r0	Rb
opc	src b 1	dst	3	6	67	Rb	r0

Note: In the second byte of the 3-byte instruction formats, the destination (or source) address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that R1 = 07h and register 01h = 05h.

BAND R1, 01h.1 → R1 = 06h, register 01h = 05h
 BAND 01h.1, R1 → Register 01h = 05h, R1 = 07h

In the first example, source register 01h contains the value 05h (00000101b) and destination working register R1 contains 07h (00000111b). The *BAND R1, 01h.1* statement ANDs the bit 1 value of the source register (0) with the bit 0 value of register R1 (destination), leaving the value 06h (00000110b) in register R1.

Bit Compare

BCP dst, src.b

Operation dst(0)–src(b)

The specified bit of the source is compared to (subtracted from) bit 0 (LSB) of the destination. The zero flag is set if the bits are the same; otherwise it is cleared. The contents of both operands are unaffected by the comparison.

Flags

- C** Unaffected.
- Z** Set if the two bits are the same; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode				
				dst	src			
<table border="1" style="display: inline-table;"> <tr> <td>opc</td> <td>dst b 0</td> <td>src</td> </tr> </table>	opc	dst b 0	src	3	6	17	r0	Rb
opc	dst b 0	src						

Note: In the second byte of the instruction format, the destination address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that R1 = 07h and register 01h = 01h.

BCP R1, 01h.1 → R1 = 07h, register 01h = 01h

If destination working register R1 contains the value 07h (00000111b) and the source register 01h contains the value 01h (00000001b), the *BCP R1, 01h.1* statement compares bit 1 of the source register (01h) and bit 0 of the destination register (R1). Because the bit values are not identical, the zero flag bit (Z) is cleared in the Flags Register (0D5h).

Bit Complement

BITC dst.b

Operation $\text{dst}(b) \leftarrow \text{NOT } \text{dst}(b)$

This instruction complements the specified bit within the destination without affecting any other bits in the destination.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode dst		
<table border="1" style="display: inline-table;"> <tr> <td>opc</td> <td>dst b 0</td> </tr> </table>	opc	dst b 0	2	4	57	rb
opc	dst b 0					

Note: In the second byte of the instruction format, the destination address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that R1 = 07h.

BITC R1.1 → R1 = 05h

If working register R1 contains the value 07h (00000111b), the *BITC R1.1* statement complements bit 1 of the destination and leaves the value 05h (00000101b) in register R1. Because the result of the complement is not 0, the zero flag (Z) in the Flags Register (0D5h) is cleared.

Bit Reset

BITR dst.b

Operation $\text{dst}(b) \leftarrow 0$

The BITR instruction clears the specified bit within the destination without affecting any other bits in the destination.

Flags No flags are affected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst
opc	dst b 0	2	4	77	rb

Note: In the second byte of the instruction format, the destination address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that $R1 = 07\text{h}$.

BITR R1.1 → $R1 = 05\text{h}$

If the value of working register R1 is 07h (00000111b), the *BITR R1.1* statement clears bit 1 of the destination register R1, leaving the value 05h (00000101b).

Bit Set

BITS dst.b

Operation $\text{dst}(b) \leftarrow 1$

The BITS instruction sets the specified bit within the destination without affecting any other bits in the destination.

Flags No flags are affected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst
opc	dst b 1	2	4	77	rb

Note: In the second byte of the instruction format, the destination address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that $R1 = 07h$.

`BITR R1.3` → $R1 = 0Fh$

If working register R1 contains the value 07h (00000111b), the *BITS R1.3* statement sets bit 3 of the destination register R1 to 1, leaving the value 0Fh (00001111b).

Bit OR

BOR dst, src.b

BOR dst.b, src

Operation $dst(0) \leftarrow dst(0) \text{ OR } src(b)$
or
 $dst(b) \leftarrow dst(b) \text{ OR } src(0)$

The specified bit of the source (or the destination) is logically ORed with bit 0 (LSB) of the destination (or the source). The resulting bit value is stored in the specified bit of the destination. No other bits of the destination are affected. The source is unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst b 0	src	3	6	07	r0	Rb
opc	src b 1	dst	3	6	07	Rb	r0

Note: In the second byte of the 3-byte instruction formats, the destination (or source) address is four bits, the bit address b is three bits, and the LSB address value is one bit.

Example Assume that R1 = 07h and register 01h = 03h.

BOR R1, 01h.1 → R1 = 07h, register 01h = 03h
BOR 01h.2, R1 → Register 01h = 07h, R1 = 07h

In the first example, destination working register R1 contains the value 07h (00000111b) and source register 01h the value 03h (00000011b). The *BOR R1, 01h.1* statement logically ORs bit 1 of register 01h (source) with bit 0 of R1 (destination). This leaves the same value (07h) in working register R1.

In the second example, destination register 01h contains the value 03h (00000011b) and the source working register R1 the value 07h (00000111b).

The *BOR 01h.2, R1* statement logically ORs bit 2 of register 01h (destination) with bit 0 of R1 (source). This leaves the value 07h in register 01h.

Bit Test, Jump Relative on False

BTJRF dst, src.b

Operation If src(b) is a 0, then $PC \leftarrow PC + dst$

The specified bit within the source operand is tested. If this bit is 0, the relative address is added to the program counter, and control passes to the statement for which the address is now in the PC; otherwise, the instruction following the BTJRF instruction is executed.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst b 1	dst	3	10	37	RA	rb

Note: In the second byte of the instruction format, the source address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that $R1 = 07h$.

BTJRF SKIP, R1.3 → PC jumps to SKIP location

If working register R1 contains the value 07h (00000111b), the *BTJRF SKIP, R1.3* statement tests bit 3. Because it is 0, the relative address is added to the PC and the PC jumps to the memory location pointed to by the SKIP.

► **Note:** The memory location must be within the allowed range of +127 to -128.

Bit Test, Jump Relative on True

BTJRT dst, src.b

Operation If src(b) is a 1, then $PC \leftarrow PC + dst$

The specified bit within the source operand is tested. If it is a 1, the relative address is added to the program counter and control passes to the statement for which the address is now in the PC; otherwise, the instruction following the BTJRT instruction is executed.

Flags No flags are affected.

Format				Bytes	Cycles	Op Code (Hex)	Address Mode		
							dst	src	
opc	src	b	1	dst	3	10	37	RA	rb

Note: In the second byte of the instruction format, the source address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that $R1 = 07h$.

BTJRT SKIP, R1.1

If working register R1 contains the value 07h (00000111b), the *BTJRT SKIP, R1.1* statement tests bit 1 in the source register (R1). Because it is a 1, the relative address is added to the PC and the PC jumps to the memory location pointed to by the SKIP.

► **Note:** The memory location must be within the allowed range of +127 to -128.

Bit XOR

BXOR dst, src.b

BXOR dst.b, src

Operation $\text{dst}(0) \leftarrow \text{dst}(0) \text{ XOR } \text{src}(b)$
or
 $\text{dst}(b) \leftarrow \text{dst}(b) \text{ XOR } \text{src}(0)$

The specified bit of the source (or the destination) is logically exclusive-ORed with bit 0 (LSB) of the destination (or source). The result bit is stored in the specified bit of the destination. No other bits of the destination are affected. The source is unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format				Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
	opc	dst b 0	src	3	6	27	r0	Rb
opc	src b 1	dst	3	6	27	Rb	r0	

Note: In the second byte of the 3-byte instruction formats, the destination (or source) address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that R1 = 07h (00000111b) and register 01h = 03h (00000011b).

BXOR R1, 01h.1 → R1 = 06h, register 01h = 03h
 BXOR 01h.2, R1 → Register 01h = 07h, R1 = 07h

In the first example, destination working register R1 has the value 07h (00000111b) and source register 01h has the value 03h (00000011b). The *BXOR R1, 01h.1* statement exclusive-ORs bit 1 of register 01h (source) with bit 0 of R1 (destination). The result bit value is stored in bit 0 of R1, changing its value from 07h to 06h. The value of source register 01h is unaffected.

Call Procedure

CALL	dst		
Operation	SP	←	SP-1
	@SP	←	PCL
	SP	←	SP-1
	@SP	←	PCH
	PC	←	dst

The current contents of the program counter are pushed onto the top of the stack. The program counter value used is the address of the first instruction following the CALL instruction. The specified destination address is then loaded into the program counter and points to the first instruction of a procedure. At the end of the procedure the return instruction (RET) can be used to return to the original program flow. RET pops the top of the stack back into the program counter.

Flags No flags are affected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	3	14	F6	DA
opc	dst	2	12	F4	IRR
opc	dst	2	14	D4	IA

Example Assume that R0 = 35h, R1 = 21h, PC = 1A47h, and SP = 0002h.

CALL	3521h	→	SP = 0000h (Memory locations 0000h = 1Ah, 0001h = 4Ah, in which 4Ah is the address that follows the instruction.)
CALL	@RR0	→	SP = 0000h (0000h = 1Ah, 0001h = 49h)
CALL	#40h	→	SP = 0000h (0000h = 1Ah, 0001h = 49h)

In the first example, if the program counter value is 1A47h and the stack pointer contains the value 0002h, the *CALL 3521h* statement pushes the current PC value onto the top of the stack. The stack pointer now points to mem-

ory location 0000h. The PC is then loaded with the value 3521h, the address of the first instruction in the program sequence to be executed.

If the contents of the program counter and stack pointer are the same as in the first example, the *CALL @RR0* statement produces the same result except that the 49h is stored in stack location 0001h (because the two-byte instruction format is used). The PC is then loaded with the value 3521h, the address of the first instruction in the program sequence to be executed. Assuming that the contents of the program counter and stack pointer are the same as in the first example, if program address 0040h contains 35h and program address 0041h contains 21h, the *CALL #40h* statement produces the same result as in the second example.

Complement Carry Flag

CCF

Operation $C \leftarrow \text{NOT } C$

The carry flag (C) is complemented. If $C = 1$, the value of the carry flag is changed to logic 0; if $C = 0$, the value of the carry flag is changed to logic 1.

Flags **C** Complemented.
No other flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	4	EF

Example Assume that the carry flag = 0.

CCF

If the carry flag = 0, the CCF instruction complements it in the Flags Register (0D5h), changing its value from logic 0 to logic 1.

Clear

CCF dst

Operation dst ← 0

The destination location is cleared to 0.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Addr Mode
opc	dst	2	4	B0	R
			4	B1	IR

Example

Assume that Register 00h = 4Fh, register 01h = 02h, and register 02h = 5Eh.

CLR 00h → Register 00h = 00h

CLR @01h → Register 01h = 02h, register 02h = 00h

In Register (R) Addressing Mode, the *CLR 00h* statement clears the destination register 00h value to 00h. In the second example, the *CLR @01h* statement uses Indirect Register (IR) Addressing Mode to clear the 02h register value to 00h.

Complement

COM dst

Operation dst ← NOT dst

The contents of the destination location are complemented (one's complement); all 1s are changed to 0s, and vice-versa.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always reset to 0.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	4	60	R
			4	61	IR

Example

Assume that R1 = 07h and register 07h = 0F1h.

COM R1 → R1 = 0F8h

COM @R1 → R1 = 07h, register 07h = 0Eh

In the first example, destination working register R1 contains the value 07h (00000111b). The *COM R1* statement complements all of the bits in R1: all logic 1s are changed to logic 0s, and vice-versa, leaving the value 0F8h (11111000b).

In the second example, Indirect Register (IR) Addressing Mode is used to complement the value of destination register 07h (11110001b), leaving the new value 0Eh (00001110b).

Compare

CP dst, src

Operation dst ← src

The source operand is compared to (subtracted from) the destination operand, and the appropriate flags are set accordingly. The contents of both operands are unaffected by the comparison.

Flags

- C** Set if a borrow occurred (src > dst); cleared otherwise.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format	Bytes		Cycles	Op Code (Hex)	Address Mode				
	dst	src			dst	src			
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">dst src</td> </tr> </table>	opc	dst src	2	4	6	A2	r	r	
	opc	dst src							
r	lr								
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">src</td> <td style="padding: 2px;">dst</td> </tr> </table>	opc	src	dst	3	6	6	A4	R	R
	opc	src	dst						
R	IR								
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">dst</td> <td style="padding: 2px;">src</td> </tr> </table>	opc	dst	src	3	6	6	A6	R	IM
opc	dst	src							

Example 1. Assume that R1 = 02h and R2 = 03h.

CP R1, R2 → Set the C and S flags

Destination working register R1 contains the value 02h and source register R2 contains the value 03h. The *CP R1, R2* statement subtracts the R2 value (source/subtrahend) from the R1 value (destination/minuend). Because a borrow occurs and the difference is negative, C and S are 1.

2. Assume that R1 = 05h and R2 = 0Ah

```

CP    R1, R2
JP    UGE, SKIP
INC   R1
SKIP  LD    R3, R1
    
```

In this example, destination working register R1 contains the value 05h which is less than the contents of the source working register R2 (0Ah). The *CP R1, R2* statement generates $C = 1$ and the *JP* instruction does not jump to the *SKIP* location. After the *LD R3, R1* statement executes, the value 06h remains in working register R3.

Compare, Increment, and Jump on Equal

CPIJE dst, src, RA

Operation If $\text{dst} - \text{src} = 0$, $\text{PC} \leftarrow \text{PC} + \text{RA}$

$\text{Ir} \leftarrow \text{Ir} + 1$

The source operand is compared to (subtracted from) the destination operand. If the result is 0, the relative address is added to the program counter and control passes to the statement for which the address is now in the program counter. Otherwise, the instruction immediately following the CPIJE instruction is executed. In either case, the source pointer is incremented by one before the next instruction is executed.

Flags No flags are affected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	RA	3	12	C2	r	Ir

Note: Execution time is 18 cycles if the jump is taken or 16 cycles if it is not taken.

Example Assume that $\text{R1} = 02\text{h}$, $\text{R2} = 03\text{h}$, and register $03\text{h} = 02\text{h}$.

CPIJE R1, @R2, SKIP → R2 = 04h, PC jumps to SKIP location

In this example, working register R1 contains the value 02h, working register R2 the value 03h, and register 03 contains 02h. The *CPIJE R1, @R2, SKIP* statement compares the @R2 value 02h (00000010b) to 02h (00000010b). Because the result of the comparison is equal, the relative address is added to the PC and the PC then jumps to the memory location pointed to by SKIP. The source register (R2) is incremented by one, leaving a value of 04h.

► **Note:** The memory location must be within the allowed range of +127 to -128.

Compare, Increment, and Jump on NonEqual

CPIJE dst, src, RA

Operation If $dst - src = 0$, $PC \leftarrow PC + RA$

$Ir \leftarrow Ir + 1$

The source operand is compared to (subtracted from) the destination operand. If the result is 0, the relative address is added to the program counter and control passes to the statement for which the address is now in the program counter. Otherwise, the instruction immediately following the CPIJE instruction is executed. In either case, the source pointer is incremented by one before the next instruction is executed.

Flags No flags are affected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	RA	3	12	C2	r	Ir

Note: Execution time is 18 cycles if the jump is taken or 16 cycles if it is not taken.

Example Assume that $R1 = 02h$, $R2 = 03h$, and register $03h = 02h$.

CPIJE R1, @R2, SKIP → R2 = 04h, PC jumps to SKIP location

Working register R1 contains the value 02h, working register R2 (the source pointer) the value 03h, and general register 03 the value 04h. The *CPIJE R1, @R2, SKIP* statement subtracts 04h (00000100b) from 02h (00000010b). Because the result of the comparison is nonequal, the relative address is added to the PC and the PC then jumps to the memory location pointed to by SKIP. The source pointer register (R2) is also incremented by one, leaving a value of 04h.

► **Note:** The memory location must be within the allowed range of +127 to -128.

Decimal Adjust

DA dst

Operation dst ← DA dst

The destination operand is adjusted to form two 4-bit BCD digits following an addition or subtraction operation. For addition (ADD, ADC) or subtraction (SUB, SBC), Table 31 indicates the operations performed. These operations are undefined if the destination operand is not the result of a valid addition or subtraction of BCD digits.

Table 31. DA Instruction

Instruction	Carry Before DA	Bits 4–7 Value (Hex)	H Flag Before DA	Bits 0–3 Value (Hex)	Number Added to Byte	Carry After DA
ADD	0	0–9	0	0–9	00	0
ADC	0	0–8	0	A–F	06	0
	0	0–9	1	0–3	06	0
	0	A–F	0	0–9	60	1
	0	9–F	0	A–F	66	1
	0	A–F	1	0–3	66	1
	1	0–2	0	0–9	60	1
	1	0–2	0	A–F	66	1
	1	0–3	1	0–3	66	1
	SUB	0	0–9	0	0–9	00 == 00
SBC	0	0–8	1	6–F	FA == 06	0
	1	7–F	0	0–9	A0 == 60	1
	1	6–F	1	6–F	9A == 66	1

Flags

- C Set if there is a carry from the most significant bit; cleared otherwise (see Table 31).
- Z Set if result is 0; cleared otherwise.
- S Set if result bit 7 is set; cleared otherwise.
- V Undefined.
- D Unaffected.
- H Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst
opc	dst	2	4	40	R
			4	41	IR

Example

Assume that Working register R0 contains the value 15 (BCD), working register R1 contains 27 (BCD), and address 27h contains 46 (BCD).

```
ADD    R1, R0    ; C ← 0, H ← 0, Bits 4–7 = 3, bits 0–3 = C, R1 ← 3Ch
DA     R1        ; R1 ← 3Ch + 06
```

If addition is performed using the BCD values 15 and 27, the result should be 42. The sum is incorrect, however, when the binary representations are added in the destination location using standard binary arithmetic:

	0001	0101		15
+	0010	0111		27
	0011	1100	=	3Ch

The DA instruction adjusts this result so that the correct BCD representation is obtained:

	0011	1100		
+	0000	0110		
	0100	0010	=	42

Assuming the same values given above, the following statements leave the value 31 (BCD) in address 27h (@R1).

```
SUB    27h, R0    ; C ← 0, H ← 0, Bits 4–7 = 3, bits 0–3 = 1
DA     @R1        ; @R1 ← 31–0
```

Decrement

DEC dst

Operation $dst \leftarrow dst - 1$

The contents of the destination operand are decremented by one.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Cleared to 0.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	4	00	R
			4	01	IR

Example

Assume that R1 = 03h and register 03h = 10h.

DEC R1 → R1 = 02h
 DEC @R1 → Register 03h = 0Fh

In the first example, if working register R1 contains the value 03h, the *DEC R1* statement decrements the hexadecimal value by one, leaving the value 02h. In the second example, the *DEC @R1* statement decrements the value 10h contained in the destination register 03h by one, leaving the value 0Fh.

Decrement Word

DECW dst

Operation $dst \leftarrow dst - 1$

The contents of the destination location (which must be an even address) and the operand following that location are treated as a single 16-bit value that is decremented by one.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	8	80	RR
			8	81	IR

Example Assume that R0 = 12h, R1 = 34h, R2 = 30h, register 30h = 0Fh, and register 31h = 21h.

DECW RR0 → R0 = 12h, R1 = 33h

DECW @R2 → Register 30h = 0Fh, register 31h = 20h

In the first example, destination register R0 contains the value 12h and register R1 the value 34h. The *DECW RR0* statement addresses R0 and the following operand R1 as a 16-bit word and decrements the value of R1 by one, leaving the value 33h.

Note A system malfunction may occur if you use a Zero flag (FLAGS.6) result together with a DECW instruction. To avoid this problem, Zilog recommends that you use DECW as shown in the following example:

```

LOOP:  DECW    R0
        LD     R2, R1
        OR    R2, R0
        JR    NZ, LOOP
    
```

Disable Interrupts

DI

Operation SYM (0) ← 0

Bit 0 of the System Mode Control Register, SYM.0, is cleared to 0, globally disabling all interrupt processing. Interrupt requests will continue to set their respective interrupt pending bits; however, the CPU will not service them while interrupt processing is disabled.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)	
<table border="1"><tr><td>opc</td></tr></table>	opc	1	4	8F
opc				

Example

Assume that SYM = 01h.

DI

If the value of the SYM Register is 01h, the *DI* statement leaves the new value 00h in the register and clears SYM.0 to 0, disabling interrupt processing.

Execute a DI instruction prior to changing the Interrupt Mask (IMR), Interrupt Pending (IPR), and Interrupt Request (IRQ) registers.

Divide (Unsigned)

DIV dst, src

Operation dst \div src
dst (UPPER) \leftarrow REMAINDER
dst (LOWER) \leftarrow QUOTIENT

The destination operand (16 bits) is divided by the source operand (8 bits). The quotient (8 bits) is stored in the lower half of the destination. The remainder (8 bits) is stored in the upper half of the destination. When the quotient is ≥ 28 , the numbers stored in the upper and lower halves of the destination for quotient and remainder are incorrect. Both operands are treated as unsigned integers.

Flags

- C** Set if the V flag is set and quotient is between 2^8 and $2^9 - 1$; cleared otherwise.
- Z** Set if divisor or quotient = 0; cleared otherwise.
- S** Set if MSB of quotient = 1; cleared otherwise.
- V** Set if quotient is ≥ 28 or if divisor = 0; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src	
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">src</td> <td style="padding: 2px;">dst</td> </tr> </table>	opc	src	dst	3	26/10	94	RR	R
	opc	src	dst					
	26/10	95	RR				IR	
26/10	96	RR	IM					

Note: Execution takes 10 cycles if the divide-by-zero is attempted; otherwise it takes 26 cycles.

Example Assume that R0 = 10h, R1 = 03h, R2 = 40h, register 40h = 80h.

```
DIV    RR0, R2    →    R0 = 03h, R1 = 40h
DIV    RR0, @R2   →    R0 = 03h, R1 = 20h
DIV    RR0, #20h  →    R0 = 03h, R1 = 80h
```

In the first example, destination working register pair RR0 contains the values 10h (R0) and 03h (R1), and register R2 contains the value 40h. The *DIV RR0, R2* statement divides the 16-bit RR0 value by the 8-bit value of the R2 (source) register. After the *DIV* instruction, R0 contains the value 03h and R1 contains

40h. The 8-bit remainder is stored in the upper half of the destination register RR0 (R0) and the quotient in the lower half (R1).

Decrement and Jump if NonZero

DJNZ r, dst

Operation $r \leftarrow r - 1$

If $r \neq 0$, $PC \leftarrow PC + \text{dst}$

The working register being used as a counter is decremented. If the contents of the register are not logic 0 after decrementing, the relative address is added to the program counter and control passes to the statement for which the address is now in the PC. The range of the relative address is +127 to -128, and the original value of the PC is taken to be the address of the instruction byte following the *DJNZ* statement.

► **Note:** In case of using DJNZ instruction, the working register being used as a counter should be set at the one of location 0C0h to 0CFh with SRP, SRP0, or SRP1 instruction.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode			
<table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>r</td><td>opc</td><td>dst</td></tr></table>	r	opc	dst	2	8 (jump taken) 8 (no jump)	rA r = 0 to F	dst RA
r	opc	dst					

Example Assume that R1 = 02h and LOOP is the label of a relative address.

```
SRP    #0C0h
DJNZ   R1, LOOP
```

DJNZ is typically used to control a loop of instructions. In many cases, a label is used as the destination operand instead of a numeric relative address value. In the example, working register R1 contains the value 02h, and LOOP is the label for a relative address.

The *DJNZ R1, LOOP* statement decrements register R1 by one, leaving the value 01h. Because the contents of R1 after the decrement are nonzero, the jump is taken to the relative address specified by the LOOP label.

Enable Interrupts

EI

Operation SYM (0) ← 1

An EI instruction sets bit 0 of the System Mode Register, SYM.0, to 1. This allows interrupts to be serviced as they occur (assuming they have highest priority). If an interrupt's pending bit is set while interrupt processing is disabled (by executing a DI instruction), it will be serviced when you execute the EI instruction.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4	9F

Example

Assume that SYM = 00h.

EI

If the SYM Register contains the value 00h, i.e., if interrupts are currently disabled, the *EI* statement sets the SYM Register to 01h, enabling all interrupts. (SYM.0 is the enable bit for global interrupt processing.)

Enter

ENTER

Operation	SP	←	SP-2
	@SP	←	IP
	IP	←	PC
	PC	←	@IP
	IP	←	IP + 2

This instruction is useful when implementing threaded-code languages. The contents of the instruction pointer are pushed to the stack. The program counter (PC) value is then written to the instruction pointer. The program memory word that is pointed to by the instruction pointer is loaded into the PC, and the instruction pointer is incremented by two.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	14	1F

Example Figure 48 shows an example of how to use an *ENTER* statement.

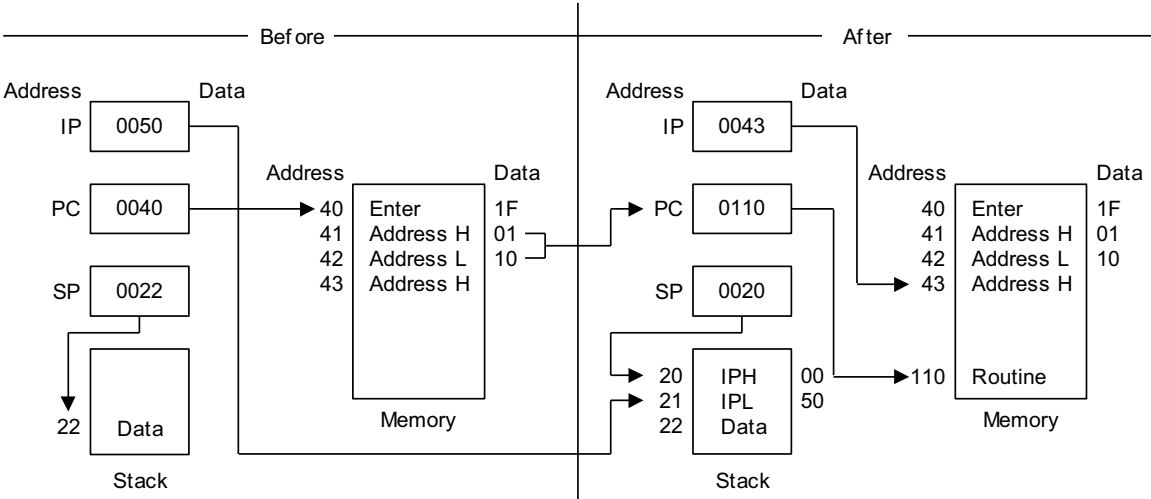


Figure 48. How to Use an ENTER Statement

Exit

EXIT

Operation	IP	←	@SP
	SP	←	SP + 2
	PC	←	@IP
	IP	←	IP + 2

This instruction is useful when implementing threaded-code languages. The stack value is popped and loaded into the instruction pointer. The program memory word that is pointed to by the instruction pointer is then loaded into the program counter, and the instruction pointer is incremented by two.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	14 (internal stack) 16 (internal stack)	2F

Example Figure 49 shows an example of how to use an *EXIT* statement.

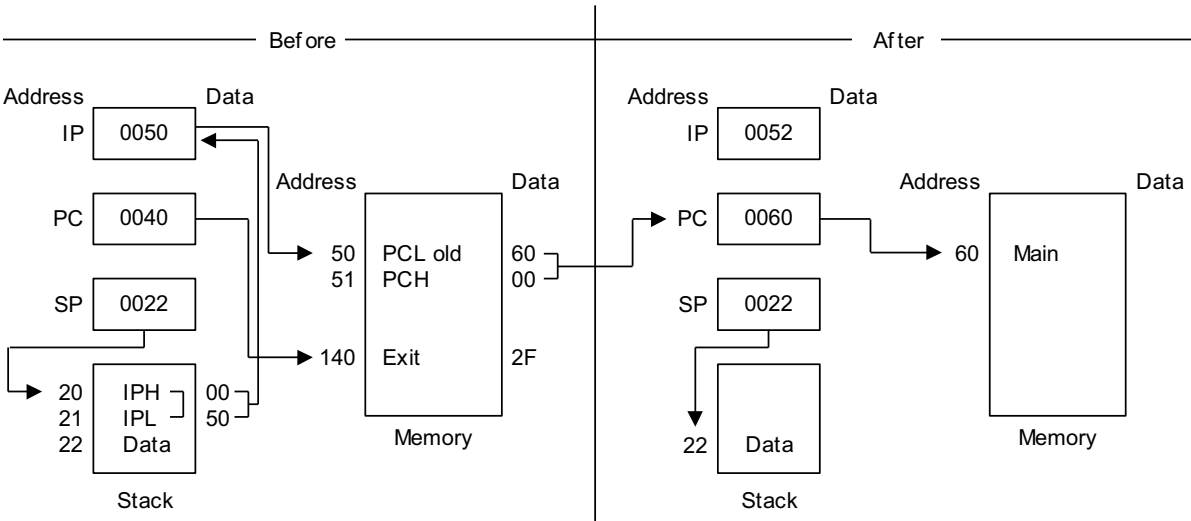


Figure 49. How to Use an EXIT Statement

Idle Operation

IDLE

Operation The IDLE instruction stops the CPU clock while allowing system clock oscillation to continue. Idle Mode can be released by an interrupt request (IRQ) or an external reset operation.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)	
<table border="1"><tr><td>opc</td></tr></table>	opc	1	4	6F
opc				

Example The IDLE instruction stops the CPU clock but not the system clock.

Increment

INC dst

Operation $dst \leftarrow dst + 1$

The contents of the destination operand are incremented by one.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode
dst src	1	4	rE r = 0 to F	dst r
opc dst	2	4	20	R
		4	21	IR

Example Assume that R0 = 1Bh, register 00h = 0Ch, and register 1Bh = 0Fh.

```

INC    R0        →    R0 = 1Ch
INC    00h       →    Register 00h = 0Dh
INC    @R0       →    R0 = 1Bh, register 01h = 10h
  
```

In the first example, if destination working register R0 contains the value 1Bh, the *INC R0* statement leaves the value 1Ch in that same register.

The next example shows the effect an INC instruction has on register 00h, assuming that it contains the value 0Ch.

In the third example, INC is used in Indirect Register (IR) Addressing Mode to increment the value of register 1Bh from 0Fh to 10h.

Increment Word

INCW dst

Operation $dst \leftarrow dst + 1$

The contents of the destination (which must be an even address) and the byte following that location are treated as a single 16-bit value that is incremented by one.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	8	A0	RR
			8	A1	IR

Example Assume that R0 = 1Ah, R1 = 02h, register 02h = 0Fh, and register 03h = 0FFh.

INCW RR0 → R0 = 1Ah, R1 = 03h

INCW @R1 → Register 02h = 10h, register 03h = 00h

In the first example, the working register pair RR0 contains the value 1Ah in register R0 and 02h in register R1. The *INCW RR0* statement increments the 16-bit destination by one, leaving the value 03h in register R1. In the second example, the *INCW @R1* statement uses Indirect Register (IR) Addressing Mode to increment the contents of general register 03h from 0FFh to 00h and register 02h from 0Fh to 10h.

► **Note:** A system malfunction may occur if you use a Zero (Z) flag (FLAGS.6) result together with an INCW instruction. To avoid this problem, Zilog recommends that you use INCW as shown in the following example:

LOOP:	INCW	RR0
	LD	R2, R1
	OR	R2, R0
	JR	NZ, LOOP

Interrupt Return

IRET IRET (Normal), IRET (FAST)

Operation

FLAGS	←	@SP
SP	←	SP + 1
PC	←	@SP
SP	←	SP + 2
SYM (0)	←	1
PC	↔	IP
FLAGS	←	FLAGS
FIS	←	0

This instruction is used at the end of an interrupt service routine. It restores the Flags Register and the program counter. It also reenables global interrupts. A *normal IRET* is executed only if the fast interrupt status bit (FIS, bit 1 of the Flags Register, 0D5h) is cleared (= 0). If a fast interrupt occurred, IRET clears the FIS bit that is set at the beginning of the service routine.

Flags All flags are restored to their original settings (i.e., the settings before the interrupt occurred).

Format	IRET (Normal)	Bytes	Cycles	Op Code (Hex)
	opc	1	10 (internal stack) 12 (internal stack)	BF
	IRET (Fast)	Bytes	Cycles	Op Code
	opc	1	6	BF

Example In the Figure 50, the instruction pointer is initially loaded with 100h in the main program before interrupts are enabled. When an interrupt occurs, the program counter and instruction pointer are swapped, causing the PC to jump to address 100h and the IP to keep the return address.

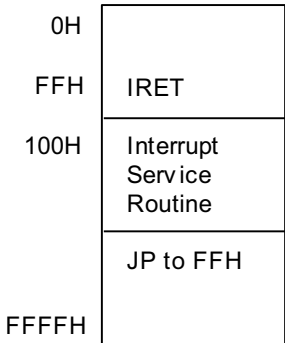


Figure 50. Instruction Pointer

► **Note:** In the fast interrupt example above, if the last instruction is not a jump to IRET, you must pay attention to the order of the last two instructions. The IRET cannot be immediately preceded by a clearing of the interrupt status (as with a reset of the IPR Register).

The last instruction in the service routine normally is a jump to IRET at address FFh. This causes the instruction pointer to be loaded with 100h again and the program counter to jump back to the main program. Now, the next interrupt can occur and the IP is still correct at 100h.

Jump

JP cc, dst (Conditional)

JP dst (Unconditional)

Operation If cc is true, PC ← dst

The conditional JUMP instruction transfers program control to the destination address if the condition specified by the condition code (cc) is true; otherwise, the instruction following the JP instruction is executed. The unconditional JP simply replaces the contents of the PC with the contents of the specified register pair. Control then passes to the statement addressed by the PC.

Flags No flags are affected.

Format

		Bytes ¹	Cycles	Op Code (Hex)	Address Mode
cc opc ² dst		3	8	ccD	DA
			6	cc = 0 to F	
opc src		2	8	30	IRR

Notes:

1. The 3-byte format is used for a conditional jump and the 2-byte format for an unconditional jump.
2. In the first byte of the three-byte instruction format (conditional jump), the condition code and the op code are both four bits.

Example

Assume that the carry flag (C) = 1, register 00 = 01h and register 01 = 20h.

JP C, LABEL_W → LABEL_W = 1000h, PC = 1000h

JP @00h → PC = 0120h

The first example shows a conditional JP. Assuming that the carry flag is set to 1, the *JP C, LABEL_W* statement replaces the contents of the PC with the value 1000h and transfers control to that location. Had the carry flag not been set, control would then have passed to the statement immediately following the JP instruction.

The second example shows an unconditional JP. The *JP @00* statement replaces the contents of the PC with the contents of the register pair 00h and 01h, leaving the value 0120h.

Jump Relative

JR cc, dst

Operation If cc is true, $PC \leftarrow PC + dst$

If the condition specified by the condition code (cc) is true, the relative address is added to the program counter and control passes to the statement for which the address is now in the program counter; otherwise, the instruction following the JR instruction is executed; see the list of condition codes in [Table 30](#) on page 93.

The range of the relative address is +127, -128, and the original value of the program counter is taken to be the address of the first instruction byte following the *JR* statement.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)	Address Mode
*				dst
cc opc dst	2	6	ccb	RA
			cc = 0 to F	

Note: *In the first byte of the two-byte instruction format, the condition code and the op code are each four bits.

Example

Assume that the carry flag = 1 and LABEL_X = 1FF7h.

JR C, LABEL_X → PC = 1FF7h

If the carry flag is set (i.e., if the condition code is true), the *JR C, LABEL_X* statement passes control to the statement for which the address is now in the PC. Otherwise, the program instruction following the JR would be executed.

Load

LD dst, src

Operation dst ← src

The contents of the source are loaded into the destination. The source's contents are unaffected.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src	
dst src	src	2	4	rC	r	IM	
			4	r8	r	R	
src opc	dst	2	4	r9 r = 0 to F	R	r	
opc	dst src	2	4	C7	r	lr	
			4	D7	lr	r	
opc	src	3	6	E4	R	R	
			6	E5	R	IR	
opc	dst	3	6	E6	R	IM	
			6	D6	IR	IM	
opc	src	dst	3	6	F5	IR	R
opc	dst src	x	3	6	87	r	x[r]
opc	src dst	x	3	6	97	x[r]	r

Example

Assume that R0 = 01h, R1 = 0Ah, register 00h = 01h, register 01h = 20h, register 02h = 02h, LOOP = 30h and register 3Ah = 0FFh.

```
LD R0, #10h    → R0 = 10h
LD R0, 01h     → R0 = 20h, register 01h = 20h
LD 01h, R0     → Register 01h = 01h, R0 = 01h
```

LD R1, @R0 → R1 = 20h, R0 = 01h
LD @R0, R1 → R0 = 01h, R1 = 0Ah, register 01h = 0Ah
LD 00h, 01h → Register 00h = 20h, register 01h = 20h
LD 02h, @00h → Register 02h = 20h, register 00h = 01h
LD 00h, #0Ah → Register 00h = 0Ah
LD @00h, #10h → Register 00h = 01h, register 01h = 10h
LD @00h, 02h → Register 00h = 01h, register 01h = 02, register
02h = 02h
LD R0, #LOOP[R1] → R0 = 0FFh, R1 = 0Ah
LD #LOOP[R0], R1 → Register 31h = 0Ah, R0 = 01h, R1 = 0Ah

Load Bit

LDB	dst, src.b
LDB	dst.b, src
Operation	dst(0) ← src(b) or dst(b) ← src(0)

The specified bit of the source is loaded into bit 0 (LSB) of the destination, or bit 0 of the source is loaded into the specified bit of the destination. No other bits of the destination are affected. The source is unaffected.

Flags No flags are affected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode	
						dst	src
opc	dst b 0	src	3	6	47	r0	Rb
opc	src b 1	dst	3	6	47	Rb	r0

Note: In the second byte of the instruction formats, the destination (or source) address is four bits, the bit address b is three bits, and the LSB address value is one bit in length.

Example Assume that R0 = 06h and general register 00h = 05h.

LDB R0, 00h.2 → R0 = 07h, register 00h = 05h

LDB 00h.0, R0 → R0 = 06h, register 00h = 04h

In the first example, destination working register R0 contains the value 06h and the source general register 00h the value 05h. The *LD R0, 00h.2* statement loads the bit 2 value of the 00h register into bit 0 of the R0 register, leaving the value 07h in register R0.

In the second example, 00h is the destination register. The *LD 00h.0, R0* statement loads bit 0 of register R0 to the specified bit (bit 0) of the destination register, leaving 04h in general register 00h.

Load Memory

LDC/LDE dst, src

Operation dst ← src

This instruction loads a byte from program or data memory into a working register or vice-versa. The source values are unaffected. LDC refers to program memory and LDE to data memory. The assembler causes Irr or rr values to be even numbers for program memory and odd numbers for data memory.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	2	10	C3	r	Irr
opc	src dst	2	10	D3	Irr	r
opc	dst src XS	3	12	E7	r	XS[rr]
opc	src dst XS	3	12	F7	XS[rr]	r
opc	dst src XL _L XL _H	4	14	A7	r	XL[rr]
opc	src dst XL _L XL _H	4	14	B7	XL[rr]	r
opc	dst 0000 DA _L DA _H	4	14	A7	r	DA
opc	src 0000 DA _L DA _H	4	14	B7	DA	r
opc	dst 0001 DA _L DA _H	4	14	A7	r	DA

					Bytes	Cycles	Op Code (Hex)	Address Mode dst src	
opc	src	0001	DA _L	DA _H	4	14	B7	DA	r

Note:

1. The source (src) or working register pair[rr] for formats 5 and 6 cannot use register pair 0–1.
2. For formats 3 and 4, the destination address XS[rr] and the source address XS[rr] are each one byte.
3. For formats 5 and 6, the destination address XL[rr] and the source address XL[rr] are each two bytes.
4. The DA and r source values for formats 7 and 8 are used to address program memory; the second set of values, used in formats 9 and 10, are used to address data memory.

Example

Assume that R0 = 11h, R1 = 34h, R2 = 01h, R3 = 04h. Program memory locations 0103h = 4Fh, 0104h = 1A, 0105h = 6Dh, and 1104h = 88h. External data memory locations 0103h = 5Fh, 0104h = 2Ah, 0105h = 7Dh, and 1104h = 98h.

LDC	R0, @RR2	; R0 ← contents of program memory location 0104h, R0 = Ah, R2 = 01h, R3 = 04h
LDE	R0, @RR2	; R0 ← contents of external data memory location 0104h, R0 = 2Ah, R2 = 01h, R3 = 04h
LDC*	@RR2, R0	; 11h (contents of R0) is loaded into program memory location 0104h (RR2), working registers R0, R2, R3 → no change
LDE	@RR2, R0	; 11h (contents of R0) is loaded into external data memory location 0104h (RR2), working registers R0, R2, R3 → no change
LDC	R0, #01h[RR2]	; R0 ← contents of program memory location 0105h (01h + RR2), R0 = 6Dh, R2 = 01h, R3 = 04h
LDE	R0, #01h[RR2]	; R0 ← contents of external data memory location 0105h (01h + RR2), R0 = 7Dh, R2 = 01h, R3 = 04h
LDC*	#01h[RR2], R0	; 11h (contents of R0) is loaded into program memory location 0105h (01h + 0104h)
LDE	#01h[RR2], R0	; 11h (contents of R0) is loaded into external data memory location 0105h (01h + 0104h)
LDC	R0, #1000h[RR2]	; R0 ← contents of program memory location 1104h (1000h + 0104h), R0 = 88h, R2 = 01h, R3 = 04h

Note: *These instructions are not supported by masked ROM type devices.

LDE	R0, #1000h[RR2]	; R0 ← contents of external data memory location 1104h (1000h + 0104h), R0 = 98h, R2 = 01h, R3 = 04h
LDC	R0, 1104h	; R0 ← contents of program memory location 1104h, R0 = 88h
LDE	R0, 1104h	; 0 ← contents of external data memory location 1104h, R0 = 98h
LDC*	1105h, R0	; 11h (contents of R0) is loaded into program memory location 1105h, (1105h) ← 11h
LDE	1105h, R0	; 11h (contents of R0) is loaded into external data memory location 1105h, (1105h) ← 11h

Note: *These instructions are not supported by masked ROM type devices.

Load Memory and Decrement

LDCD/LDED dst, src

Operation dst ← src

rr ← rr – 1

These instructions are used for user stacks or block transfers of data from program or data memory to the register file. The address of the memory location is specified by a working register pair. The contents of the source location are loaded into the destination location. The memory address is then decremented. The contents of the source are unaffected.

LDCD references program memory and LDED references external data memory. The assembler causes Irr to be an even number for program memory and an odd number for data memory.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	2	10	E2	r	lrr

Example

Assume that R6 = 10h, R7 = 33h, R8 = 12h, program memory location 1033h = 0CDh, and external data memory location 1033h = 0DDh.

LDCD R8, @RR6 ; 0CDh (contents of program memory location 1033h) is loaded into R8 and RR6 is decremented by one, R8 = 0CDh, R6 = 10h, R7 = 32h (RR6 ← RR6 – 1)

LDED R8, @RR6 ; 0DDh (contents of data memory location 1033h) is loaded into R8 and RR6 is decremented by one (RR6 ← RR6 – 1), R8 = 0DDh, R6 = 10h, R7 = 32h

Load Memory and Increment

LDCI/LDEI dst, src

Operation dst ← src

rr ← rr + 1

These instructions are used for user stacks or block transfers of data from program or data memory to the register file. The address of the memory location is specified by a working register pair. The contents of the source location are loaded into the destination location. The memory address is then incremented automatically. The contents of the source are unaffected.

LDCI refers to program memory and LDEI refers to external data memory. The assembler causes Irr to be an even number for program memory and an odd number for data memory.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	2	10	E3	r	Irr

Example

Assume that R6 = 10h, R7 = 33h, R8 = 12h, program memory locations 1033h = 0CDh and 1034h = 0C5h, external data memory locations 1033h = 0DDh and 1034h = 0D5h.

LDCI R8, @RR6 ; 0CDh (contents of program memory location 1033h) is loaded into R8 and RR6 is incremented by one (RR6 ← RR6 + 1), R8 = 0CDh, R6 = 10h, R7 = 34h

LDEI R8, @RR6 ; 0DDh (contents of data memory location 1033h) is loaded into R8 and RR6 is incremented by one (RR6 ← RR6 + 1), R8 = 0DDh, R6 = 10h, R7 = 34h

Load Memory with PreDecrement

**LDCPD/
LDEPD** dst, src

Operation $rr \leftarrow rr - 1$
 $dst \leftarrow src$

These instructions are used for block transfers of data from program or data memory from the register file. The address of the memory location is specified by a working register pair and is first decremented. The contents of the source location are then loaded into the destination location. The contents of the source are unaffected.

LDCPD refers to program memory and LDEPD refers to external data memory. The assembler causes Irr to be an even number for program memory and an odd number for external data memory.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode	
				dst	src
opc dst src	2	14	F2	Irr	r

Example Assume that $R0 = 77h$, $R6 = 30h$ and $R7 = 00h$.

LDCPD @RR6, R0 ; ($RR6 \leftarrow RR6 - 1$) 77h (contents of R0) is loaded into program memory location 2FFFh ($3000h - 1h$), $R0 = 77h$, $R6 = 2Fh$, $R7 = 0FFh$

LDEPD @RR6, R0 ; ($RR6 \leftarrow RR6 - 1$) 77h (contents of R0) is loaded into external data memory location 2FFFh ($3000h - 1h$), $R0 = 77h$, $R6 = 2Fh$, $R7 = 0FFh$

Load Memory with PreIncrement

**LDCPI/
LDEPI** dst, src

Operation rr ← rr + 1
dst ← src

These instructions are used for block transfers of data from program or data memory from the register file. The address of the memory location is specified by a working register pair and is first incremented. The contents of the source location are loaded into the destination location. The contents of the source are unaffected.

LDCPI refers to program memory and LDEPI refers to external data memory. The assembler causes Irr to be an even number for program memory and an odd number for data memory.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode	
				dst	src
opc dst src	2	14	F3	Irr	r

Example Assume that R0 = 7Fh, R6 = 21h and R7 = 0FFh.

LDCPI @RR6, R0 ; (RR6 ← RR6 + 1) 7Fh (contents of R0) is loaded into program memory location 2200h (21FFh + 1h), R0 = 7Fh, R6 = 22h, R7 = 00h

LDEPD @RR6, R0 ; (RR6 ← RR6 + 1) 7Fh (contents of R0) is loaded into external data memory location 2200h (21FFh + 1h), R0 = 7Fh, R6 = 22h, R7 = 00h

Load Word

LDW dst, src

Operation dst ← src

The contents of the source (a word) are loaded into the destination. The contents of the source are unaffected.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	src	dst	3	8	C4	RR	RR
				8	C5	RR	IR
			4	8	C6	RR	IML
opc	dst	src					

Example

Assume that R4 = 06h, R5 = 1Ch, R6 = 05h, R7 = 02h, register 00h = Ah, register 01h = 02h, register 02h = 03h, and register 03h = 0Fh.

LDW RR6, RR4 → R6 = 06h, R7 = 1Ch, R4 = 06h, R5 = 1Ch
 LDW 00h, 02h → Register 00h = 03h, register 01h = 0Fh, register 02h = 03h, register 03h = 0Fh
 LDW RR2, @R7 → R2 = 03h, R3 = 0Fh
 LDW 04h, @01h → Register 04h = 03h, register 05h = 0Fh
 LDW RR6, #1234h → R6 = 12h, R7 = 34h
 LDW 02h, #0FEDh → Register 02h = 0Fh, register 03h = 0EDh

In the second example, the *LDW 00h, 02h* statement loads the contents of the source word 02h, 03h into the destination word 00h, 01h. This leaves the value 03h in general register 00h and the value 0Fh in register 01h.

The other examples show how to use the LDW instruction with multiple addressing modes and formats.

Multiply (Unsigned)

MULT dst, src

Operation $dst \leftarrow dst \times src$

The 8-bit destination operand (even register of the register pair) is multiplied by the source operand (8 bits) and the product (16 bits) is stored in the register pair specified by the destination address. Both operands are treated as unsigned integers.

Flags

- C** Set if result is > 255; cleared otherwise.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if MSB of the result is a 1; cleared otherwise.
- V** Cleared.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	src	dst	3	22	84	RR	R
				22	85	RR	IR
				22	86	RR	IM

Example Assume that Register 00h = 20h, register 01h = 03h, register 02h = 09h, register 03h = 06h.

MULT 00h, 02h → Register 00h = 01h, register 01h = 20h, register 02h = 09h

MULT 00h, @01h → Register 00h = 00h, register 01h = 0C0h

MULT 01h, @02h → Register 00h = 06h, register 01h = 00h

In the first example, the *MULT 00h, 02h* statement multiplies the 8-bit destination operand (in the register 00h of the register pair 00h, 01h) by the source register 02h operand (09h). The 16-bit product, 0120h, is stored in the register pair 00h, 01h.

Next

NEXT

Operation $PC \leftarrow @ IP$
 $IP \leftarrow IP + 2$

The NEXT instruction is useful when implementing threaded-code languages. The program memory word that is pointed to by the instruction pointer is loaded into the program counter. The instruction pointer is then incremented by two.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	10	0F

Example Figure 51 shows an example of how to use the NEXT instruction.

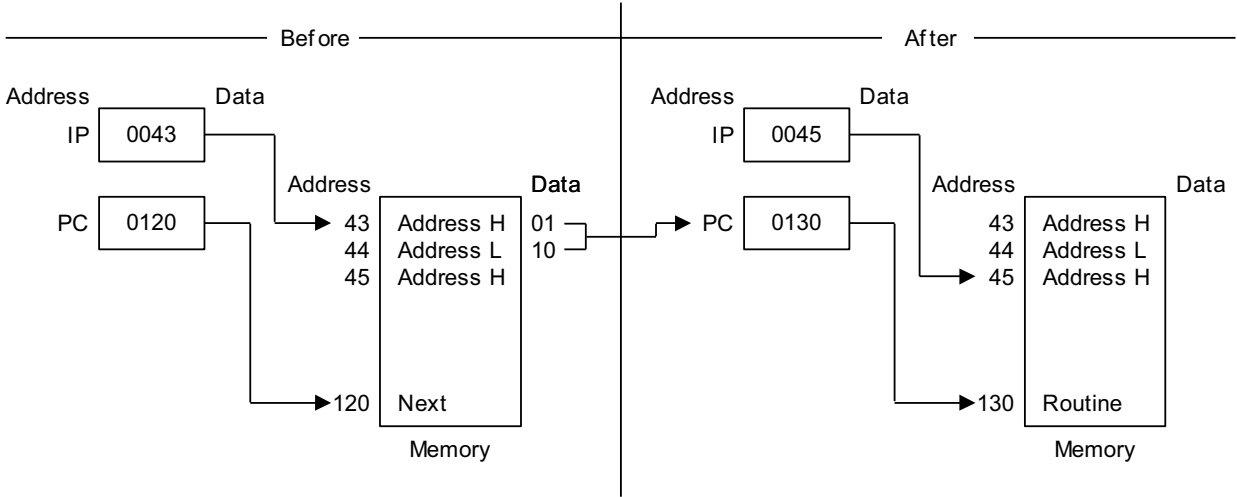


Figure 51. How to Use the NEXT Instruction

No Operation

NOP

Operation No action is performed when the CPU executes this instruction. Typically, one or more NOPs are executed in sequence to effect a timing delay of variable duration.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4	FF

Example When the NOP instruction is encountered in a program, no operation occurs. Instead, there is a delay in instruction execution time.

Logical OR

OR dst, src

Operation dst ← dst OR src

The source operand is logically ORed with the destination operand and the result is stored in the destination. The contents of the source are unaffected. The OR operation results in a 1 being stored whenever either of the corresponding bits in the two operands is a 1; otherwise a 0 is stored.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always cleared to 0.
- D** Unaffected.
- H** Unaffected.

Format			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
	opc dst src		2	4	42	r	r
				6	43	r	lr
opc src dst		3	6	44	R	R	
				6	45	R	IR
opc dst src		3	6	46	R	IM	

Example Assume that R0 = 15h, R1 = 2Ah, R2 = 01h, register 00h = 08h, register 01h = 37h and register 08h = 8Ah.

```
OR  R0, R1      →  R0 = 3Fh, R1 = 2Ah
OR  R0, @R2     →  R0 = 37h, R2 = 01h, register 01h = 37h
OR  00h, 01h   →  Register 00h = 3Fh, register 01h = 37h
OR  01h, @00h  →  Register 00h = 08h, register 01h = 0BFh
OR  00h, #02h  →  Register 00h = 0Ah
```

In the first example, if working register R0 contains the value 15h and register R1 the value 2Ah, the *OR R0, R1* statement logical-ORs the R0 and R1 register contents and stores the result (3Fh) in destination register R0.

The other examples show the use of the logical OR instruction with multiple addressing modes and formats.

Pop from Stack

ADC dst

Operation dst ← @SP
SP ← SP + 1

The contents of the location addressed by the stack pointer are loaded into the destination. The stack pointer is then incremented by one.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst
opc	dst	2	8	50	R
			8	51	IR

Example

Assume that Register 00h = 01h, register 01h = 1Bh, SPH (0D8h) = 00h, SPL (0D9h) = 0FBh and stack register 0FBh = 55h.

POP 00h → Register 00h = 55h, SP = 00FCh

POP @00h → Register 00h = 01h, register 01h = 55h, SP = 00FCh

In the first example, general register 00h contains the value 01h. The *POP 00h* statement loads the contents of location 00FBh (55h) into destination register 00h and then increments the stack pointer by one. Register 00h then contains the value 55h and the SP points to location 00FCh.

Pop User Stack (Decrementing)

POPUD dst, src

Operation dst ← src

IR ← IR – 1

This instruction is used for user-defined stacks in the register file. The contents of the register file location addressed by the user stack pointer are loaded into the destination. The user stack pointer is then decremented.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	src	dst	3	8	92	R	IR

Example

Assume that Register 00h = 42h (user stack pointer register), register 42h = 6Fh and register 02h = 70h.

POPUD 02h, @00h → Register 00h = 41h, register 02h = 6Fh, register 42h = 6Fh

If general register 00h contains the value 42h and register 42h the value 6Fh, the *POPUD 02h, @00h* statement loads the contents of register 42h into the destination register 02h. The user stack pointer is then decremented by one, leaving the value 41h.

Pop User Stack (Incrementing)

POPUI dst, src

Operation dst ← src

IR ← IR + 1

The POPUI instruction is used for user-defined stacks in the register file. The contents of the register file location addressed by the user stack pointer are loaded into the destination. The user stack pointer is then incremented.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode	
						dst	src
opc	src	dst	3	8	93	R	IR

Example

Assume that Register 00h = 01h and register 01h = 70h.

POPUI 02h, @00h → Register 00h = 02h, register 01h = 70h, register 02h = 70h

If general register 00h contains the value 01h and register 01h the value 70h, the *POPUI 02h, @00h* statement loads the value 70h into the destination general register 02h. The user stack pointer (register 00h) is then incremented by one, changing its value from 01h to 02h.

Push to Stack

PUSH src

Operation $SP \leftarrow SP - 1$

$@SP \leftarrow src$

A PUSH instruction decrements the stack pointer value and loads the contents of the source (src) into the location addressed by the decremented stack pointer. The operation then adds the new value to the top of the stack.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst
opc	src	2	8 (internal clock)	70	R
			8 (external clock)		
			8 (internal clock)	71	IR
			8 (external clock)		

Example

Assume that Register 40h = 4Fh, register 4Fh = 0AAh, SPH = 00h and SPL = 00h.

PUSH 40h → Register 40h = 4Fh, stack register 0FFh = 4Fh, SPH = 0FFh, SPL = 0FFh

PUSH @40h → Register 40h = 4Fh, register 4Fh = 0AAh, stack register 0FFh = 0AAh, SPH = 0FFh, SPL = 0FFh

In the first example, if the stack pointer contains the value 0000h, and general register 40h the value 4Fh, the *PUSH 40h* statement decrements the stack pointer from 0000 to 0FFFFh. It then loads the contents of register 40h into location 0FFFFh and adds this new value to the top of the stack.

Push User Stack (Decrementing)

PUSHUD dst, src

Operation $IR \leftarrow IR - 1$

$dst \leftarrow src$

This instruction is used to address user-defined stacks in the register file. PUSHUD decrements the user stack pointer and loads the contents of the source into the register addressed by the decremented stack pointer.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode	
						dst	src
opc	dst	src	3	8	82	IR	R

Example Assume that Register 00h = 03h, register 01h = 05h, and register 02h = 1Ah.

PUSHUD @00h, 01h → Register 00h = 02h, register 01h = 05h,
register 02h = 05h

If the user stack pointer (register 00h, for example) contains the value 03h, the *PUSHUD @00h, 01h* statement decrements the user stack pointer by one, leaving the value 02h. The 01h register value, 05h, is then loaded into the register addressed by the decremented user stack pointer.

Push User Stack (Incrementing)

PUSHUI dst, src

Operation $IR \leftarrow IR + 1$

$dst \leftarrow src$

This instruction is used for user-defined stacks in the register file. PUSHUI increments the user stack pointer and then loads the contents of the source into the register location addressed by the incremented user stack pointer.

Flags No flags are affected.

Format

			Bytes	Cycles	Op Code (Hex)	Address Mode	
						dst	src
opc	dst	src	3	8	83	IR	R

Example

Assume that Register 00h = 03h, register 01h = 05h, and register 04h = 2Ah.

PUSHUI @00h, 01h → Register 00h = 04h, register 01h = 05h,
register 04h = 05h

If the user stack pointer (register 00h, for example) contains the value 03h, the *PUSHUI @00h, 01h* statement increments the user stack pointer by one, leaving the value 04h. The 01h register value, 05h, is then loaded into the location addressed by the incremented user stack pointer.

Reset Carry Flag

RCF RCF

Operation $C \leftarrow 0$

The carry flag is cleared to logic 0, regardless of its previous value.

Flags **C** Cleared to 0.
No other flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	4	CF

Example Assume that $C = 1$ or 0 . The RCF instruction clears the carry flag (C) to logic 0.

Return

RET

Operation $PC \leftarrow @SP$
 $SP \leftarrow SP + 2$

The RET instruction is normally used to return to the previously executing procedure at the end of a procedure entered by a CALL instruction. The contents of the location addressed by the stack pointer are popped into the program counter. The next statement that is executed is the one that is addressed by the new program counter value.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)
opc	1	8 (internal stack) 10 (internal stack)	CF

Example Assume that $SP = 00FCh$, $(SP) = 101Ah$, and $PC = 1234$.

RET \rightarrow $PC = 101Ah$, $SP = 00FEh$

The RET statement pops the contents of stack pointer location 00FCh (10h) into the high byte of the program counter. The stack pointer then pops the value in location 00FEh (1Ah) into the PC's low byte and the instruction at location 101Ah is executed. The stack pointer now points to memory location 00FEh.

Rotate Left

RL dst

Operation $C \leftarrow \text{dst}(7)$

$\text{dst}(0) \leftarrow \text{dst}(7)$

$\text{dst}(n + 1) \leftarrow \text{dst}(n), n = 0 - 6$

The contents of the destination operand are rotated left one bit position. The initial value of bit 7 is moved to the bit 0 (LSB) position and also replaces the carry flag.

Figure 52 shows how bits rotate left.

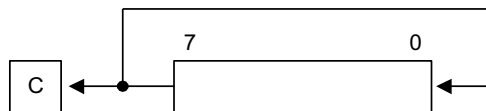


Figure 52. Rotate Left

Flags

- C** Set if the bit rotated from the most significant bit position (bit 7) is 1.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Set if arithmetic overflow occurred; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode		
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">opc</td> <td style="padding: 2px 10px;">dst</td> </tr> </table>	opc	dst		2	4	90	R
	opc	dst					
			4	91	IR		

Example

Assume that Register 00h = 0AAh, register 01h = 02h and register 02h = 17h.

RL 00h → Register 00h = 55h, C = 1

RL @01h → Register 01h = 02h, register 02h = 2Eh, C = 0

In the first example, if general register 00h contains the value 0AAh (10101010b), the *RL 00h* statement rotates the 0AAh value left one bit position, leaving the new value 55h (01010101b) and setting the carry and overflow flags.

Rotate Left through Carry

RCL dst

Operation $\text{dst}(0) \leftarrow C$

$C \leftarrow \text{dst}(7)$

$\text{dst}(n + 1) \leftarrow \text{dst}(n), n = 0 - 6$

The contents of the destination operand with the carry flag are rotated left one bit position. The initial value of bit 7 replaces the carry flag (C); the initial value of the carry flag replaces bit 0.

Figure 53 shows how bits rotate left through carry.

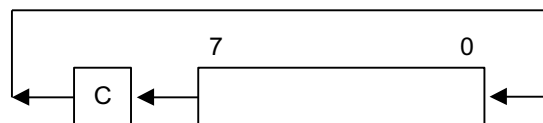


Figure 53. Rotate Left through Carry

Flags

- C** Set if the bit rotated from the most significant bit position (bit 7) is 1.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Set if arithmetic overflow occurred, i.e., if the sign of the destination changed during rotation; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	4	10	R
			4	11	IR

Example

Assume that Register 00h = 0AAh, register 01h = 02h, and register 02h = 17h, C = 0.

RCL 00h Register 00h = 54h, C = 1

RCL @01h Register 01h = 02h, register 02h = 2Eh, C = 0

In the first example, if general register 00h has the value 0AAh (10101010b), the *RLC 00h* statement rotates 0AAh one bit position to the left. The initial value of bit 7 sets the carry flag and the initial value of the C flag replaces bit 0 of register 00h, leaving the value 55h (01010101b). The MSB of register 00h resets the carry flag to 1 and sets the overflow flag.

Rotate Right

RR dst

Operation $C \leftarrow \text{dst}(0)$

$\text{dst}(7) \leftarrow \text{dst}(0)$

$\text{dst}(n) \leftarrow \text{dst}(n + 1), n = 0 - 6$

The contents of the destination operand are rotated right one bit position. The initial value of bit 0 (LSB) is moved to bit 7 (MSB) and also replaces the carry flag (C).

Figure 54 shows how bits rotate right.

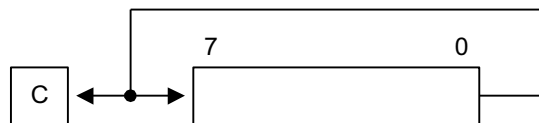


Figure 54. Rotate Right

Flags

- C** Set if the bit rotated from the least significant bit position (bit 0) is 1.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Set if arithmetic overflow occurred, i.e., if the sign of the destination changed during rotation; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	4	E0	R
			4	E1	IR

Example

Assume that Register 00h = 31h, register 01h = 02h, and register 02h = 17h.

RR 00h Register 00h = 98h, C = 1

RR @01h Register 01h = 02h, register 02h = 8Bh, C = 1

In the first example, if general register 00h contains the value 31h (00110001b), the *RR 00h* statement rotates this value one bit position to the right. The initial value of bit 0 is moved to bit 7, leaving the new value 98h (10011000b) in the destination register. The initial bit 0 also resets the C flag to 1 and the sign flag and overflow flag are also set to 1.

Rotate Right through Carry

RRC dst

Operation $dst(7) \leftarrow C$

$C \leftarrow dst(0)$

$dst(n) \leftarrow dst(n + 1), n = 0 - 6$

The contents of the destination operand and the carry flag are rotated right one bit position. The initial value of bit 0 (LSB) replaces the carry flag; the initial value of the carry flag replaces bit 7 (MSB).

Figure 55 shows how bits rotate right through carry.

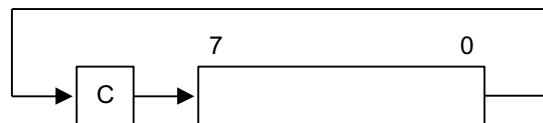


Figure 55. Rotate Right through Carry

Flags

- C** Set if the bit rotated from the least significant bit position (bit 0) is 1.
- Z** Set if the result is 0 cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Set if arithmetic overflow occurred, i.e., if the sign of the destination changed during rotation; cleared otherwise.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode	
<table border="1" style="display: inline-table;"> <tr> <td style="border: none;">opc</td> <td style="border: none;">dst</td> </tr> </table>	opc	dst	2	4	C0	R
	opc	dst				
C1	IR					

Example

Assume that Register 00h = 55h, register 01h = 02h, register 02h = 17h, and C = 0.

RRC 00h Register 00h = 2Ah, C = 1

RRC @01h Register 01h = 02h, register 02h = 0Bh, C = 1

In the first example, if general register 00h contains the value 55h (01010101b), the *RRC 00h* statement rotates this value one bit position to the right. The initial value of bit 0 (1) replaces the carry flag and the initial value of the C flag (1) replaces bit 7. This leaves the new value 2Ah (00101010b) in destination register 00h. The sign flag and overflow flag are both cleared to 0.

Select Bank0

SB0

Operation BANK ← 0

The SB0 instruction clears the bank address flag in the Flags Register (FLAGS.0) to logic 0, selecting Bank0 register addressing in the Set1 area of the register file.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4	4F

Example The *SB0* statement clears FLAGS.0 to 0, selecting Bank0 register addressing.

Select Bank1

SB1

Operation BANK ← 1

The SB1 instruction sets the bank address flag in the Flags Register (FLAGS.0) to logic 1, selecting Bank1 register addressing in the Set1 area of the register file. (Bank1 is not implemented in some KS88-series microcontrollers.)

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4	5F

Example The *SB1* statement sets FLAGS.0 to 1, selecting Bank1 register addressing, if implemented.

Subtract with Carry

SBC dst, src

Operation $dst \leftarrow dst - src - c$

The source operand, along with the current value of the carry flag, is subtracted from the destination operand and the result is stored in the destination. The contents of the source are unaffected. Subtraction is performed by adding the two's-complement of the source operand to the destination operand. In multiple precision arithmetic, this instruction permits the carry borrow from the subtraction of the low-order operands to be subtracted from the subtraction of high-order operands.

Flags

- C** Set if a borrow occurred ($src > dst$); cleared otherwise.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred, i.e., if the operands were of opposite sign and the sign of the result is the same as the sign of the source; cleared otherwise.
- D** Always set to 1.
- H** Cleared if there is a carry from the most significant bit of the low-order four bits of the result; set otherwise, indicating a borrow.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src	
opc	dst src	2	4	32	r	r	
			6	33	r	lr	
opc	src	3	6	34	R	R	
			6	35	R	IR	
opc	dst	src	3	6	36	R	IM

Example Assume that R1 = 10h, R2 = 03h, C = 1, register 01h = 20h, register 02h = 03h and register 03h = 0Ah.

SBC	R1, R2	R1 = 0Ch, R2 = 03h
SBC	R1, @R2	R1 = 05h, R2 = 03h, register 03h = 0Ah
SBC	01h, 02h	Register 01h = 1Ch, register 02h = 03h

SBC 01h, @02h Register 01h = 15h, register 02h = 03h, register 03h = 0Ah

SBC 01h, #8Ah Register 01h = 95h; C, S, and V = 1

In the first example, if working register R1 contains the value 10h and register R2 the value 03h, the *SBC R1, R2* statement subtracts the source value (03h) and the C flag value (1) from the destination (10h) and then stores the result (0Ch) in register R1.

Set Carry Flag

SCF

Operation $C \leftarrow 1$

The carry flag (C) is set to logic 1, regardless of its previous value.

Flags **C** Set to 1.

No other flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4	DF

Example The *SCF* statement sets the carry flag to logic 1.

Shift Right Arithmetic

SRA dst

Operation $\text{dst}(7) \leftarrow \text{dst}(7)$

$C \leftarrow \text{dst}(0)$

$\text{dst}(n) \leftarrow \text{dst}(n + 1), n = 0 - 6$

An arithmetic shift-right of one bit position is performed on the destination operand. Bit 0 (the LSB) replaces the carry flag. The value of bit 7 (the sign bit) is unchanged and is shifted into bit position 6.

Figure 56 shows how bits shift right.

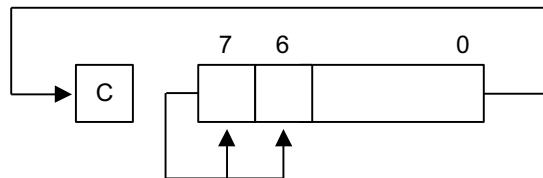


Figure 56. Shift Right

Flags

- C** Set if the bit shifted from the LSB position (bit 0) is 1.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Always cleared to 0.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode		
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">opc</td> <td style="padding: 2px 10px;">dst</td> </tr> </table>	opc	dst		2	4	D0	R
	opc	dst					
			4	D1	IR		

Example

Assume that Register 00h = 9Ah, register 02h = 03h, register 03h = 0BCh, and C = 1.

SRA 00h Register 00h = 0CD, C = 0

SRA @02h Register 02h = 03h, register 03h = 0DEh, C = 0

In the first example, if general register 00h contains the value 9Ah (10011010B), the *SRA 00h* statement shifts the bit values in register 00h right one bit position. Bit 0 (0) clears the C flag and bit 7 (1) is then shifted into the bit 6 position (bit 7 remains unchanged). This leaves the value 0CDh (11001101b) in destination register 00h.

Set Register Pointer

SRP src

SRP0 src

SRP1 src

Operation

If src(1) = 1 and src(0) = 0 then:	RP0 (3–7)	src (3–7)
If src(1) = 1 and src(0) = 0 then:	RP1(3–7)	src (3–7)
If src(1) = 1 and src(0) = 0 then:	RP0 (4–7)	src (4–7)
	RP0 (3)	0
	RP1 (4–7)	src (4–7)
	RP1 (3)	1

The sources data bits one and zero (LSB) determine whether to write one or both of the register pointers, RP0 and RP1. Bits 3–7 of the selected register pointer are written unless both register pointers are selected. RP0.3 is then cleared to logic 0 and RP1.3 is set to logic 1.

Flags No flags are affected.

Format

		Bytes	Cycles	Op Code	Address Mode
		(Hex)			src
opc	src	2	4	31	IM

Example The *SRP #40h* statement sets register pointer 0 (RP0) at location 0D6h to 40h and register pointer 1 (RP1) at location 0D7h to 48h.

The *SRP0 #50h* statement sets RP0 to 50h, and the *SRP1 #68h* statement sets RP1 to 68h.

Stop Operation

STOP

Operation The STOP instruction stops the both the CPU clock and system clock and causes the microcontroller to enter Stop Mode. During Stop Mode, the contents of on-chip CPU registers, peripheral registers, and I/O port control and data registers are retained. Stop Mode can be released by an external reset operation or by external interrupts. For the reset operation, the RESET pin must be held to Low level until the required oscillation stabilization interval has elapsed.

Flags No flags are affected.

Format	Bytes	Cycles	Op Code (Hex)	Address Mode	
				dst	src
opc	1	4	7F	-	-

Example The *STOP* statement halts all microcontroller operations.

Subtract

SUB dst, src

Operation $dst \leftarrow dst - src$

The source operand is subtracted from the destination operand and the result is stored in the destination. The contents of the source are unaffected. Subtraction is performed by adding the two's complement of the source operand to the destination operand.

Flags

- C** Set if a borrow occurred; cleared otherwise.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result is negative; cleared otherwise.
- V** Set if arithmetic overflow occurred, i.e., if the operands were of opposite signs and the sign of the result is of the same as the sign of the source operand; cleared otherwise.
- D** Always set to 1.
- H** Cleared if there is a carry from the most significant bit of the low-order four bits of the result; set otherwise indicating a borrow.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src	
opc	dst src	2	4	22	r	r	
			6	23	r	lr	
opc	src	3	6	24	R	R	
			6	25	R	IR	
opc	dst	src	3	6	26	R	IM

Example Assume that R1 = 12h, R2 = 03h, register 01h = 21h, register 02h = 03h, register 03h = 0Ah.

SUB	R1, R2	R1 = 0Fh, R2 = 03h
SUB	R1, @R2	R1 = 08h, R2 = 03h
SUB	01h, 02h	Register 01h = 1Eh, register 02h = 03h
SUB	01h, @02h	Register 01h = 17h, register 02h = 03h
SUB	01h, #90h	Register 01h = 91h; C, S, and V = 1
SUB	01h, #65h	Register 01h = 0BCh; C and S = 1, V = 0

In the first example, if working register R1 contains the value 12h and if register R2 contains the value 03h, the *SUB R1, R2* statement subtracts the source value (03h) from the destination value (12h) and stores the result (0Fh) in destination register R1.

Swap Nibbles

SRA dst

Operation dst(0-3) ↔ dst(4-7)

The contents of the lower four bits and upper four bits of the destination operand are swapped.

Figure 57 shows how to swap nibbles.

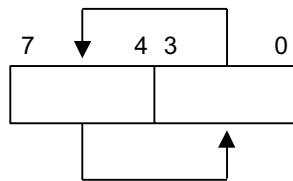


Figure 57. Swap Nibbles

Flags

- C** Undefined.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Undefined.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode
opc	dst	2	4	F0	R
			4	F1	IR

Example

Assume that Register 00h = 3Eh, register 02h = 03h, and register 03h = 0A4h.

SWAP 00h Register 00h = 0E3h

SWAP @02h Register 02h = 03h, register 03h = 4Ah

In the first example, if general register 00h contains the value 3Eh (00111110b), the *SWAP 00h* statement swaps the lower and upper four bits (nibbles) in the 00h register, leaving the value 0E3h (11100011b).

Test Complement under Mask

TCM dst, src

Operation (NOT dst) AND src

This instruction tests selected bits in the destination operand for a logic 1 value. The bits to be tested are specified by setting a 1 bit in the corresponding position of the source operand (mask). The TCM statement complements the destination operand, which is then ANDed with the source mask. The zero (Z) flag can then be checked to determine the result. The destination and source operands are unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always cleared to 0.
- D** Unaffected.
- H** Unaffected.

Format

		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src		
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">dst src</td> </tr> </table>	opc	dst src	2	4	62	r	r	
	opc	dst src						
6	63	r	lr					
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">src</td> <td style="padding: 2px;">dst</td> </tr> </table>	opc	src	dst	3	6	64	R	R
	opc	src	dst					
6	65	R	IR					
<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px;">opc</td> <td style="padding: 2px;">dst</td> <td style="padding: 2px;">src</td> </tr> </table>	opc	dst	src	3	6	66	R	IM
opc	dst	src						

Example

Assume that R0 = 0C7h, R1 = 02h, R2 = 12h, register 00h = 2Bh, register 01h = 02h and register 02h = 23h.

TCM	R0, R1	R0 = 0C7h, R1 = 02h, Z = 1
TCM	R0, @R1	R0 = 0C7h, R1 = 02h, register 02h = 23h, Z = 0
TCM	00h, 01h	Register 00h = 2Bh, register 01h = 02h, Z = 1
TCM	00h, @01h	Register 00h = 2Bh, register 01h = 02h, register 02h = 23h, Z = 1
TCM	00h, #34	Register 00h = 2Bh, Z = 0

In the first example, if working register R0 contains the value 0C7h (11000111b) and register R1 the value 02h (0000010b), the *TCM R0, R1* statement tests bit 1 in the destination register for a 1 value. Because the mask value corresponds to the test bit, the Z flag is set to logic 1 and can be tested to determine the result of the TCM operation.

Test Under Mask

TM dst, src

Operation dst AND src

This instruction tests selected bits in the destination operand for a logic 0 value. The bits to be tested are specified by setting a 1 bit in the corresponding position of the source operand (mask), which is ANDed with the destination operand. The zero (Z) flag can then be checked to determine the result. The destination and source operands are unaffected.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always reset to 0.
- D** Unaffected.
- H** Unaffected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src
opc	dst src	2	4	72	r	r
			6	73	r	lr
opc	src dst	3	6	74	R	R
			6	75	R	IR
opc	dst src	3	6	76	R	IM

Example Assume that R0 = 0C7h, R1 = 02h, R2 = 18h, register 00h = 2Bh, register 01h = 02h and register 02h = 23h.

TM	R0, R1	R0 = 0C7h, R1 = 02h, Z = 0
TM	R0, @R1	R0 = 0C7h, R1 = 02h, register 02h = 23h, Z = 0
TM	00h, 01h	Register 00h = 2Bh, register 01h = 02h, Z = 0
TM	00h, @01h	Register 00h = 2Bh, register 01h = 02h, register 02h = 23h, Z = 0
TM	00h, #54	Register 00h = 2Bh, Z = 1

In the first example, if working register R0 contains the value 0C7h (11000111b) and register R1 the value 02h (0000010b), the *TM R0, R1*

statement tests bit 1 in the destination register for a 0 value. Because the mask value does not match the test bit, the Z flag is cleared to logic 0 and can be tested to determine the result of the TM operation.

Wait for Interrupt

WFI

Operation The CPU is effectively halted until an interrupt occurs, except that DMA transfers can still take place during this wait state. The WFI status can be released by an internal interrupt, including a fast interrupt.

Flags No flags are affected.

Format

	Bytes	Cycles	Op Code (Hex)
opc	1	4n	3F

Note: n = 1, 2, 3, etc.

Example Figure 58 presents a sample program structure that depicts the sequence of operations that follow a *WFI* statement.

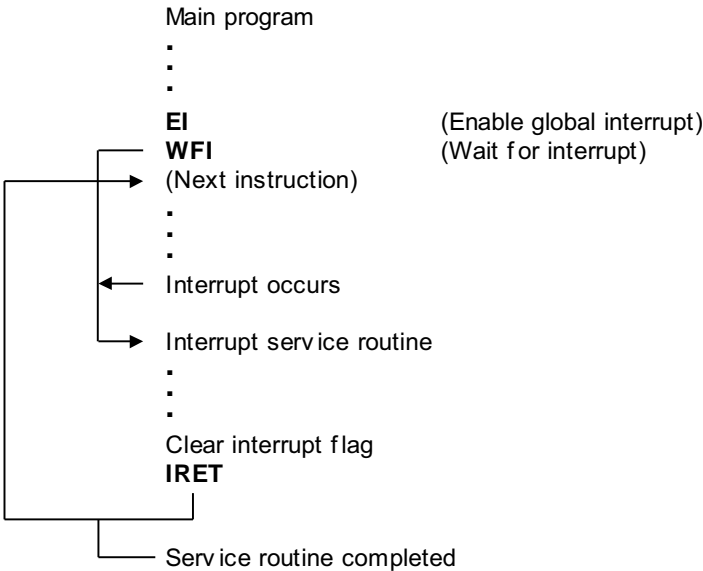


Figure 58. Sample Program Structure

Logical Exclusive OR

XOR dst, src

Operation dst ← dst XOR src

The source operand is logically exclusive-ORed with the destination operand and the result is stored in the destination. The exclusive-OR operation results in a 1 bit being stored whenever the corresponding bits in the operands are different; otherwise, a 0 bit is stored.

Flags

- C** Unaffected.
- Z** Set if the result is 0; cleared otherwise.
- S** Set if the result bit 7 is set; cleared otherwise.
- V** Always reset to 0.
- D** Unaffected.
- H** Unaffected.

Format		Bytes	Cycles	Op Code (Hex)	Address Mode dst	src	
opc	dst src	2	4	B2	r	r	
			6	B3	r	lr	
opc	src	3	6	B4	R	R	
			6	B5	R	IR	
opc	dst	src	3	6	B6	R	IM

Example Assume that R0 = 0C7h, R1 = 02h, R2 = 18h, register 00h = 2Bh, register 01h = 02h and register 02h = 23h.

```
XOR R0, R1      R0 = 0C5h, R1 = 02h
XOR R0, @R1     R0 = 0E4h, R1 = 02h, register 02h = 23h
XOR 00h, 01h   Register 00h = 29h, register 01h = 02h
XOR 00h, @01h  Register 00h = 08h, register 01h = 02h, register 02h = 23h
XOR 00h, #54h  Register 00h = 7Fh
```

In the first example, if working register R0 contains the value 0C7h and if register R1 contains the value 02h, the *XOR R0, R1* statement logically exclusive-ORs the R1 value with the R0 value and stores the result (0C5h) in the destination register R0.

Clock Circuit

The S3F8S5A microcontroller features two oscillator circuits: a main clock and a subclock circuit. The CPU and peripheral hardware operate on the system clock frequency supplied through these circuits. The maximum CPU clock frequency of the S3F8S5A MCU is determined by the settings in the CLKCON Register. These main oscillator circuits are shown in Figures 59 through 63.

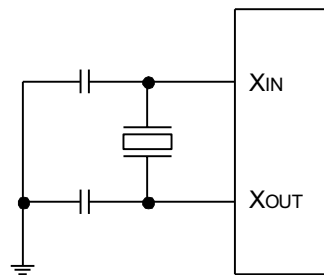


Figure 59. Crystal/Ceramic Oscillator (f_x)

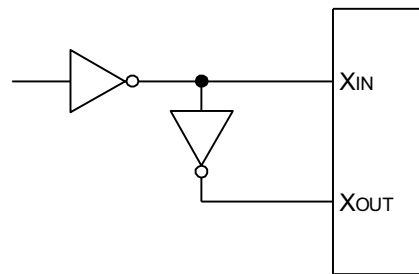


Figure 60. External Oscillator (f_x)

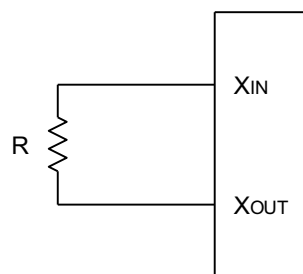


Figure 61. RC Oscillator (f_x)

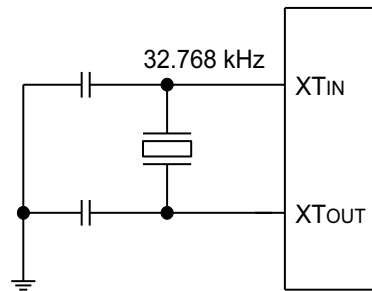


Figure 62. Crystal Oscillator (f_{XT})

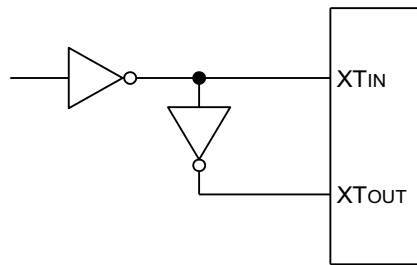


Figure 63. External Oscillator (f_{XT})

System Clock Circuit

The system clock circuit features the following components:

- External crystal, ceramic resonator, RC oscillation source, or an external clock source
- Oscillator stop and wake-up functions
- Programmable frequency divider for the CPU clock (f_{XX} divided by 1, 2, 8, or 16)
- System Clock Control (CLKCON) Register
- Oscillator Control (OSCCON) and Stop Control (STPCON) registers

CPU Clock Notation

In this document, the following notations are used to describe the CPU clock:

- f_X = Main clock

- f_{XT} = Subclock
- f_{XX} = Selected system clock

Clock Status During Power-Down Modes

Two power-down modes, Stop Mode and Idle Mode, affect the system clock as follows:

- In Stop Mode, the main oscillator is halted. Stop Mode is released, and the oscillator is started, by a reset operation or an external interrupt (with an RC delay noise filter), and can also be released by internal interrupt when the subsystem oscillator is running and the watch timer is operating with the subsystem clock.
- In Idle Mode, the internal clock signal is gated to the CPU, but not to the interrupt structure, timers, and timer/counters. Idle Mode is released by a reset or by an external or internal interrupt.

A block diagram of the system clock circuit is shown in Figure 64.

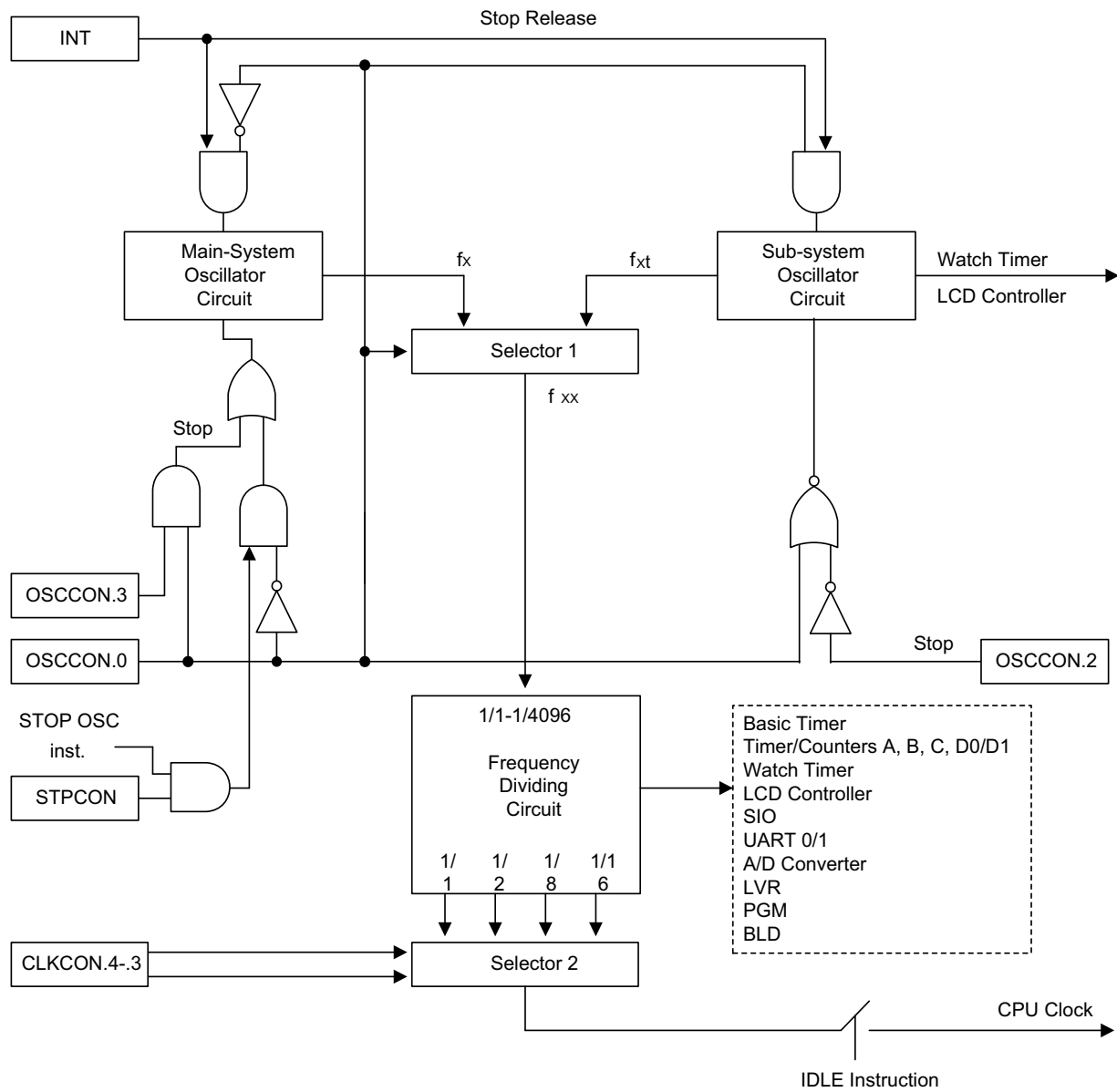


Figure 64. System Clock Circuit Diagram

System Clock Control Register

The System Clock Control (CLKCON) Register, shown in Table 32, is located at address D4h, Set1. This register is read/write-addressable and offers an oscillator frequency divide-by value.

After the main oscillator is activated, $f_{XX}/16$ (the slowest clock speed) is selected as the CPU clock. If necessary, the CPU clock speed can be increased to $f_{XX}/8$, $f_{XX}/2$, or $f_{XX}/1$.

Table 32. System Clock Control Register (CLKCON; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	–	0	0	–	–	–
R/W	R/W	–	–	R/W	R/W	–	–	–
Address	D4h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Oscillator IRQ Wake-up Function Bit 0: Enable IRQ for main wake-up in Power Down Mode. 1: Disable IRQ for main wake-up in Power Down Mode.
[6:5]	Reserved
[4:3]	CPU Clock (System Clock) Selection Bits* 00: $f_{XX}/16$. 01: $f_{XX}/8$. 10: $f_{XX}/2$. 11: $f_{XX}/1$.
[2:0]	Reserved

Note: *After a reset, the slowest clock (divided by 16) is selected as the system clock. To select faster clock speeds, load the appropriate values to CLKCON.3 and CLKCON.4.

Oscillator Control Register

The Oscillator Control (OSCCON) Register, shown in Table 33, is located in Set1, Bank0, at address FAh. It is read/write addressable and offers the following functions:

- System clock selection
- Main oscillator control
- Suboscillator control

Table 33. Oscillator Control Register (OSCCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	–	–	0	0	–	0
R/W	–	–	–	–	R/W	R/W	–	R/W
Address	FAh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7:4]	Reserved
[3]	Main Oscillator Control Bit 0: Main oscillator RUN. 1: Main oscillator STOP.
[2]	Suboscillator Control Bit 0: Suboscillator RUN. 1: Suboscillator STOP.
[1]	Reserved
[0]	System Clock Selection Bit 0: Select main oscillator for system clock. 1: Select suboscillator for system clock.

The OSCCON.0 register settings select the main clock or the subclock as the system clock. After a reset, the main clock is selected for the system clock because the reset value of OSCCON.0 is 0.

The main oscillator can be stopped or run by setting OSCCON.3. The suboscillator can be stopped or run by setting OSCCON.2.

Stop Control Register

The Stop Control (STPCON) Register, shown in Table 34, is located in Set1, Bank0, at address EDh. It is read/write addressable and offers an enable/disable STOP instruction. After a reset, this STOP instruction is disabled, because the value of STPCON is *other values*.

Table 34. Stop Control Register (STPCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	EDh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7]	Stop Control Bits* 10100101: Enable stop instruction. All other values: disable stop instruction.							
Note: *Before executing a stop instruction, this STPCON Register must be set as 10100101b; otherwise, the stop instruction will not execute, and a reset will be generated.								

If necessary, the STOP instruction can be used by setting the value of STPCON to 10100101b, as shown in the following example, which shows how to enter Stop Mode when a main clock is selected as the system clock.

Example

```
LD      STOPCON, #1010010b      ; Enable STOP instruction
STOP                               ; Enter Stop Mode
NOP
NOP
NOP                               ; Release STOP mode
LD      STOPCON, #00000000b     ; Disable STOP instruction
```

Switching the CPU Clock

Data loading in the Oscillator Control (OSCCON) Register determines whether a main clock or a subclock is selected as the CPU clock, and also how this frequency is to be

divided by setting CLKCON. As a result, it is possible to dynamically switch between main and subclocks and to modify operating frequencies.

OSCCON.0 selects the main clock (f_X) or the subclock (f_{XT}) for the CPU clock. OSCCON.3 starts or stops the main clock oscillation, and OSCCON.2 starts or stops the subclock oscillation. CLKCON.4–.3 controls the frequency divider circuit and divides the selected f_{XX} clock by 1, 2, 8, and 16. If the subclock (f_{XT}) is selected as the system clock, CLKCON.4–.3 must be set to 11.

As an example, if you are using the default CPU clock (i.e., under normal operating mode and with a main clock of $f_X/16$) and you want to switch from the f_X clock to a subclock and to stop the main clock, you must set CLKCON.4–.3 to 11, OSCCON.0 to 1, and OSCCON.3 to 1 in sequence. As a result, the clock is switched from f_X to f_{XT} , and main clock oscillation is stopped.

The following example presents the steps that must be taken to switch from a subclock to the main clock. First, set OSCCON.3 to 0 to enable main clock oscillation. Next, after a certain number of machine cycles have elapsed, select the main clock by setting OSCCON.0 to 0.

Example 1. The following example shows how to change from the main clock to the subclock.

```

MA2SUB OR   CLKCON,#18h      ; Nondivided clock for system clock
LD          OSCCON,#01h     ; Switches to the subclock
CALL       DLY16            ; Delay 16 ms
OR          OSCCON,#08h     ; Stop the main clock oscillation RET

```

Example 2. This next example shows how to change from the subclock to the main clock.

```

SUB2MA     AND OSCCON,#07h   ; Start the main clock oscillation
CALL       DLY16            ; Delay 16 ms
AND        OSCCON,#06h     ; Switch to the main clock
RET
DLY16     SRP #0C0h
LD        R0,#20h
DEL       NOP
DJNZ     R0,DEL
RET

```

Reset and Power-Down

This chapter discusses system reset and power-down modes.

System Reset

During a power-on reset, the voltage at V_{DD} goes High and the nRESET pin is forced Low. The nRESET signal is input through a Schmitt trigger circuit, where it is synchronized with the CPU clock. This procedure brings the S3F8S5A MCU into a known operating status.

To allow time for internal CPU clock oscillation to stabilize, the nRESET pin must be held Low for a minimum time interval after the power supply comes within tolerance. The minimum required time of a reset operation for oscillation stabilization is one millisecond.

Whenever a reset occurs during normal operation (i.e., when both V_{DD} and nRESET are High), the nRESET pin is forced Low, and the reset operation starts. All system and peripheral control registers are then reset to their default hardware values. In summary, the following sequence of events occurs during a reset operation:

- All interrupts are disabled.
- The watchdog (basic timer) function is enabled.
- Ports 0–4 are set to Input Mode, and all pull-up resistors are disabled for the I/O port.
- Peripheral control and data register settings are disabled and reset to their default hardware values.
- The program counter (PC) is loaded with the 0100h program reset address within ROM.
- When the programmed oscillation stabilization time interval has elapsed, the instruction stored at ROM location 0100h (and at 0101h) is fetched and executed in Normal Mode by the Smart Option.
- The reset address in ROM can be changed by the Smart Option in the S3F8S5A full-flash device. Refer to the [Embedded Flash Memory Interface](#) chapter on page 334 to learn more.

Normal Mode Reset Operation

In Normal Mode, the Test pin is tied to V_{SS} . A reset enables access to the 16KB on-chip ROM; the external interface is not automatically configured.

► **Note:** To program the duration of the oscillation stabilization interval, make the appropriate settings to the Basic Timer Control (BTCN) Register before entering Stop Mode. Additionally, if not using the basic timer watchdog function (which causes a system reset if a basic timer counter overflow occurs), it can be disabled by writing 1010b to the upper nibble of BTCN.

Hardware Reset Values

Tables 35 through 38 list the reset values for the CPU and system registers, the peripheral control registers, and the peripheral data registers following a reset operation. The following notation is used to represent these reset values:

- A 1 or a 0 shows the reset bit value as logic 1 or logic 0, respectively
- An x means that the bit value is undefined after a reset
- A dash (–) means that the bit is either not used or not mapped (however, a 0 is read from the bit position)

Table 35. Set1 Register Values After RESET

Register Name	Mnemonic	Address		Bit Values After Reset								
		Dec	Hex	7	6	5	4	3	2	1	0	
Locations D0h–D2h are not mapped.												
Basic Timer Control	BTCN	211	D3h	0	0	0	0	0	0	0	0	0
System Clock Control	CLKCON	212	D4h	0	–	–	0	0	–	–	–	–
System Flags	FLAGS	213	D5h	x	x	x	x	x	x	0	0	0
Register Pointer 0	RP0	214	D6h	1	1	0	0	0	–	–	–	–
Register Pointer 1	RP1	215	D7h	1	1	0	0	1	–	–	–	–
Stack Pointer (High Byte)	SPH	216	D8h	x	x	x	x	x	x	x	x	x
Stack Pointer (Low Byte)	SPL	217	D9h	x	x	x	x	x	x	x	x	x
Instruction Pointer (High Byte)	IPH	218	DAh	x	x	x	x	x	x	x	x	x
Instruction Pointer (Low Byte)	IPL	219	DBh	x	x	x	x	x	x	x	x	x
Interrupt Request	IRQ	220	DCh	0	0	0	0	0	0	0	0	0
Interrupt Mask	IMR	221	DDh	x	x	x	x	x	x	x	x	x

Notes:

1. An x means that the bit value is undefined following reset.
2. A dash (–) means that the bit is neither used nor mapped, but the bit is read as 0.

Table 35. Set1 Register Values After RESET (Continued)

Register Name	Mnemonic	Address		Bit Values After Reset							
		Dec	Hex	7	6	5	4	3	2	1	0
System Mode	SYM	222	DEh	0	–	–	x	x	x	0	0
Register Page	PP	223	DFh	0	0	0	0	0	0	0	0

Notes:

1. An x means that the bit value is undefined following reset.
2. A dash (–) means that the bit is neither used nor mapped, but the bit is read as 0.

Table 36. Set1, Bank0 Register Values After Reset

Register Name	Mnemonic	Address		Bit Values After Reset							
		Dec	Hex	7	6	5	4	3	2	1	0
A/D Converter Data (High Byte)	ADDATAH	208	D0h	x	x	x	x	x	x	x	x
A/D Converter Data (Low Byte)	ADDATAL	209	D1h	–	–	–	–	–	–	x	x
A/D Converter Control	ADCON	210	D2h	–	0	0	0	0	0	0	0
Timer A Counter	TACNT	224	E0h	0	0	0	0	0	0	0	0
Timer A Data	TADATA	225	E1h	1	1	1	1	1	1	1	1
Timer A Control	TACON	226	E2h	0	0	0	0	0	0	0	0
Timer B Control	TBCON	227	E3h	–	–	0	0	0	0	0	0
Timer B Data (High Byte)	TBDATAH	228	E4h	1	1	1	1	1	1	1	1
Timer B Data (Low Byte)	TBDATAL	229	E5h	1	1	1	1	1	1	1	1
Timer B Clock Selection Register	TBCLKS	230	E6h	–	–	–	–	–	0	0	0
SIO Control	SIOCON	231	E7h	0	0	0	0	0	0	0	0
SIO Data	SIODATA	232	E8h	0	0	0	0	0	0	0	0
SIO Prescaler	SIOPS	233	E9h	0	0	0	0	0	0	0	0
Timer C Counter	TCCNT	234	EAh	0	0	0	0	0	0	0	0
Timer C Data	TCDATA	235	EBh	1	1	1	1	1	1	1	1
Timer C Control	TCCON	236	ECh	0	0	0	0	0	0	0	0
Stop Control	STPCON	237	EDh	0	0	0	0	0	0	0	0
UART0 Control (High Byte)	UART0CONH	238	EEh	0	0	0	0	0	0	0	0
UART0 Control (Low Byte)	UART0CONL	239	EFh	0	0	0	0	0	0	0	0
UART0 Data	UDATA0	240	F0h	x	x	x	x	x	x	x	x
UART0 Baud Rate Data	BRDATA0	241	F1h	1	1	1	1	1	1	1	1
UART1 Control (High Byte)	UART1CONH	242	F2h	0	0	0	0	0	0	0	0
UART1 Control (Low Byte)	UART1CONL	243	F3h	0	0	0	0	0	0	0	0

Table 36. Set1, Bank0 Register Values After Reset (Continued)

Register Name	Mnemonic	Address		Bit Values After Reset								
		Dec	Hex	7	6	5	4	3	2	1	0	
UART1 Data	UDATA1	244	F4h	x	x	x	x	x	x	x	x	x
UART1 Baud Rate Data	BRDATA1	245	F5h	1	1	1	1	1	1	1	1	1
Flash Memory Sector Address (High Byte)	FMSECH	246	F6h	0	0	0	0	0	0	0	0	0
Flash Memory Sector Address (Low Byte)	FMSECL	247	F7h	0	0	0	0	0	0	0	0	0
Flash Memory User Programming Enable	FMUSR	248	F8h	0	0	0	0	0	0	0	0	0
Flash Memory Control	FMCON	249	F9h	0	0	0	0	0	–	–	–	0
Oscillator Control	OSCCON	250	FAh	–	–	–	–	0	0	–	–	0
Interrupt pending	INTPND	251	FBh	–	–	0	0	0	0	0	0	0
Basic Timer Counter	BTCNT	253	FDh	0	0	0	0	0	0	0	0	0
Location FEh is not mapped.												
Interrupt Priority	IPR	255	FFh	x	x	x	x	x	x	x	x	x

Table 37. Set1, Bank1 Register and Values After RESET

Register Name	Mnemonic	Address		Bit Values After Reset								
		Dec	Hex	7	6	5	4	3	2	1	0	
Port 0 Control	P0CON	208	D0h	0	0	0	0	0	0	0	0	0
Port 0 Pull-up Resistor Enable	P0PUR	209	D1h	0	0	0	0	0	0	0	0	0
Port 1 n-Channel Open-Drain Mode	PNE1	210	D2h	0	0	0	0	0	0	0	0	0
Port 1 Control (High Byte)	P1CONH	224	E0h	0	0	0	0	0	0	0	0	0
Port 1 Control (Low Byte)	P1CONL	225	E1h	0	0	0	0	0	0	0	0	0
Port 1 Pull-up Resistor Enable	P1PUR	226	E2h	0	0	0	0	0	0	0	0	0
Port 1 Interrupt Control	P1INT	227	E3h	0	0	0	0	0	0	0	0	0
Port 1 Interrupt Pending	P1PND	228	E4h	0	0	0	0	0	0	0	0	0
Port 2 n-Channel Open-Drain Mode	PNE2	229	E5h	0	0	0	0	0	0	0	0	0
Port 2 Control (High Byte)	P2CONH	230	E6h	0	0	0	0	0	0	0	0	0
Port 2 Control (Low Byte)	P2CONL	231	E7h	0	0	0	0	0	0	0	0	0

Notes:

1. An x means that the bit value is undefined following reset.
2. A dash (–) means that the bit is neither used nor mapped, but the bit is read as 0.

Table 37. Set1, Bank1 Register and Values After RESET (Continued)

Register Name	Mnemonic	Address		Bit Values After Reset								
		Dec	Hex	7	6	5	4	3	2	1	0	
Port 2 Pull-Up Resistor Enable	P2PUR	232	E8h	0	0	0	0	0	0	0	0	0
Port 3 n-Channel Open-Drain Mode	PNE3	233	E9h	0	0	0	0	0	0	0	0	0
Port 3 Control (High Byte)	P3CONH	234	EAh	0	0	0	0	0	0	0	0	0
Port 3 Control (Mid Byte)	P3CONM	235	EBh	0	0	0	0	0	0	0	0	0
Port 3 Control (Low Byte)	P3CONL	236	ECh	0	0	0	0	0	0	0	0	0
Port 3 Pull-Up Resistor Enable	P3PUR	237	EDh	–	–	0	0	0	0	0	0	0
Port 4 Control (High Byte)	P4CONH	238	EEh	–	–	–	0	0	0	0	0	0
Port 4 Control (Low Byte)	P4CONL	239	EFh	0	0	0	0	0	0	0	0	0
Port 0 Data	P0	240	F0h	0	0	0	0	0	0	0	0	0
Port 1 Data	P1	241	F1h	0	0	0	0	0	0	0	0	0
Port 2 Data	P2	242	F2h	0	0	0	0	0	0	0	0	0
Port 3 Data	P3	243	F3h	0	0	0	0	0	0	0	0	0
Port 4 Data	P4	244	F4h	0	0	0	0	0	0	0	0	0
Port 4 Pull-up Resistor Enable	P4PUR	245	F5h	–	0	0	0	0	0	0	0	0
Port 4 n-Channel Open-Drain Mode	PNE4	246	F6h	–	0	0	0	0	0	0	0	0
Pattern Generation Control	PGCON	247	F7h	–	–	–	–	0	0	0	0	0
Pattern Generation Data	PGDATA	248	F8h	0	0	0	0	0	0	0	0	0
LCD Control	LCON	249	F9h	0	0	0	0	0	0	0	0	0
LCD Mode Control	LMOD	250	FAh	0	0	0	0	–	–	–	–	0
Battery Level Detection Control	BLDCON	251	FBh	–	–	–	–	0	0	0	0	0
Watch Timer Control	WTCON	252	FCh	0	0	0	0	0	0	0	0	0

Locations FDh–FFh are not mapped.

Notes:

1. An x means that the bit value is undefined following reset.
2. A dash (–) means that the bit is neither used nor mapped, but the bit is read as 0.

Table 38. Page 4 Register Values After RESET

Register Name	Mnemonic	Address		Bit Values After Reset							
		Dec	Hex	7	6	5	4	3	2	1	0
Reset Source Indicating	RESETID	0		See Table 40 on page 200							
Timer D0 Control	TD0CON	1	01h	0	0	0	0	0	0	0	0
Timer D0 Counter (High Byte)	TD0CNTH	2	02h	0	0	0	0	0	0	0	0
Timer D0 Counter (Low Byte)	TD0CNTL	3	03h	0	0	0	0	0	0	0	0
Timer D0 Data (High Byte)	TD0DATAH	4	04h	1	1	1	1	1	1	1	1
Timer D0 Data (Low Byte)	TD0DATAL	5	05h	1	1	1	1	1	1	1	1
Timer D1 Counter (High Byte)	TD1CNTH	6	06h	0	0	0	0	0	0	0	0
Timer D1 Counter (Low Byte)	TD1CNTL	7	07h	0	0	0	0	0	0	0	0
Timer D1 Data (High Byte)	TD1DATAH	8	08h	1	1	1	1	1	1	1	1
Timer D1 Data (Low Byte)	TD1DATAL	9	09h	1	1	1	1	1	1	1	1
Timer D1 Control	TD1CON	10	0Ah	0	0	0	0	0	0	0	0

Reset Source Indicating Register

The contents of the Reset Source Indicating (RESETID) Register are described in Table 39. The state of the RESETID depends on the source of the reset; see Table 40.

Table 39. Reset Source Indicating Register (RESETID; Page 4)

Bit	7	6	5	4	3	2	1	0
R/W	–	–	–	R/W	–	R/W	R/W	–
Address	00h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:5]	Reserved
[4]	nRESET Pin Indicating Bit 0: Reset is not generated by nRESET pin when read; cleared to =0 (when write). 1: Reset is generated by nRESET pin when read; no effect (when write).
[3]	Reserved
[2]	WDT Reset Indicating Bit 0: Reset is not generated by WDT (when read); cleared to 0 (when write). 1: Reset is generated by WDT (when read); no effect (when write).
[1]	LVR Reset Indicating Bit 0: Reset is not generated by LVR (when read); cleared to 0 (when write). 1: Reset is generated by LVR (when read); no effect (when write).
[0]	Reserved

Table 40. State of RESETID

Bit	7	6	5	4	3	2	1	0
LVR	–	–	–	0	–	0	1	–
WDT, nReset	–	–	–	3	–	3	2	–

Notes:

1. To clear an indicating register, write a 0 to the indicating flag bit. Writing a 1 to a reset-indicating flag (RESETID.1–2 and .4) has no effect.
2. Not affected by any other reset.
3. Bits corresponding to sources that are active at the time of reset will be set.

Power-Down Modes

This section describes the following power-down modes:

- Stop Mode
- Idle Mode

Stop Mode

Stop Mode is invoked by executing the STOP instruction after setting the Stop Control (STOPCON) Register. In Stop Mode, the operation of the CPU and all peripherals is halted. Essentially, the on-chip main oscillator stops and the current consumption can be reduced. All system functions stop when the clock freezes, but data stored in the internal register file is retained. However, the status of internal ring oscillator (ICLK, 15 kHz) is configurable. Stop Mode can be released in one of two ways: by a system reset or by an external interrupt. After releasing from Stop Mode, the value of STOPCON is cleared automatically.

► **Note:** Do not use Stop Mode if you are using an external clock source, because the X_{IN} or X_{TIN} inputs must be restricted internally to V_{SS} to reduce current leakage.

Using nRESET to Release Stop Mode

Stop Mode is released when the nRESET signal is released and returns to a high level; all system and peripheral control registers are reset to their default hardware values and the contents of all data registers are retained. A reset operation automatically selects a slow clock (e.g., $f_{XX}/16$) because CLKCON.3 and CLKCON.4 are cleared to 00b. After the programmed oscillation stabilization interval has elapsed, the CPU starts the system initialization routine by fetching the program instruction stored in ROM location 0100h (and 0101h).

Using an External Interrupt to Release Stop Mode

External interrupts with an RC-delay noise filter circuit can be used to release Stop Mode. Which interrupt you can use to release Stop Mode in a given situation depends on the microcontroller's current internal operating mode. The external interrupts in the S3F8S5A MCU's interrupt structure that can be used to release Stop Mode are P3.0–P3.6/P0.3 (INT0–VINT7).

Please note the following conditions for Stop Mode release:

- If you release Stop Mode using an external interrupt, the current values in system and peripheral control registers are unchanged except STPCON register.

- If you use an internal or external interrupt for Stop Mode release, you can also program the duration of the oscillation stabilization interval by making the appropriate control and clock settings before entering Stop Mode.
- When Stop Mode is released by external interrupt, the CLKCON.4 and CLKCON.3 bit-pair setting remains unchanged and the currently selected clock value is used.
- The external interrupt is serviced when the Stop Mode release occurs. Following the IRET from the service routine, the instruction immediately following the one that initiated Stop Mode is executed.

Using an Internal Interrupt to Release Stop Mode

Activate any enabled interrupt to release Stop Mode; all other functions remain the same as if using an external interrupt.

How to Enter Stop Mode

The following example shows how to handle the STPCON Register then writing a STOP instruction, in the sequential order shown.

```
LD STPCON,#10100101b
STOP
NOP
NOP
NOP
```

Idle Mode

Idle Mode is invoked by the IDLE instruction (op code 6Fh). In Idle Mode, CPU operations are halted while some peripherals remain active. During Idle Mode, the internal clock signal is gated away from the CPU, but all peripheral timers remain active. Port pins retain the mode (input or output) they are operating in at the time Idle Mode is entered.

The following two methods can be used to release Idle Mode:

Execute a reset. All system and peripheral control registers are reset to their default values, and the contents of all data registers are retained. The reset automatically selects the slow clock ($f_{XX}/16$) because CLKCON.4 and CLKCON.3 are cleared to 00b. If interrupts are masked, a reset is the only way to release Idle Mode.

Activate any enabled interrupt, causing idle mode to be released. When you use an interrupt to release Idle Mode, the CLKCON.4 and CLKCON.3 register values remain unchanged, and the currently selected clock value is used. The interrupt is then serviced. When the return-from-interrupt (IRET) occurs, the instruction immediately following the one that initiated Idle Mode is executed.

I/O Ports

The S3F8S5A microcontroller features twelve bit-programmable I/O ports, P0–P4. Port 0 is a 4-bit port, and the others are 8-bit ports, for a total of 36 I/O pins. Each port can be flexibly configured to meet application design requirements.

The CPU accesses these ports by directly writing or reading the port registers; no special I/O instructions are required. All ports of the S3F8S5A can be configured to input or output mode. All LCD signal pins are shared with normal I/O ports.

Table 41 provides a general overview of the S3F8S5A MCU’s I/O port functions.

Table 41. S3F8S5A Port Configuration Overview

Port	Configuration Options
0	1-bit programmable I/O port: input or push-pull output mode selected by software; software assignable pull-ups. Alternatively, P0.0–P0.3 can be used as AD0–AD3 or LCD COM.
1	1-bit programmable I/O port; Schmitt trigger input or push-pull, open drain output mode selected by software; software assignable pull-ups. P1.0–P3.3 can be used as inputs for external interrupts INT0–INT3 (with noise filter, interrupt enable and pending control). Alternatively, P1.0–P1.7 can be used as X _{TOUT} , X _{TIN} , TD1CLK, TD1OUT/TD1PWM/TD1CAP, AD5/AD6, TACLK, TAOUT/TAPWM/TACAP, BUZ, or LCD SEG.
2	1-bit programmable I/O port; Schmitt trigger input or push-pull, open drain output mode selected by software; software assignable pull-ups. Alternatively, P2.0–P2.7 can be used as TXD0, RXD0, SCK, SO, SI, AD4/AD7, TD0CLK, TD0OUT/TD0PWM/TD0CAP, PWM, TBPWM, or LCD SEG.
3	1-bit programmable I/O port; Schmitt trigger input or push-pull, open drain output mode selected by software; software assignable pull-ups. Alternatively, P3.0–P3.7 can be used as TXD1, RXD1, PG0-PG7, TCOU/TCPWM, or LCD SEG.
4	1-bit programmable I/O port; Schmitt trigger input or push-pull, open-drain output mode selected by software; software assignable pull-ups. P4.0–P4.3 can be used as inputs for external interrupts INT4–INT7 (with noise filter, interrupt enable and pending control). Alternatively, P4.0–P4.7 can be used as LCD COM and SEG.

Port Data Registers

Table 42 provides an overview of the register locations of all twelve S3F8S5A I/O port data registers. Data registers for ports 0, 1, 2, 3, and 4 feature the general format shown in Figure 65.

Table 42. Port Data Register Summary

Register Name	Mnemonic	Decimal	Hex	Location	Read/Write
Port 0 Data Register	P0	240	F0h	Set1, Bank0	R/W
Port 1 Data Register	P1	241	F1h	Set1, Bank1	R/W
Port 2 Data Register	P2	242	F2h	Set1, Bank1	R/W
Port 3 Data Register	P3	243	F3h	Set1, Bank1	R/W
Port 4 Data Register	P4	244	F4h	Set1, Bank1	R/W

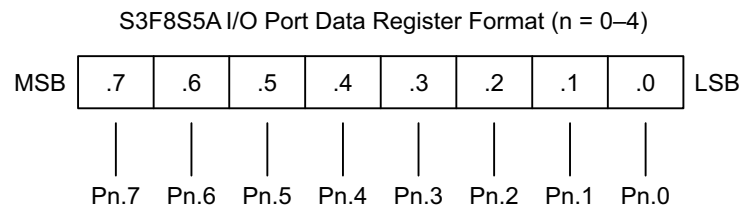


Figure 65. S3F8S5A I/O Port Data Register Format

Port 0

Port 0 is a 4-bit I/O port with individually-configurable pins that are accessed directly by writing or reading the Port 0 Data Register, P0, at location F0h in Set1, Bank1. P0.0–P0.3 can serve as inputs (with or without pull-ups) and push-pull outputs, or you can configure the following alternative functions:

- Low-byte pins (P0.0–P0.3): COM0–COM3/AD0–AD3

Port 0 Control Registers

Port 0 provides one 8-bit control register, P0CON, for P0.0–P0.3; see Table 43. A reset clears this register to 00h, configuring all pins to Input Mode. Use this control register's settings to select either Input Mode (with or without pull-ups), or to select Push-Pull Output Mode and enable the alternative functions.

Table 43. Port 0 Control High Byte Register (P0CON; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					D0h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	<p>P0.7/COM4/AD4 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode; push-pull. 10: Alternative function (AD4). 11: Alternative function (COM4).</p>
[5:4]	<p>P0.26/COM5/AD5 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode; push-pull. 10: Alternative function (AD5). 11: Alternative function (COM5).</p>
[3:2]	<p>P0.5/COM6/AD6 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode; push-pull. 10: Alternative function (AD6). 11: Alternative function (COM6).</p>
[1:0]	<p>P0.4/COM7/AD7 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode; push-pull. 10: Alternative function (AD7). 11: Alternative function (COM7).</p>

Port 0 Pull-Up Resistor Enable Register

When using the Port 0 Pull-Up Resistor Enable (POPUR) Register (D1h, Set1, Bank1; see Table 44), the pull-up resistors can be configured to individual Port 0 pins.

Table 44. Port 0 Pull-Up Resistor Enable Register (P0PUR; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					D2h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	P0.3 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[6]	P0.2 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[5]	P0.1 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[4]	P0.0 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[3]	P0.3 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[2]	P0.2 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[1]	P0.1 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[0]	P0.0 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.

Note: A pull-up resistor of port 0 is automatically disabled only when the corresponding pin is selected as push-pull output or alternative function.

Port 1

Port 1 is an 8-bit I/O port with individually-configurable pins that are accessed directly by writing or reading the Port 1 Data (P1) Register at location F1h in Set1, Bank1. P1.0–P1.7 can serve as inputs (with or without pull-ups) and outputs (push-pull or open-drain), and can be configured to the following alternative functions:

- Low-byte pins (P1.0–P1.3): INT0/TAOUT/TAPWM/SEG20, INT1/TACLK/BUZ/SEG21, INT2/TACAP, INT3/TD1OUT/TD1PWM
- High-byte pins (P1.4–P1.7): XTOUT, XTIN, TD1CAP/AD6, TD1CLK/AD5

Port 1 Control Registers

Port 1 has two 8-bit control registers: P1CONH for P1.4–P1.7 and P1CONL for P1.0–P1.3; see Tables 45 and 46. A reset clears the P1CONH and P1CONL registers to 00h, configuring all pins to Input Mode. When P1.0–P1.3 are in Input Mode, the following three selections are available:

- Schmitt trigger input with interrupt generation on falling signal edges
- Schmitt trigger input with interrupt generation on rising signal edges
- Schmitt trigger input with interrupt generation on falling/rising signal edges

Use this control register's settings to select either Input Mode (with or without pull-ups), or to select Push-Pull Output Mode and enable the alternative functions.

When programming the port, note that any alternative peripheral I/O function configured using the Port 1 Control registers must also be enabled in the associated peripheral module.

Table 45. Port 1 Control Register High Byte Register (P1CONH; Set1,

Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					E0h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	P1.7/COM0 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Not available. 11: Alternative function (COM0).
[5:4]	P1.6/COM1 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Not available. 11: Alternative function (COM1).
[3:2]	P1.5/COM2 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Not available. 11: Alternative function (COM2).
[1:0]	P1.4/COM3/TCOUT/TCPWM Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (TCOUT/TCPWM). 11: Alternative function (COM3).

Table 46. Port 1 Control Register Low Byte Register (P1CONL; Set1,

Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					E1h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	P1.3/AD0/TXD1 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (AD0). 11: Alternative function (TXD1).
[5:4]	P1.2/AD1/RXD1 Configuration Bits 00: Schmitt Trigger Input Mode (RXD1 In). 01: Output Mode. 10: Alternative function (AD1). 11: Alternative function (RXD1 Out).
[3:2]	P1.1/AD2/BUZ Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (AD2). 11: Alternative function (BUZ).
[1:0]	P1.0/AD3/TBPWM Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (AD3). 11: Alternative function (TBPWM).

Port 1 Interrupt Enable and Pending Registers

To process external interrupts at the Port 1 pins, two additional control registers are provided: the Port 1 Interrupt Enable (P1INT) Register (E3h, Set1, Bank1) and the Port 1 Interrupt Pending (PIPND) Register (E4h, Set1, Bank1); see Tables 47 and 48.

The Port 1 Interrupt Pending (PIPND) Register lets you check for interrupt pending conditions, and to clear a pending condition when an interrupt service routine has been initiated. The application software detects interrupt requests by polling the PIPND Register at regular intervals.

When the interrupt enable bit of any Port 1 pin is 1, a rising or falling signal edge at that pin will generate an interrupt request. The corresponding P1PND bit is then automatically set to 1 and the IRQ level goes Low to signal the CPU that an interrupt request is waiting. When the CPU acknowledges the interrupt request, application software must clear the pending condition by writing a 0 to the corresponding P1PND bit.

Table 47. Port 1 Interrupt Enable Register (P1INT; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	E3h							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7:6] INT3	P1.7–P1.6 Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.
[5:4] INT2	P1.5–P1.4 Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.
[3:2] INT1	P1.3–P1.2 Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.
[1:0] INT0	P1.1–P1.0 Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.

Table 48. Port 1 Interrupt Pending Register (P1PND; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	E4h							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7:4]	Reserved
[3] PND3	P1.3 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[2] PND2	P1.2 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[1] PND1	P1.1 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[0] PND0	P1.0 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.

Port 1 Pull-Up Resistor Enable Register

When using the Port 1 Pull-Up Resistor Enable (P1PUR) Register (E2h, Set1, Bank1; see Table 49), the pull-up resistors can be configured to individual Port 1 pins.

Table 49. Port 1 Output Pull-Up Resistor Enable Register (P1PUR; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					E2h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	P1.7 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[6]	P1.6 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[5]	P1.5 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[4]	P1.4 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[3]	P1.3 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[2]	P1.2 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[1]	P1.1 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[0]	P1.0 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.

Note: Port 1 pull-up resistors are automatically disabled only when the corresponding pin is selected as a push-pull output or as an alternative function.

Port 1 n-Channel Open Drain Mode Register

When using the Port 1 n-Channel Open Drain Mode (PNE1) Register (E3h, Set1, Bank1; see Table 50), the Push-Pull or Open Drain Output Mode can be configured to individual Port 1 pins.

Table 50. Port 1 n-Channel Open Drain Mode Register (PNE1; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					D2h			
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7:4]	Reserved							
[3]	P1.3 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[2]	P1.2 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[1]	P1.1 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[0]	P1.0 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							

Port 2

Port 2 is an 8-bit I/O port with individually-configurable pins which are accessed directly by writing or reading the Port 2 Data (P2) Register at location F2h in Set1, Bank1.

P2.0–P2.7 can serve as inputs (with or without pull-ups) and outputs (push pull or open-drain), or can be configured to the following alternative functions:

- Low-byte pins (P2.0–P2.3): TD0CLK/TBPWM, TD0CAP/PWM, AD4/TD0OUT/TD0PWM, SI/AD7
- High-byte pins (P2.4–P2.7): SO/SEG0, SCK/SEG1, RXD0/SEG2, TXD0/SEG3

Port 2 Control Registers

Port 2 provides two 8-bit control registers, P2CONH for P2.4–P2.7 and P2CONL for P2.0–P2.3; see Tables 51 and 52. A reset clears these P2CONH and P2CONL registers to 00h, configuring all pins to Input Mode. Use control register settings to select Input Mode (with or without pull-ups) or to select Push-Pull Output Mode and enable the alternative functions.

Table 51. Port 2 Control Register High Byte Register (P2CONH; Set1,

Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	E6h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	P2.7/TXD0/SEG3 Configuration Bits 00: Schmitt Trigger Input Mode (RXD0 in, SCK in) 01: Output Mode. 10: Alternative function (TXD0, RXD0 out, SCK out, SO). 11: Alternative function (SEG3–SEG0).
[5:4]	P2.6/RXD0/SEG2 Configuration Bits 00: Schmitt Trigger Input Mode (RXD0 in, SCK in) 01: Output Mode. 10: Alternative function (TXD0, RXD0 out, SCK out, SO). 11: Alternative function (SEG3–SEG0).
[3:2]	P2.5/SCK/SEG1 Configuration Bits 00: Schmitt Trigger Input Mode (RXD0 in, SCK in) 01: Output Mode. 10: Alternative function (TXD0, RXD0 out, SCK out, SO). 11: Alternative function (SEG3–SEG0).
[1:0]	P2.4/SO/SEG0 Configuration Bits 00: Schmitt Trigger Input Mode (RXD0 in, SCK in) 01: Output Mode. 10: Alternative function (TXD0, RXD0 out, SCK out, SO). 11: Alternative function (SEG3–SEG0).

Table 52. Port 2 Control Register Low Byte Register (P2CONL; Set1,

Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	E7h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	<p>P2.3/SI/AD7 Configuration Bits 00: Schmitt Trigger Input Mode (SI, TD0CAP, TD0CLK). 01: Output Mode. 10: Alternative function (AD7, PWM, TBPWM). 11: Not available.</p>
[5:4]	<p>P2.2 Bit-Pair Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (AD4). 11: Alternative function (TD0OUT, TD0PWM).</p>
[3:2]	<p>P2.1/TD0CAP/PWM Configuration Bits 00: Schmitt Trigger Input Mode (SI, TD0CAP, TD0CLK). 01: Output Mode. 10: Alternative function (AD7, PWM, TBPWM). 11: Not available.</p>
[1:0]	<p>P2.0/TD0CLK/TBPWM Configuration Bits 00: Schmitt Trigger Input Mode (SI, TD0CAP, TD0CLK). 01: Output Mode. 10: Alternative function (AD7, PWM, TBPWM). 11: Not available.</p>

Port 2 Pull-Up Resistor Enable Register

When using the Port 2 Pull-Up Resistor Enable (P2PUR) Register (E8h, Set1, Bank1; see Table 53), the pull-up resistors can be configured to individual Port 2 pins.

Table 53. Port 2 Pull-Up Resistor Enable Register (P2PUR; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					E8h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	P2.7 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[6]	P2.6 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[5]	P2.5 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[4]	P2.4 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[3]	P2.3 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[2]	P2.2 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[1]	P2.1 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.
[0]	P2.0 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.

Note: Port 2 pull-up resistors are automatically disabled only when the corresponding pin is selected as a push-pull output or as an alternative function.

Port 2 n-Channel Open Drain Mode Register

When using the Port 2 n-Channel Open Drain Mode (PNE2) Register (E5h, Set1, Bank1; see Table 54), the Push-Pull or Open Drain Output Mode can be configured to individual Port 2 pins.

Table 54. Port 2 n-Channel Open Drain Mode Register (PNE2; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	E5h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	P2.7 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[6]	P2.6 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[5]	P2.5 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[4]	P2.4 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[3]	P2.3 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[2]	P2.2 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[1]	P2.1 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.
[0]	P2.0 n-Channel Open Drain Mode Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.

Note: Port 2 pull-up resistors are automatically disabled only when the corresponding pin is selected as a push-pull output or as an alternative function.

Port 3

Port 3 is an 8-bit I/O port with individually-configurable pins which are accessed directly by writing or reading the Port 3 Data (P3) Register at location F3h in Set1, Bank1.

P3.0–P3.7 can serve as inputs (with or without pull-ups) and outputs (push pull or open-drain), or can be configured for the following alternative functions:

- Low-byte pins (P3.0–P3.3): PG0/SEG4, PG1/SEG5, PG2/SEG6, PG3/SEG7
- High-byte pins (P3.4–P3.7): PG4/SEG8, TCOUT/TCPWM/PG5/SEG9, RXD1/PG6/SEG10, TXD1/PG7/SEG11

Port 3 Control Registers

Port 3 provides two 8-bit control registers, P3CONH for P3.6–P3.7, P3CONM for P3.4–P3.5, and P3CONL for P3.0–P3.3; see Tables 55 through 57. A reset clears these three registers to 00h, configuring all pins to Input Mode. Use these control register's settings to select Input Mode (with or without pull-ups), or to select Output Mode and enable the alternative functions.

When programming Port 3, any alternative peripheral I/O function you configure using the Port 3 Control registers must also be enabled in the associated peripheral module.

Table 55. Port 3 Control High-Byte Register (P3CONH; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	0	0	0	0	0	0
R/W	–	–	R/W	R/W	R/W	R/W	R/W	R/W
Address	EAh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	Reserved
[5:3]	<p>P3.7/TXD1/PG7/SEG11 Configuration Bits 000: Schmitt Trigger Input Mode (RXD1 in). 001: Output Mode. 010: Alternative function (TXD1, RXD1 out). 011: Alternative function (PG7, PG6). 100: Alternative function (SEG11, SEG10). 101–111: Not available.</p>
[2:0]	<p>P3.6/RXD1/PG6/SEG10 Configuration Bits 000: Schmitt Trigger Input Mode (RXD1 in). 001: Output Mode. 010: Alternative function (TXD1, RXD1 out). 011: Alternative function (PG7, PG6). 100: Alternative function (SEG11, SEG10). 101–111: Not available.</p>

Table 56. Port 3 Control Mid Byte Register (P3CONM; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	0	0	0	–	0	0
R/W	–	–	R/W	R/W	R/W	–	R/W	R/W
Address	EBh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	Reserved
[5:3]	<p>P3.5 Bit-Pair Pin Configuration Bits</p> <p>000: Schmitt Trigger Input Mode. 001: Output Mode. 010: Alternative function (TCOUT/TCPWM). 011: Alternative function (PG5). 100: Alternative function (SEG9). 101–111: Not available.</p>
[2]	Reserved
[1:0]	<p>P3.4 Bit-Pair Pin Configuration Bits</p> <p>00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (PG4). 11: Alternative function (SEG15).</p>

Table 57. Port 3 Control Low Byte Register (P3CONL; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	ECh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	P3.3/PG3/SEG7 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (PG3–PG0). 11: Alternative function (SEG7–SEG4).
[5:4]	P3.2/PG2/SEG6 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (PG3–PG0). 11: Alternative function (SEG7–SEG4).
[3:2]	P3.1/PG1/SEG5 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (PG3–PG0). 11: Alternative function (SEG7–SEG4).
[1:0]	P3.0/PG0/SEG4 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (PG3–PG0). 11: Alternative function (SEG7–SEG4).

Port 3 Pull-Up Resistor Enable Register

When using the Port 3 Pull-Up Resistor Enable (P3PUR) Register (EDh, Set1, Bank1; see Table 58), pull-up resistors can be configured to individual Port 3 pins.

Table 58. Port3[4:5] Control Register (P3PUR; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	EDh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7]	P3.7 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[6]	P3.6 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[5]	P3.5 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[4]	P3.4 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[3]	P3.3 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[2]	P3.2 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[1]	P3.1 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
[0]	P3.0 Pull-Up Resistor Enable Bit 0: Pull-up disable. 1: Pull-up enable.							
Note: Port 3 pull-up resistors are automatically disabled only when the corresponding pin is selected as a push-pull output or as an alternative function.								

Port 3 n-Channel Open Drain Mode Register

When using the Port 3 n-Channel Open Drain Mode (PNE3) Register (E9h, Set1, Bank1; see Table 59), the Push-Pull or Open Drain Output Mode can be configured to individual Port 3 pins.

Table 59. Port 3 Output Pull-Up Resistor Enable Register (PNE3; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	E9h							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7]	P3.7 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[6]	P3.6 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[5]	P3.5 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[4]	P3.4 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[3]	P3.3 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[2]	P3.2 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[1]	P3.1 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							
[0]	P3.0 Output Mode Enable Bit 0: Output Mode, push-pull. 1: Output Mode, open-drain.							

Port 4

Port 4 is an 7-bit I/O port with individually-configurable pins which are accessed directly by writing or reading the Port 4 Data (P4) Register at location F4h in Set1, Bank1.

P4.0–P4.6 can serve as inputs (with or without pull-ups), and outputs (push pull or open-drain), or can be configured to the following alternative functions:

- Low-byte pins (P4.0-P4.3): INT4/SEG12, INT5/SEG13, INT6/SEG14, INT7/SEG15
- High-byte pins (P4.4-P4.7): COM4/SEG16, COM5/SEG17, COM6/SEG18, COM7/SEG19

Port 4 Control Registers

Port 4 provides two 7-bit control registers, P4CONH for P4.4–P4.7 and P4CONL for P4.0–P4.3; see Tables 60 and 61. A reset clears each of these registers to 00h, configuring all pins to Input Mode. When P4.0–P4.3 are in Input Mode, the following three selections are available:

- Schmitt trigger input with interrupt generation on falling signal edges
- Schmitt trigger input with interrupt generation on rising signal edges
- Schmitt trigger input with interrupt generation on falling/rising signal edges

Table 60. Port 4 Control High Byte Register (P4CONH; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	0	0	0	0	0	0
R/W	–	–	R/W	R/W	R/W	R/W	R/W	R/W
Address	EEh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	Reserved
[5:4]	P4.6/TD1CLK/SEG14 Configuration Bits 00: Schmitt Trigger Input Mode (TD1CLK). 01: Output Mode. 10: Not available. 11: Alternative function (SEG14).

Bit	Description (Continued)
[3:2]	P4.5/TD1OUT/TD1PWM/TD1CAP/SEG13 Configuration Bits 00: Schmitt Trigger Input Mode (TD1CAP). 01: Output Mode. 10: Alternative function (TD1OUT/TD1PWM). 11: Alternative function (SEG13).
[1:0]	P4.4/TD0CLK/SEG12 Configuration Bits 00: Schmitt Trigger Input Mode (TD0CLK). 01: Output Mode. 10: Not available. 11: Alternative function (SEG12).

Table 61. Port 4 Control Low Byte Register (P4CONL; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	1	1	1	1	1	1	1	1
R/W	R/W							
Address	EFh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	P4.3/TD0OUT/TD0PWM/TD0CAP/SEG11 Configuration Bits 00: Schmitt Trigger Input Mode (TD0CAP). 01: Output Mode. 10: Alternative function (TD0OUT/TD0PWM). 11: Alternative function (SEG11).
[5:4]	P4.2/SCK/SEG2 Configuration Bits 00: Schmitt Trigger Input Mode (SCK In). 01: Output Mode. 10: Alternative function (SCK Out). 11: Alternative function (SEG2).
[3:2]	P4.1/SI/SEG1 Configuration Bits 00: Schmitt Trigger Input Mode (SI). 01: Output Mode. 10: Not available. 11: Alternative function (SEG1).
[1:0]	P4.0/SO/SEG0 Configuration Bits 00: Schmitt Trigger Input Mode. 01: Output Mode. 10: Alternative function (SO). 11: Alternative function (SEG0).

Use these control register settings to select Input Mode (with or without pull-ups) or to select Push-Pull Output Open-Drain Mode and enable the alternative functions.

When programming the port, note that any alternative peripheral I/O function you configure using the Port 4 Control registers must also be enabled in the associated peripheral module.

Port 4 Interrupt Enable and Pending Registers

To process external interrupts at the Port 4 pins, two additional control registers are provided: the Port 4 Interrupt Enable (P4INT) Register (F6h, Set1, Bank1) and the Port 4 Interrupt Pending (P4PND) Register (F7h, Set1, Bank1); see Tables 62 and 63.

The Port 4 Interrupt Pending (P4PND) Register lets you check for interrupt pending conditions, and to clear a pending condition when an interrupt service routine has been initiated. The application software detects interrupt requests by polling the P4PND Register at regular intervals.

When the interrupt enable bit of any Port 4 pin is 1, a rising or falling signal edge at that pin will generate an interrupt request. The corresponding P4PND bit is then automatically set to 1 and the IRQ level goes Low to signal the CPU that an interrupt request is waiting. When the CPU acknowledges the interrupt request, application software must clear the pending condition by writing a 0 to the corresponding P4PND bit.

Table 62. Port 4 Pull-Up Interrupt Enable Register (P4INT; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	F6h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6] INT7	P4.7–P4.6 Pull-Up Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.
[5:4] INT6	P4.5–P4.4 Pull-Up Interrupt Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.

Bit	Description (Continued)
[3:2] INT5	P4.3–P4.2 Pull-Up Resistor Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.
[1:0] INT4	P4.1–P4.0 Pull-Up Resistor Enable Bit 00: Disable interrupt. 01: Enable interrupt by falling edge. 10: Enable interrupt by rising edge. 11: Enable interrupt by both falling and rising edge.

Table 63. Port 4 Interrupt Pending Register (P4PND; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	F7h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:4]	Reserved
[3] PND7	P4.3 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[2] PND6	P4.2 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[1] PND5	P4.1 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.
[0] PND4	P4.0 Interrupt Pending Bit 0: An interrupt request is not pending; clear pending bit when write = 0. 1: An interrupt request is pending.

Port 4 Pull-Up Resistor Enable Register

When using the Port 4 Pull-Up Resistor Enable (P4PUR) Register (E2h, Set1, Bank1; see Table 49), the pull-up resistors can be configured to individual Port 4 pins.

Table 64. Port 4 Output Pull-Up Resistor Enable Register (P4PUR; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					F5h			
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7]	P4.7 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[6]	P4.6 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[5]	P4.5 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[4]	P4.4 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[3]	P4.3 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[2]	P4.2 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[1]	P4.1 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
[0]	P4.0 Pull-Up Resistor Enable Bit 0: Disable pull-up resistor. 1: Enable pull-up resistor.							
Note: Port 4 pull-up resistors are automatically disabled only when the corresponding pin is selected as a push-pull output or as an alternative function.								

Basic Timer

The S3F8S5A MCU features an 8-bit basic timer (BT) that can be used in the following two ways:

- As a watchdog timer to provide an automatic reset mechanism in the event of a system malfunction
- To signal the end of the required oscillation stabilization interval after a reset or a Stop Mode release

The functional components of the basic timer block are:

- Clock frequency divider (f_{XX} divided by 4096, 1024, 128, or 16) with multiplexer
- 8-bit Basic Timer Counter (BTCNT) Register (FDh, Set1, Bank0; read-only)
- Basic Timer Control (BTCON) Register (D3h, Set1; read/write)

Figure 66 diagrams the Basic Timer.

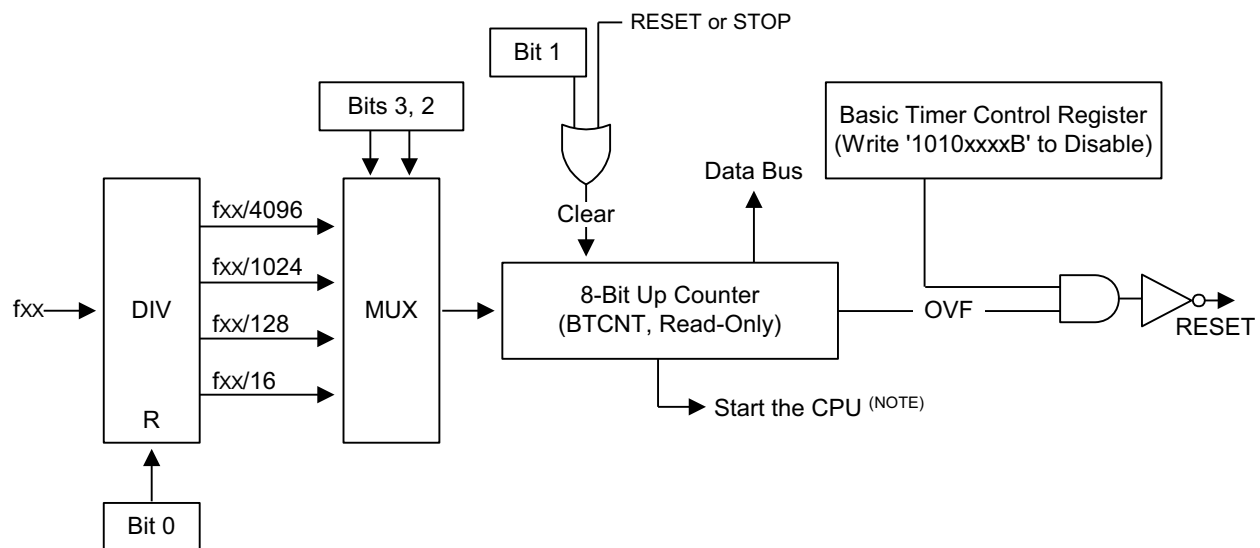


Figure 66. Basic Timer Block Diagram

Basic Timer Control Register

The Basic Timer Control (BTCON) Register, shown in Table 65, is used to select the input clock frequency, to clear the basic timer counter and frequency dividers, and to enable or

disable the watchdog timer function. It is located in Set1, address D3h, and is read/write addressable using Register Addressing Mode.

Table 65. Basic Timer Control Register (BTCON; Set1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	D3h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:4]	Watchdog Timer Enable Bits 0000–1001b: Enable the watchdog timer function. 1010b: Disable the watchdog timer function. 1011–1111b: Enable the watchdog timer function.
[3:2]	Basic Timer Input Clock Selection Bits 00: $f_{XX}/4096$. 01: $f_{XX}/1024$. 10: $f_{XX}/128$. 11: $f_{XX}/16$.
[1]	Basic Timer Counter Clear Bit 0: No effect. 1: Clear the basic timer counter value.
[0]	Clock Frequency Divider Clear Bit for Basic Timer and Timer/Counters 0: No effect. 1: Clear both clock frequency dividers.

A reset clears BTCON to 00h, enabling the watchdog function and selecting a basic timer clock frequency of $f_{XX}/4096$. To disable the watchdog function, write the signature code 1010b to the basic timer register control bits BTCON.7–BTCON.4.

The 8-bit Basic Timer Counter (BTCNT) Register (FDh, Set1, Bank0), can be cleared at any time during normal operation by writing a 1 to BTCON.1. To clear the frequency dividers, write a 1 to BTCON.0.

Watchdog Timer Function

The basic timer overflow signal (BTOVF) can be programmed to generate a reset by setting BTCON.7–BTCON.4 to any value other than 1010b. (The 1010b value disables the watchdog function.) A reset clears BTCON to 00h, automatically enabling the watchdog timer function. A reset also selects the CPU clock (as determined by the current CLKCON Register setting) divided by 4096 as the BT clock.

A reset is generated whenever a basic timer counter overflow occurs. During normal operation, application software must prevent the overflow and the accompanying reset operation from occurring by clearing the BTCNT value (i.e., by writing a 1 to BTCON.1) at regular intervals.

If a system malfunction occurs due to circuit noise or some other error condition, the BT counter clear operation will not be executed and a basic timer overflow will occur, initiating a reset. In other words, during normal operation, the basic timer overflow loop (a bit 7 overflow of the 8-bit basic timer counter, BTCNT) is always broken by a BTCNT clear instruction. If a malfunction does occur, a reset is triggered automatically.

Oscillation Stabilization Interval Timer Function

The basic timer can also be used to program a specific oscillation stabilization interval after a reset, or when Stop Mode has been released by an external interrupt.

In Stop Mode, whenever a reset or an external interrupt occurs, the oscillator starts. The BTCNT value then begins increasing at the rate of $f_{XX}/4096$ (for a reset), or at the rate of the preset clock source (for an external interrupt). When BTCNT.4 overflows, a signal is generated to indicate that the stabilization interval has elapsed and to gate the clock signal off to the CPU so that it can resume normal operation.

In summary, the following events occur when Stop Mode is released:

1. During Stop Mode, a power-on reset or an external interrupt occurs to trigger the Stop Mode release, and oscillation begins.
2. If a power-on reset occurs, the basic timer counter will increase at the rate of $f_{XX}/4096$. If an interrupt is used to release Stop Mode, the BTCNT value increases at the rate of the preset clock source.
3. A clock oscillation stabilization interval begins and continues until bit 4 of the basic timer counter overflows.
4. When a BTCNT.4 overflow occurs, normal CPU operation resumes.

8-Bit Timer A/B

This chapter discusses the S3F8S5A MCU's two 8-bit timers, Timer A and Timer B.

8-Bit Timer A

The 8-bit Timer A is an 8-bit general-purpose timer/counter featuring three operating modes, each of which can be selected using one of the following TACON settings:

- Interval Timer Mode (toggle output at TAOOUT pin)
- Capture Input Mode with a rising or falling edge trigger at the TACAP pin
- PWM Mode (TAPWM)

Timer A provides the following functional components:

- Clock frequency divider (f_{XX} divided by 1024, 256, 64, 8, or 1) with multiplexer
- External clock input pin (TACLK)
- 8-bit counter (TACNT), 8-bit comparator, and 8-bit reference data register (TADATA)
- I/O pins for capture input (TACAP), PWM output (TAPWM), or match output (TAOUT)
- Timer A overflow interrupt (IRQ0 vector D0h) and match/capture interrupt (IRQ0 vector CEh) generation
- Timer A Control (TACON) Register (E2h, Set1, Bank0; read/write)

Figure 67 presents a block diagram of the Timer A function.

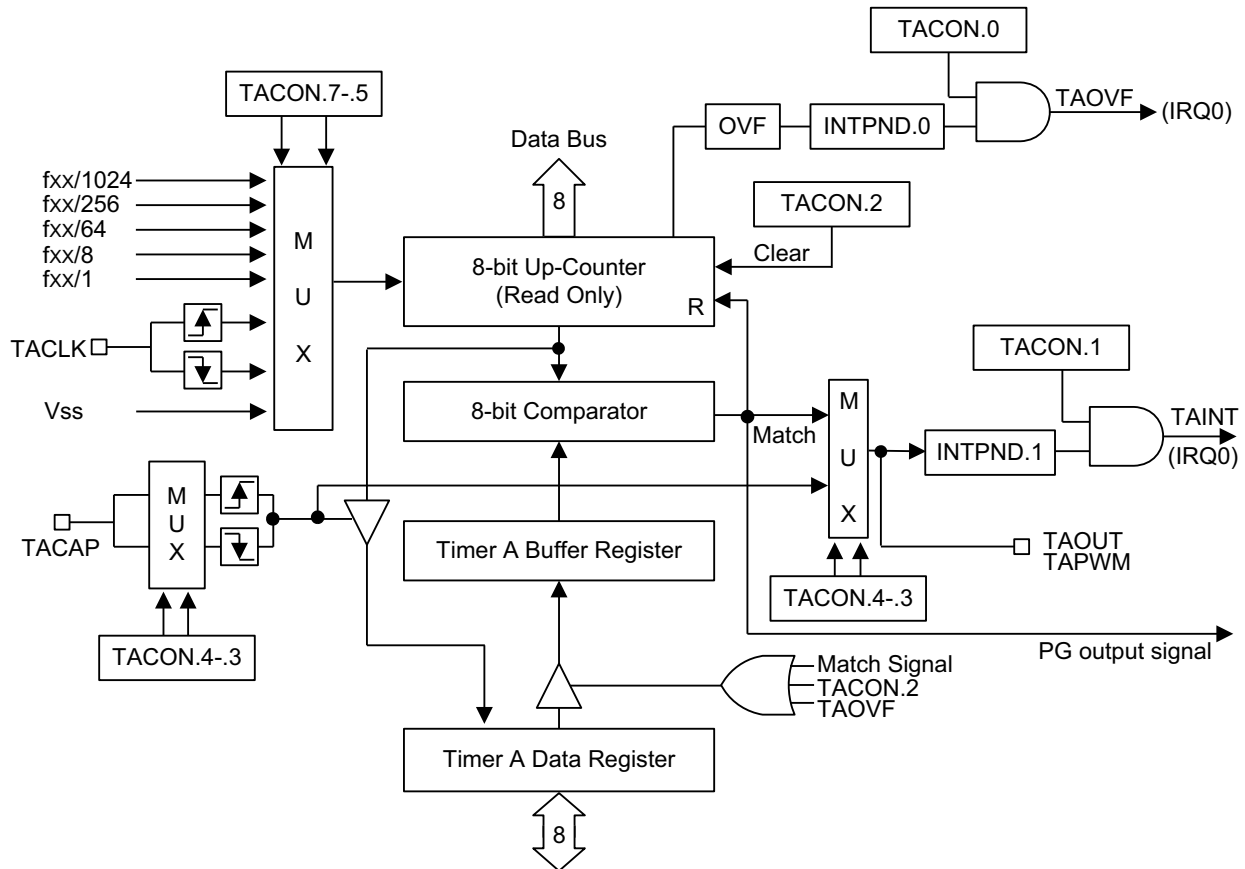


Figure 67. Timer A Functional Block Diagram

Timer A Control Register

The Timer A Control (TACON) Register, shown in Table 66, can be used to perform the following tasks:

- Select the Timer A operating mode (Interval Timer, Capture Mode, or PWM Mode)
- Select the Timer A input clock frequency
- Clear the Timer A counter, TACNT
- Enable the Timer A overflow interrupt or Timer A match/capture interrupt

Table 66. Timer A Control Register (TACON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					E2h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:5]	Timer A Input Clock Selection Bits 000: $f_{XX}/1024$. 001: $f_{XX}/256$. 010: $f_{XX}/64$. 011: $f_{XX}/8$. 100: $f_{XX}/1$. 101: External clock (TACLK) falling edge. 110: External clock (TACLK) rising edge. 111: Counter stop.
[4:3]	Timer A Operating Mode Selection Bits 00: Interval Mode (TAOUT). 01: Capture Mode (Capture on rising edge, counter running, OVF can occur). 10: Capture Mode (Capture on falling edge, counter running, OVF can occur). 11: PWM Mode; OVF and match interrupt can occur.
[2]	Timer A Counter Enable Bit 0: No effect. 1: Clear the Timer A counter (when write).
[1]	Timer A Match/Capture Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[0]	Timer A Overflow Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.

TACON is located in Set1, Bank0 at address E2h, and is read/write addressable using Register Addressing Mode.

A reset clears TACON to 00h, thereby setting Timer A to normal Interval Timer Mode and selecting an input clock frequency of $f_{XX}/1024$; all Timer A interrupts are disabled. The Timer A counter can be cleared at any time during normal operation by writing a 1 to TACON.2.

The IRQ0-level Timer A overflow interrupt (TAOVF) is at vector address D0h. When a Timer A overflow interrupt occurs and is serviced by the CPU, the pending condition is cleared automatically by hardware or must be cleared by software.

To enable the Timer A match/capture interrupt (IRQ0, vector CEh), write a 1 to TACON.1. To detect a match/capture interrupt pending condition, the application software polls INTPND.1. When a 1 is detected, a Timer A match or capture interrupt is pending. When the interrupt request has been serviced, the pending condition must be cleared by software by writing a 0 to the Timer A match/capture interrupt pending bit, INTPND.1.

Timer A Function Description

This section describes the features and functions of the Timer A interrupt.

Timer A Interrupts

Timer A can generate two interrupts: the Timer A overflow interrupt (TAOVF) and the Timer A match/capture interrupt (TAINT). TAOVF occurs at interrupt level IRQ0, vector D0h. TAINT also occurs at IRQ0, but is assigned the separate vector address CEh.

A Timer A overflow interrupt pending condition is automatically cleared by hardware when it has been serviced, or should be cleared by software in the interrupt service routine by writing a 0 to the INTPND.0 interrupt pending bit. However, a Timer A match/capture interrupt pending condition must be cleared by the application's interrupt service routine by writing a 0 to the INTPND.1 interrupt pending bit.

Timer A Interval Timer Mode

In Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer A Reference Data (TADATA) Register. The match signal generates a Timer A match interrupt (TAINT, vector CEh) and clears the counter.

If, for example, you write the value 10h to TADATA, the counter will increment until it reaches 10h. At this point, the Timer A interrupt request is generated, the counter value is reset, and counting resumes. With each match, the level of the signal at the Timer A output pin is inverted; see Figure 68.

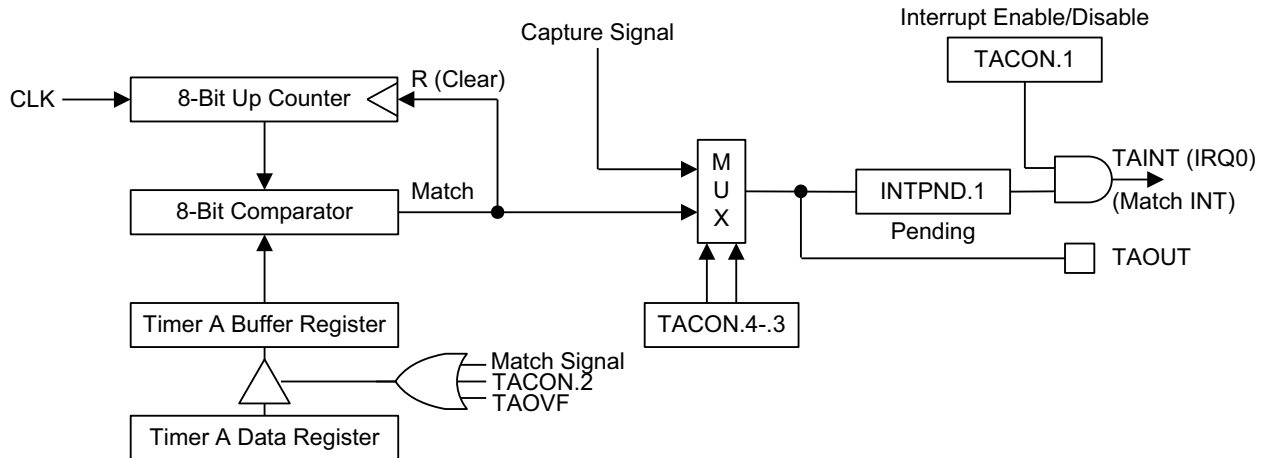


Figure 68. Simplified Timer A Function Diagram: Interval Timer Mode

Timer A Pulse Width Modulation Mode

Pulse Width Modulation (PWM) Mode lets you program the width (duration) of the pulse that is output at the TAPWM pin. As in Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer A Data Register. In PWM Mode, however, the match signal does not clear the counter. Instead, it runs continuously, overflowing at FFh, then continues incrementing from 00h.

Although the match signal can be used to generate a Timer A overflow interrupt, interrupts are not typically used in PWM-type applications. Instead, the pulse at the TAPWM pin is held Low as long as the reference data value is less than or equal to (\leq) the counter value, the pulse is then held High for as long as the data value is greater than ($>$) the counter value. One pulse width is equal to $t_{CLK} \times 256$; see Figure 69.

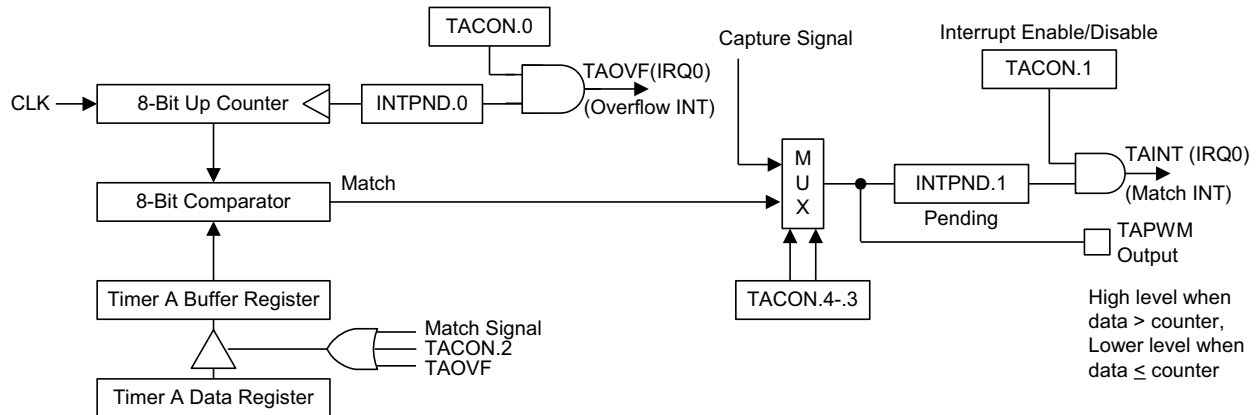


Figure 69. Simplified Timer A Function Diagram: PWM Mode

Timer A Capture Mode

In Capture Mode, a signal edge that is detected at the TACAP pin opens a gate and loads the current counter value into the Timer A Data Register. Rising or falling edges can be selected to trigger this operation.

Timer A also provides a capture input source: the signal edge at the TACAP pin. Select the capture input by setting the values of the Timer A capture input selection bits in the Port 1 Control Register, P1CONL.4, (E1h, Set1, Bank1). When P1CONL.4 is 0, the TACAP input is selected.

Both kinds of Timer A interrupts can be used in Capture Mode: the Timer A overflow interrupt is generated whenever a counter overflow occurs, and the Timer A match/capture interrupt is generated whenever the counter value is loaded into the Timer A Data Register.

By reading the captured data value in TADATA, and assuming a specific value for the Timer A clock frequency, you can calculate the pulse width (duration) of the signal that is being input at the TACAP pin; see Figure 70.

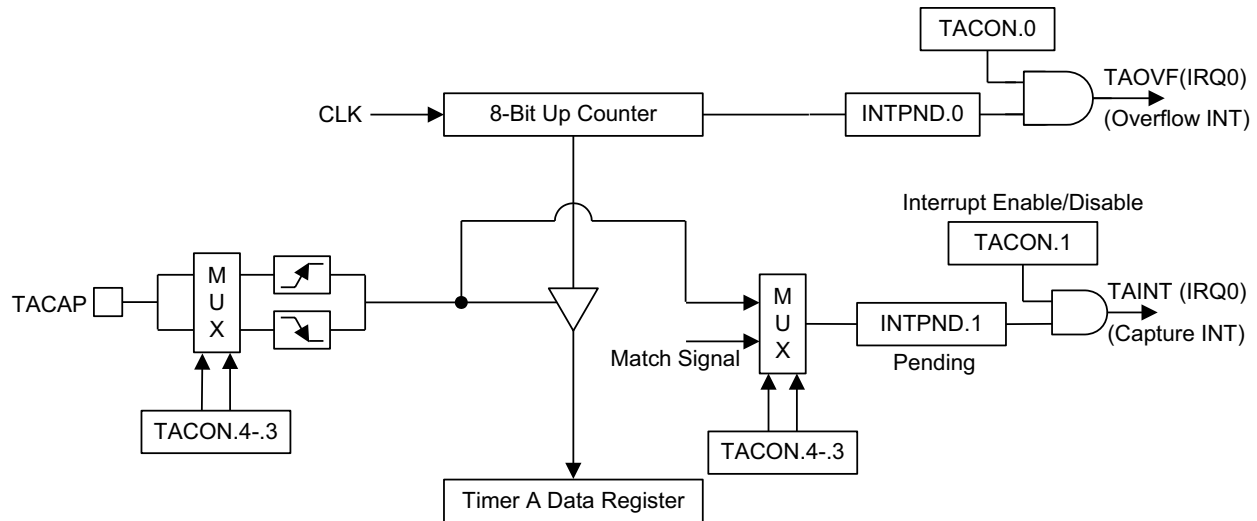


Figure 70. Simplified Timer A Function Diagram: Capture Mode

8-Bit Timer B

The S3F8S5A microcontroller has an 8-bit counter called Timer B, which can be used to generate the carrier frequency of a remote controller signal. Timer B offers the following two functions:

- As a normal interval timer, generating a Timer B interrupt at programmed time intervals
- To supply a clock source to the 8-bit timer/counter module, Timer B, for generating the Timer B overflow interrupt

Figure 71 presents a block diagram of the Timer B function.

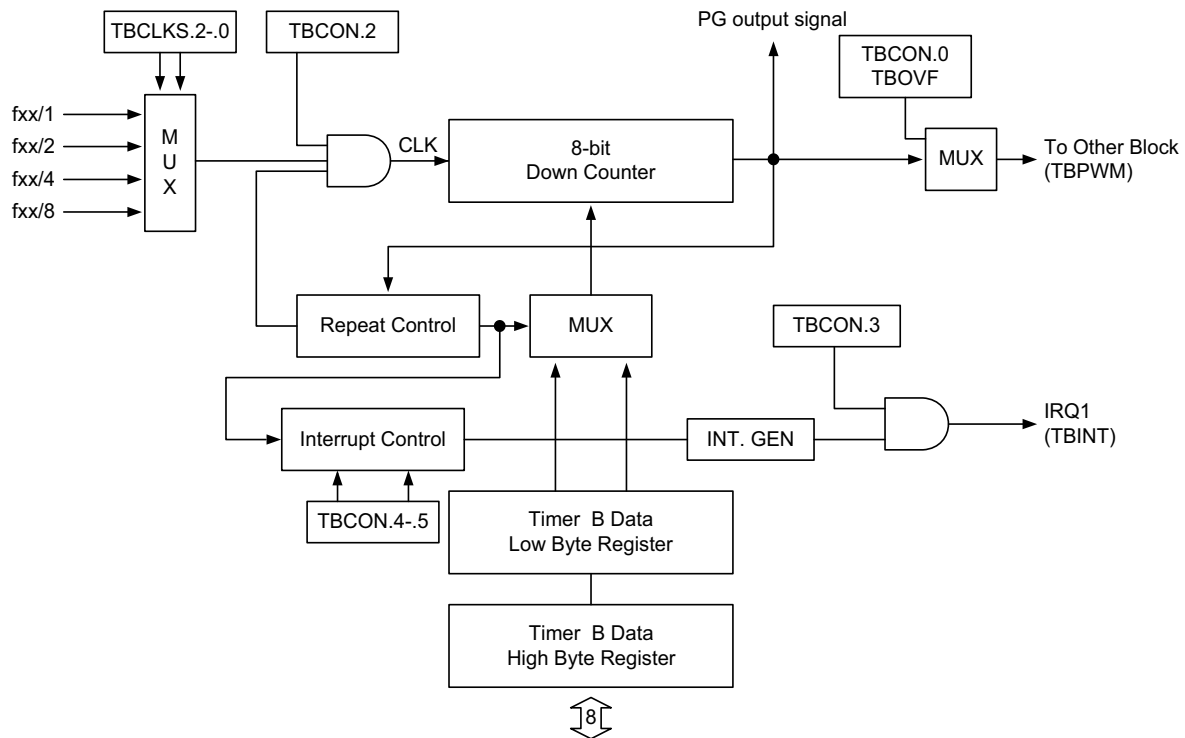


Figure 71. Timer B Functional Block Diagram

-
- **Note:** The value of the TBDATAL Register is loaded into the 8-bit counter when the operation of Timer B starts. If a borrow occurs in the counter, the value of the TBDATAH Register is loaded into the 8-bit counter. However, on the next borrow, the value of the TBDATAL Register is loaded into the bit counter.
-

The Timer B Control (TBCON) Register is shown in Table 67.

Table 67. Timer B Control Register (TBCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	E3h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	Reserved
[5:4]	Timer B Interrupt Time Selection Bits 00: Generating after low data is borrowed. 01: Generating after high data is borrowed. 10: Generating after low and high data are borrowed. 11: Not available.
[3]	Timer B Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[2]	Timer B Start/Stop Bit 0: Stop Timer B. 1: Start Timer B.
[1]	Timer B Mode Selection Bit 0: One-Shot Mode. 1: Repeat Mode.
[0]	Timer B Output Flip-Flop Control Bit 0: TBOF is Low (TBPWM: low level for low data, high level for High data). 1: TBOF is High (TBPWM: high level for low data, low level for High data).

The Timer B Clock Selection (TBCLKS) Register is shown in Table 68.

Table 68. Timer B Clock Selection Register (TBCLKS; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	E6h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:3]	Reserved
[2:0]	Timer B Clock Selection Bits 000: f_{XX} . 001: $f_{XX}/2$. 001: $f_{XX}/4$. 001: $f_{XX}/8$. 001: $f_{XX}/64$. 001: $f_{XX}/256$. 001: Not available.

Timer B Pulse Width Calculations

Figure 72 presents an example waveform consisting of a low period time, t_{LOW} , and high period time, t_{HIGH} .

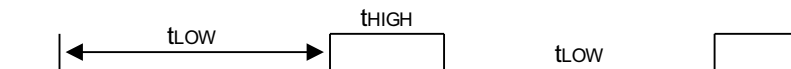


Figure 72. Timer B Waveform, Example #1 of 3

To generate the waveform in Figure 72, observe the following calculations.

When TBOF = 0:

$$t_{LOW} = (TBDATAL + 2) \times 1/f_X, 0h < TBDATAL < 100h, \text{ where } f_X = \text{the selected clock.}$$

$$t_{HIGH} = (TBDATAH + 2) \times 1/f_X, 0h < TBDATAH < 100h, \text{ where } f_X = \text{the selected clock.}$$

When TBOF = 1:

$$t_{LOW} = (TBDATAH + 2) \times 1/f_X, 0h < TBDATAH < 100h, \text{ where } f_X = \text{the selected clock.}$$

$$t_{HIGH} = (TBDATAL + 2) \times 1/f_X, 0h < TBDATAL < 100h, \text{ where } f_X = \text{the selected clock.}$$

To make $t_{\text{LOW}} = 24\mu\text{s}$ and $t_{\text{HIGH}} = 15\mu\text{s}$. $f_{\text{OSC}} = 4\text{MHz}$, $f_{\chi} = 4\text{MHz}/4 = 1\text{MHz}$

When TBOF = 0:

$$t_{\text{LOW}} = 24\mu\text{s} = (\text{TBDATAL} + 2) / f_{\chi} = (\text{TBDATAL} + 2) \times 1\mu\text{s}, \text{TBDATAL} = 22.$$

$$t_{\text{HIGH}} = 15\mu\text{s} = (\text{TBDATAH} + 2) / f_{\chi} = (\text{TBDATAH} + 2) \times 1\mu\text{s}, \text{TBDATAH} = 13.$$

When TBOF = 1:

$$t_{\text{HIGH}} = 15\mu\text{s} = (\text{TBDATAL} + 2) / f_{\chi} = (\text{TBDATAL} + 2) \times 1\mu\text{s}, \text{TBDATAL} = 13.$$

$$t_{\text{LOW}} = 24\mu\text{s} = (\text{TBDATAH} + 2) / f_{\chi} = (\text{TBDATAH} + 2) \times 1\mu\text{s}, \text{TBDATAH} = 22.$$

Figure 73 presents the waveform output of the Timer B output in Repeat Mode.

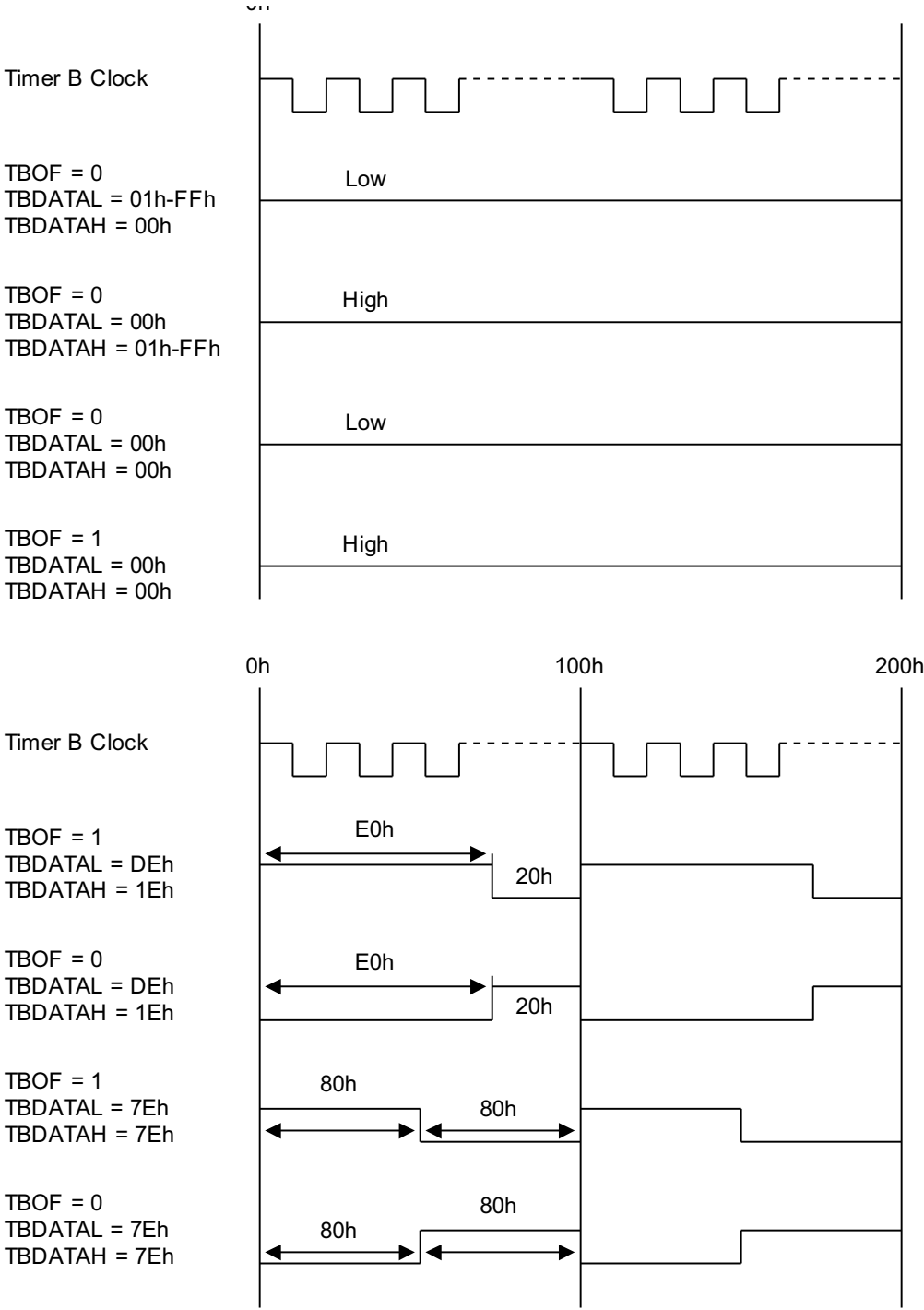


Figure 73. Timer B Output Flip-Flop Waveforms in Repeat Mode

Figure 74 presents an example waveform that sets Timer B to Repeat Mode, sets the oscillation frequency as the Timer B clock source, and causes TBDATAH and TBDATAL to establish a 38kHz, 1/3-duty carrier frequency.

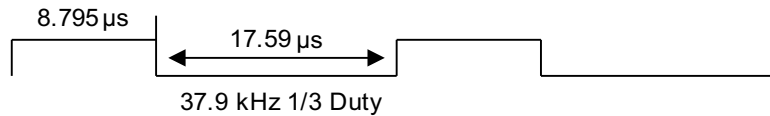


Figure 74. Timer B Waveform, Example #2 of 3

To generate the waveform in Figure 74, the following factors form the calculation, which follows.

- Timer B is used in Repeat Mode
- The oscillation frequency is 4MHz (1 clock = 0.25μs)
- TBDATAH = 8.795μs/0.25μs = 35.18, TBDATAL = 17.59μs/0.25μs = 70.36
- P2.0 is set to TBPWM Mode

```

        ORG 0100h                ;Reset address
START DI
    .
    .
    .
    LD  TBDATAL,#(70-2)         ;Set 17.5 μs
    LD  TBDATAH,#(35-2)        ;Set 8.75 μs
    LD  TBCON,#00000111b       ;Clock Source ← fxx
                                ;Disable Timer B interrupt.
                                ;Select Repeat Mode for Timer B.
                                ;Start Timer B operation.
                                ;Set Timer B Output flip-flop (TBOF)
                                ;High.
    OR  P2CONL,#00000011b      ;Set P2.0 to TBPWM Mode.
                                ;This command generates 38kHz, 1/3
                                ;duty pulse signal through P2.0.
    .
    .
    .

```

Figure 75 presents an example waveform that sets Timer B to One Shot Mode, sets the oscillation frequency as the Timer B clock source, and causes TBDATAH and TBDATAL to establish a 40μs-width pulse.

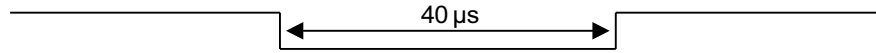


Figure 75. Timer B Waveform, Example #3 of 3

To generate the waveform in Figure 75, the following factors form the calculation, which follows.

- Timer B is used in One Shot Mode
- The oscillation frequency is 4MHz (1 clock = 0.25μs)
- TBDATAH = 40μs/0.25μs = 160, TBATAL = 1
- P2.0 is set to TBPWM Mode

```

        ORG    0100h           ;Reset address
START DI
        .
        .
        .
        LD    TBDATAH,# (160-2);Set 40 μs
        LD    TBATAL,# 1      ;Set any value except 00H
        LD    TBCON,#0000001b;Clock Source ← fOSC
                                ;Disable Timer B interrupt.
                                ;Select One Shot Mode for Timer B.
                                ;Stop Timer B operation.
                                ;Set Timer B output flip-flop (TBOF)
                                ;High
        OR    P2CONL, #00000011b ;Set P2.0 to TBPWM Mode.
        .
        .
Pulse_out: LD TBCON,#00000101b ;Start Timer B operation
                                ;To make the pulse at this point.
                                ;After the instruction is executed,
                                ;0.75 μs is required
                                ;before the falling edge of the pulse
                                ;starts.
        .
        .
        .
    
```

8-Bit Timer C

This chapter discusses the S3F8S5A MCU's 8-bit Timer C, an 8-bit general-purpose timer/counter featuring two operating modes, each of can be selected using one of the following two TCCON settings:

- Interval Timer Mode (toggle output at the TCOUT/TCPWM pins), in which only a match interrupt occurs
- PWM Mode (TCOUT/TCPWM pin), in which match and overflow interrupts can occur

Timer C also features the following functional components:

- Clock frequency divider with multiplexer
- 8-bit counter, 8-bit comparator, and 8-bit reference data register (TCDATA)
- PWM or match output (TCOUT/TCPWM)
- Timer C match/overflow interrupt (IRQ2, vector D4h) generation
- Timer C Control (TCCON) Register; Set1, Bank0, ECh, read/write

Figure 76 presents a block diagram of the Timer C function.

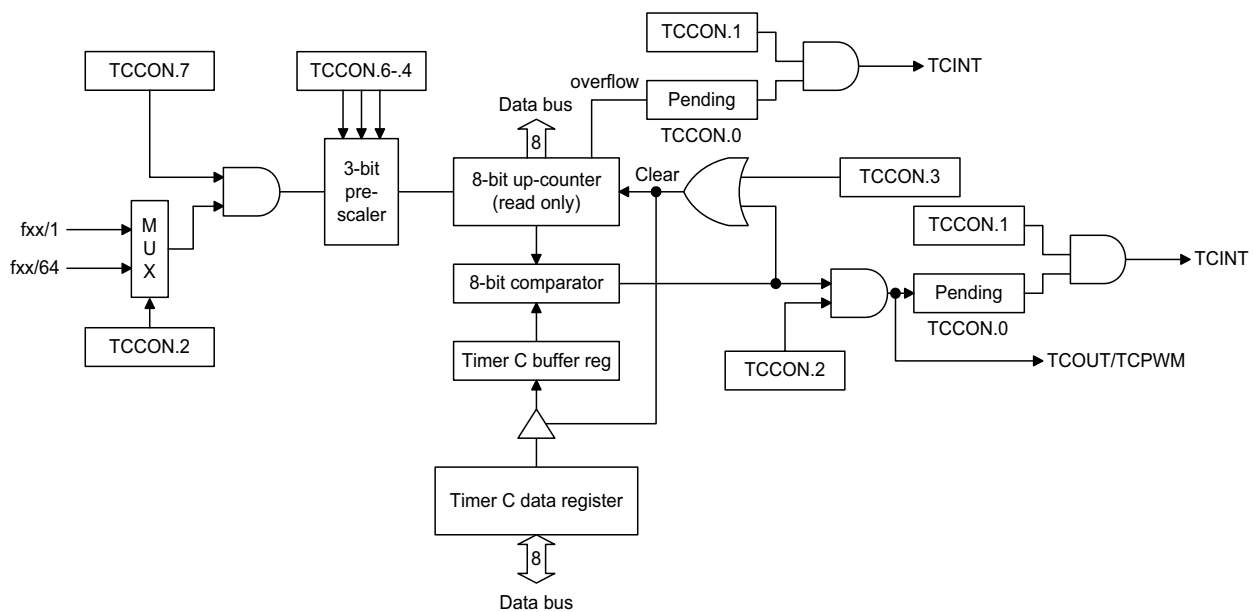


Figure 76. Timer C Functional Block Diagram

► **Note:** When operating in PWM Mode, the match signal cannot clear the counter.

Timer C Control Register

The Timer C Control (TCCON) Register, shown in Table 69, can be used to perform the following tasks:

- Select the Timer C operating mode ($f_{XX}/1$ & PWM Mode or $f_{XX}/64$ & Interval Mode)
- Select the Timer C 3-bits prescaler
- Clear the Timer C counter, TCCNT
- Enable the Timer C match/overflow interrupt
- Start the Timer C

TCCON is located in Set1, Bank0 at address ECh, and is read/write-addressable using Register Addressing Mode. A System Reset clears TCCON, thereby disabling Timer C. The Timer C counter can be cleared at any time during normal operation by writing a 1 to TCCON.3.

To enable the Timer C match/overflow interrupt (IRQ2, vector D4h), write a 1 to TCCON.7 and TCCON.1. To generate the exact time interval, write a 0 to TCCON.3 to clear the counter and the interrupt pending bit. To detect an interrupt pending condition when TCINT is disabled, the application software polls the pending bit, TCCN.0. When a 1 is detected, a Timer C match/overflow interrupt is pending. When the TCINT subroutine has been serviced, the pending condition must be cleared by software by writing a 0 to the Timer C interrupt pending bit, TCCON.0.

Table 69. Timer C Control Register (TCCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					ECh			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Timer C Start/Stop Bit 0: Stop Timer C. 1: Start Timer C.
[6:4]	Timer C 3-Bit Prescaler Bits 000: Not divided. 001: Divided by 2. 010: Divided by 3. 011: Divided by 4. 100: Divided by 5. 101: Divided by 6. 110: Divided by 7. 111: Divided by 8.
[3]	Timer C Counter Clear Bit* 0: No effect. 1: Clear the Timer C counter (when write).
[2]	Timer C Mode Selection Bit 0: $f_{XX}/1$ and PWM Mode. 1: $f_{XX}/64$ and Interval Mode.
[1]	Timer C Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[0]	Timer C Interrupt Pending Bit 0: No interrupt pending (when read), clear pending bit (when write). 1: Interrupt is pending (when read).

Note: *The TCCON.3 value is automatically cleared to 0 after being cleared by the counter.

16-Bit Timer D0/D1

This chapter discusses the S3F8S5A MCU's 16-bit Timer D0/D1, a 16-bit general-purpose timer. Timer D0 features the following three operating modes, each of which can be selected using the appropriate TD0CON setting:

- Interval Timer Mode (toggle output at the TD0OUT pin)
- Capture Input Mode with a rising or falling edge trigger at the TD0CAP pin
- PWM Mode (TD0PWM); the PWM output shares its output port with the TD0OUT pin

Timer D0 also features the following functional components:

- Clock frequency divider (f_{XX} divided by 1024, 256, 64, 8, 1) with multiplexer
- External clock input pin (TD0CLK)
- A 16-bit counter (TD0CNTH/TD0CNTHL), a 16-bit comparator, and two 16-bit reference data registers (TD0DATAH/TD0DATAL)
- I/O pins for capture input (TD0CAP) or match output (TD0OUT)
- Timer D0 overflow interrupt (IRQ3, vector DAh) and match/capture interrupt generation (IRQ3, vector D8h)
- Timer D0 Control (TD0CON) Register (Page 4, 01h; read/write)

Figure 77 presents a block diagram of the Timer D0 function.

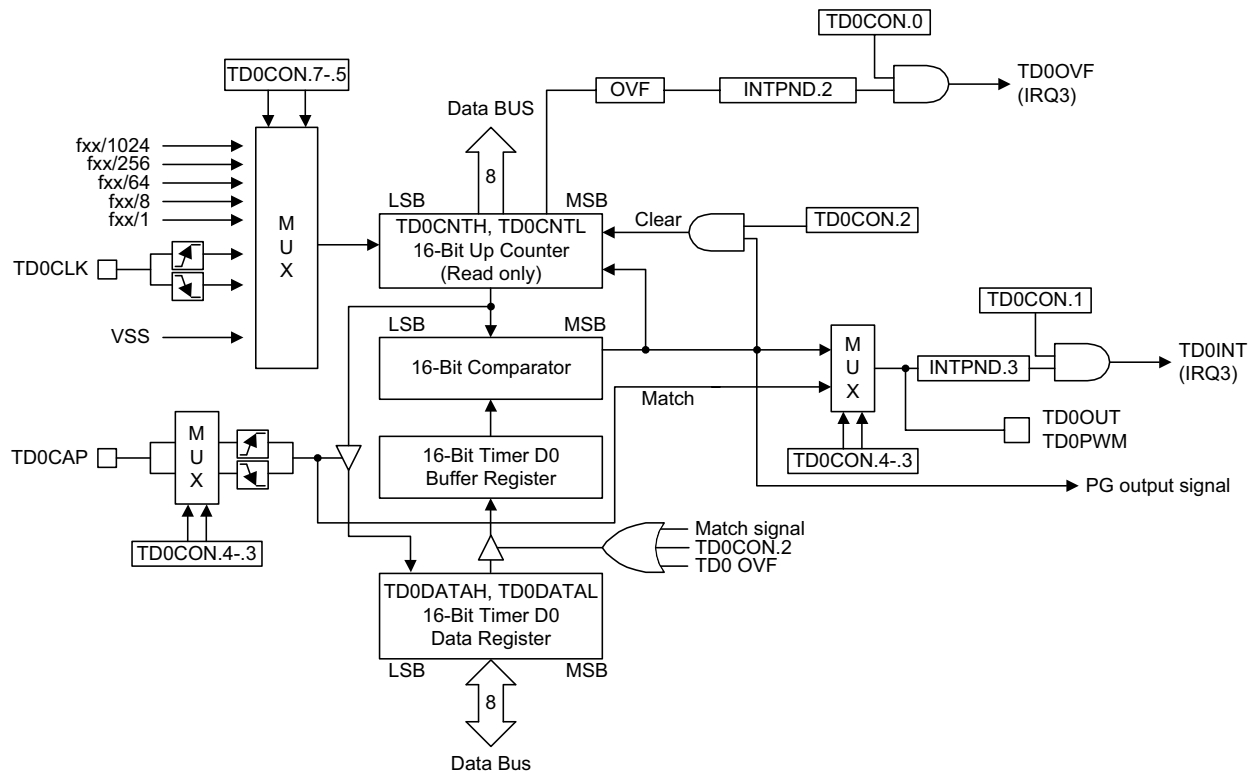


Figure 77. Timer D0 Functional Block Diagram

Timer D0 Control Register

Use the Timer D0 Control (TD0CON) Register, shown in Table 70, to perform the following tasks:

- Select the Timer D0 operating mode (Interval Timer, Capture Mode, or PWM Mode)
- Select the Timer D0 input clock frequency
- Clear the Timer D0 counter, TD0CNTL/TD0CNTH
- Enable the Timer D0 overflow interrupt or Timer D0 match/capture interrupt

TD0CON is located in Page 4 at address 01h, and is read/write addressable using Register Addressing Mode.

A reset clears TD0CON to 00h, thereby setting Timer D0 to normal Interval Timer Mode, and selecting an input clock frequency of $f_{XX}/1024$; all Timer D0 interrupts are disabled.

To disable counter operation, set TD0CON.7–.5 to 111b. Clear the Timer D0 counter at any time during normal operation by writing a 1 to TD0CON.2.

Table 70. Timer D0 Control Register (TD0CON; Page 4)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	01h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:5]	Timer D0 Input Clock Selection Bits 000: $f_{XX}/1024$. 001: $f_{XX}/256$. 010: $f_{XX}/64$. 011: $f_{XX}/8$. 100: $f_{XX}/1$. 101: External clock (TD0CLK) falling edge. 110: External clock (TD0CLK) rising edge. 111: Counter stop.
[4:3]	Timer D0 Operating Mode Selection Bits 00: Interval Mode (TD0OUT). 01: Capture Mode (Capture on rising edge, counter running, OVF can occur). 10: Capture Mode (Capture on falling edge, counter running, OVF can occur). 11: PWM Mode (OVF and match interrupt can occur).
[2]	Timer D0 Counter Clear Bit* 0: No effect. 1: Clear the Timer D0 counter (when write).
[1]	Timer D0 Match/Capture Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[0]	Timer D0 Overflow Interrupt Enable Bit 0: Disable overflow interrupt. 1: Enable overflow interrupt.

Note: *Refer to the Interrupt Pending (INTPND) Register for the Timer D0 pending bits.

The IRQ3-level Timer D0 overflow interrupt (TD0OVF) is at vector address DAh. When a Timer D0 overflow interrupt occurs and is serviced by an interrupt (IRQ3, vector DAh), write a 1 to TD0CON.0. When a Timer D0 overflow interrupt occurs and is serviced by the CPU, the pending condition is cleared automatically by hardware or must be cleared by software.

To enable the Timer D0 match/capture interrupt (IRQ3, vector D8h), write a 1 to TD0CON.1. To detect a match/capture interrupt pending condition, the application software polls INTPND.3. When a 1 is detected, a Timer D0 match or capture interrupt is pending. When the interrupt request has been serviced, the pending condition must be cleared by software by writing a 0 to the Timer D0 match/capture interrupt pending bit, INTPND.3.

Timer D0 Function Description

This section describes the features and functions of the Timer A interrupt.

Timer D0 Interrupts

Timer D0 can generate two interrupts: the Timer D0 overflow interrupt (TD0OVF) and the Timer D0 match/capture interrupt (TD0INT). TD0OVF is associated to interrupt level IRQ3 at vector DAh. TD0INT is also associated to interrupt level IRQ3, but is assigned the separate vector address, D8h.

A Timer D0 overflow interrupt pending condition is automatically cleared by hardware when it has been serviced or should be cleared by software in the interrupt service routine by writing a 0 to the INTPND.2 interrupt pending bit. However, the Timer D0 match/capture interrupt pending condition must be cleared by the application's interrupt service routine by writing a 0 to the INTPND.3 interrupt pending bit.

Timer D0 Interval Timer Mode

In Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer D0 Reference Data Register, TD0DATAH/TD0DATAL. The match signal generates a Timer D0 match interrupt (TD0INT, vector D8h) and clears the counter.

If, for example, you write the value 1087h to TD0DATAH/TD0DATAL, the counter will increment until it reaches 1087h. At this point, the Timer D0 interrupt request is generated, the counter value is reset, and counting resumes. With each match, the level of the signal at the Timer D0 output pin is inverted; see Figure 78.

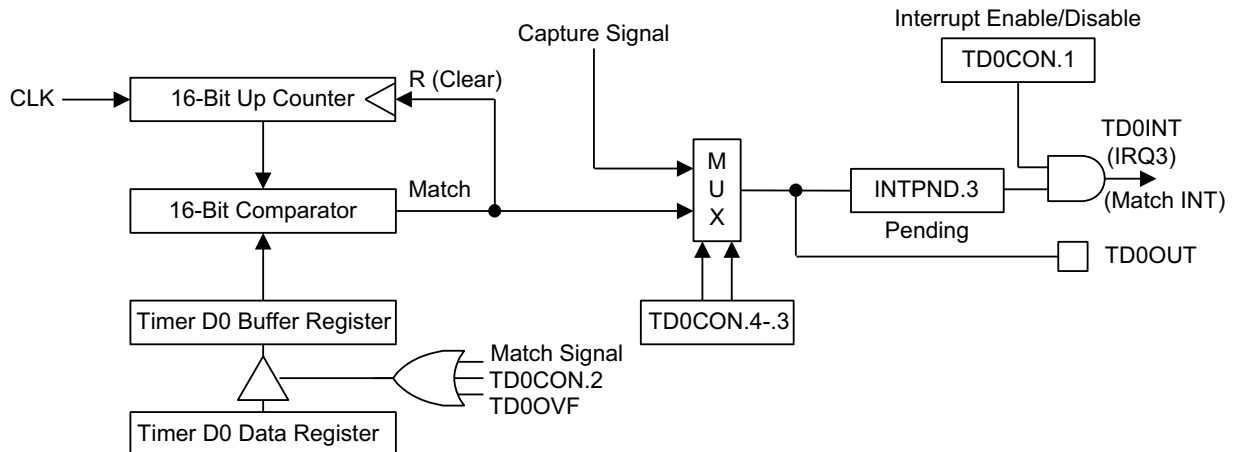


Figure 78. Simplified Timer D0 Function Diagram: Interval Timer Mode

Timer D0 Pulse Width Modulation Mode

Pulse Width Modulation (PWM) Mode lets you program the width (duration) of the pulse that is output at the TD0PWM pin. As in Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer D0 Data Register. In PWM Mode, however, the match signal does not clear the counter. Instead, it runs continuously, overflowing at $FFFFh$, then continues incrementing from $0000h$.

Although you can use the match signal to generate a Timer D0 overflow interrupt, interrupts are not typically used in PWM-type applications. Instead, the pulse at the TD0PWM pin is held Low as long as the reference data value is less than or equal to (\leq) the counter value; the pulse is then held High for as long as the data value is greater than ($>$) the counter value. One pulse width is equal to $t_{CLK} \times 65536$; see Figure 79.

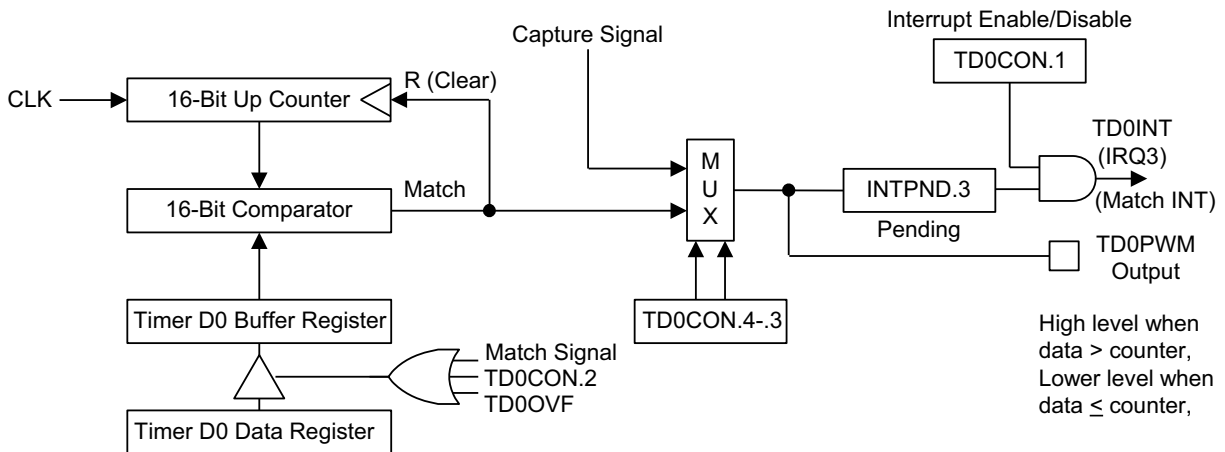


Figure 79. Simplified Timer D0 Function Diagram: PWM Mode

Timer D0 Capture Mode

In Capture Mode, a signal edge that is detected at the TD0CAP pin opens a gate and loads the current counter value into the Timer D0 Data Register. Rising or falling edges can be selected to trigger this operation.

Timer D0 also provides an capture input source: the signal edge at the TD0CAP pin. Select the capture input by setting the values of the Timer D0 capture input selection bits in the Port 2 Control Register, P2CONL.3–.2 (Set1, Bank1, E7h). When P2CONL.3–.2 is 00, the TD0CAP input is selected.

Both kinds of Timer D0 interrupts can be used in Capture Mode: the Timer D0 overflow interrupt is generated whenever a counter overflow occurs; the Timer D0 match/capture interrupt is generated whenever the counter value is loaded into the Timer D0 Data Register.

By reading the captured data value in TD0DATAH/TD0DATAL, and assuming a specific value for the Timer D0 clock frequency, you can calculate the pulse width (duration) of the signal that is being input at the TD0CAP pin; see Figure 80.

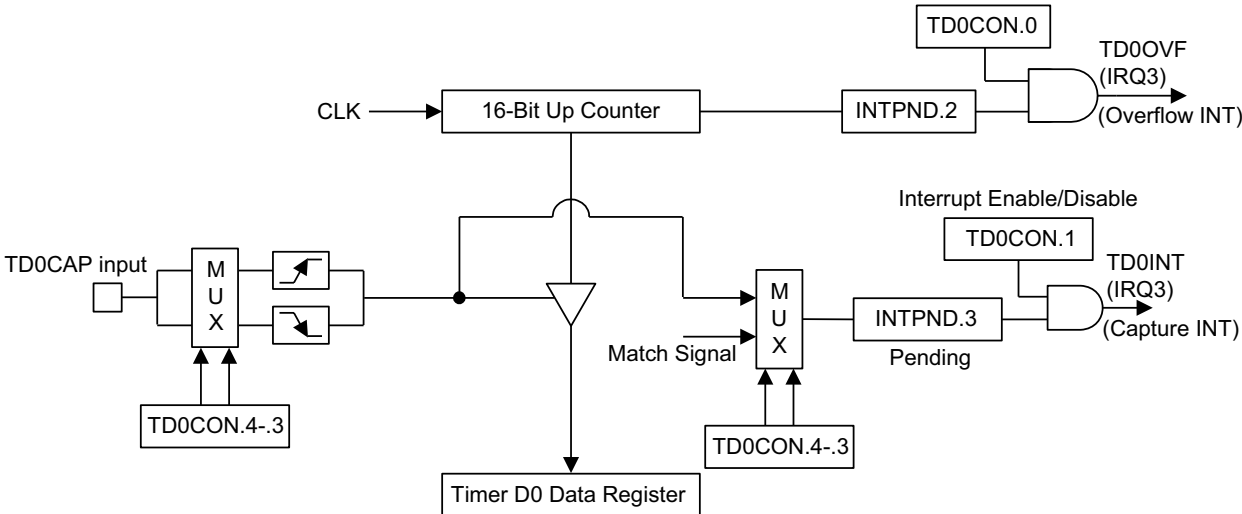


Figure 80. Simplified Timer D0 Function Diagram: Capture Mode

16-Bit Timer D1

The 16-bit Timer D1 is a 16-bit general-purpose timer featuring three operating modes, each of which can be selected using one of the following TD1CON settings:

- Interval Timer Mode (toggle output at the TD1OUT pin)
- Capture Input Mode with a rising or falling edge trigger at the TD1CAP pin
- PWM Mode (TD1PWM); PWM output shares its output port with the TD1OUT pin

Timer D1 also features the following functional components:

- Clock frequency divider (f_{XX} divided by 1024, 256, 64, 8, 1) with multiplexer
- External clock input pin (TD1CLK)
- A 16-bit counter (TD1CNTH/TD1CNTL), a 16-bit comparator, and two 16-bit reference data registers (TD1DATAH/TD1DATAL)
- I/O pins for capture input (TD1CAP), or match output (TD1OUT)
- Timer D1 overflow interrupt (IRQ3, vector DEh) and match/capture interrupt (IRQ3, vector DCh) generation
- Timer D1 Control (TD1CON) Register (Page 4, 0Ah; read/write)

Figure 81 presents a block diagram of the Timer D1 function.

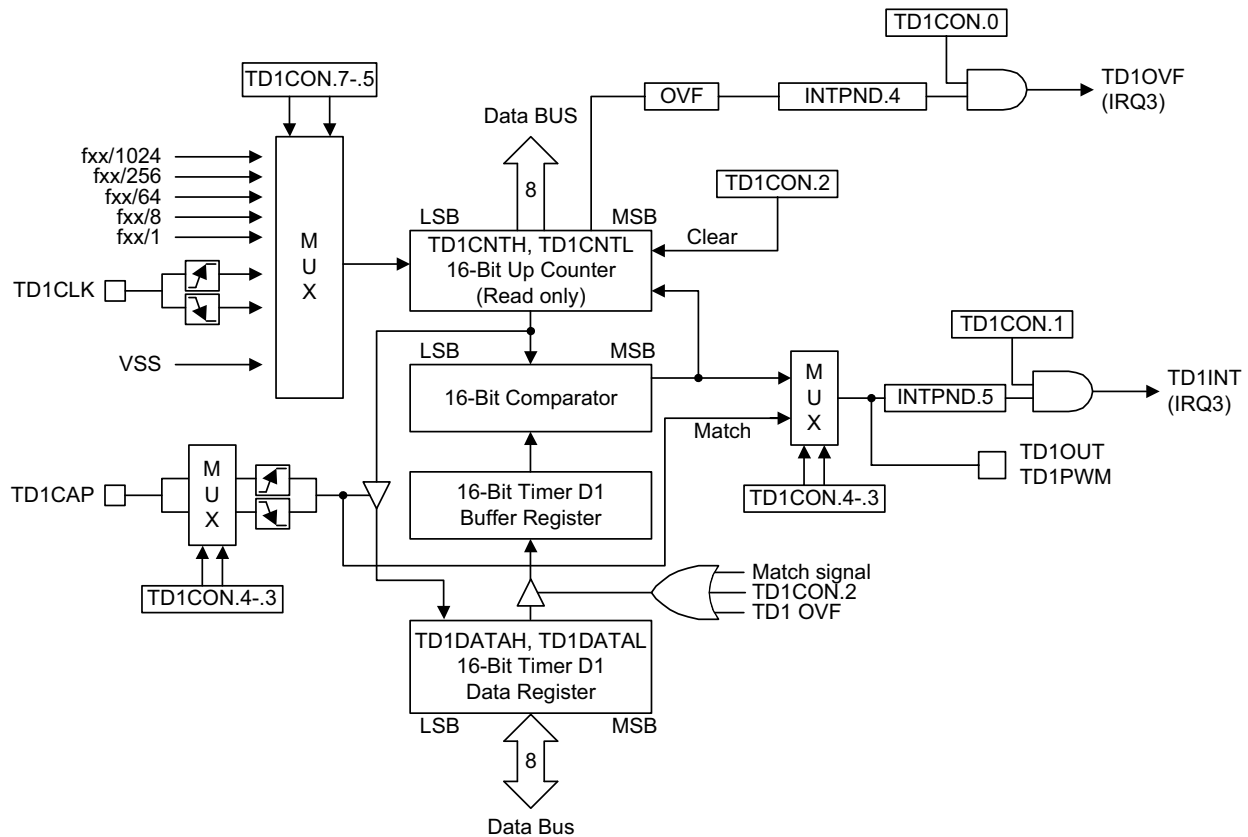


Figure 81. Timer D1 Functional Block Diagram

Timer D1 Control Register

Use the Timer D1 Control (TD1CON) Register, shown in Table 71, to perform the following tasks:

- Select the Timer D1 operating mode (Interval Timer, Capture Mode, or PWM Mode)
- Select the Timer D1 input clock frequency
- Clear the Timer D1 counter, TD1CNTH/T D1CNTL
- Enable the Timer D1 overflow interrupt or Timer D1 match/capture interrupt

TD1CON is located in Set1 and Bank1 at address FBh, and is read/write addressable using Register Addressing Mode.

A reset clears TD1CON to 00h, thereby setting Timer D1 to normal Interval Timer Mode, selecting an input clock frequency of $f_{XX}/1024$, and disabling all Timer D1 interrupts. To disable the counter operation, set TD1CON.7–.5 to 111b. The Timer D1 counter can be cleared at any time during normal operation by writing a 1 to TD1CON.2. The IRQ3-level Timer D1 overflow interrupt (TD1OVF) is at vector address DEh.

Table 71. Timer D1 Control Register (TD1CON; Page 4)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	0Ah							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7:5]	Timer D1 Input Clock Selection Bits 000: $f_{XX}/1024$. 001: $f_{XX}/256$. 010: $f_{XX}/64$. 011: $f_{XX}/8$. 100: $f_{XX}/1$. 101: External clock (TD1CLK) falling edge. 110: External clock (TD1CLK) rising edge. 111: Counter stop.
[4:3]	Timer D1 Operating Mode Selection Bits 00: Interval Mode (TD1OUT). 01: Capture Mode (Capture on rising edge, counter running, OVF can occur). 10: Capture Mode (Capture on falling edge, counter running, OVF can occur). 11: PWM Mode (OVF and match interrupt can occur).
[2]	Timer D1 Counter Clear Bit* 0: No effect. 1: Clear the Timer D1 counter (when write).
[1]	Timer D1 Match/Capture Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[0]	Timer D1 Overflow Interrupt Enable Bit 0: Disable overflow interrupt. 1: Enable overflow interrupt.

Note: *Refer to the Interrupt Pending (INTPND) Register for the Timer D1 pending bits.

When a Timer D1 overflow interrupt occurs and is serviced interrupt (IRQ3, vector DEh), write a 1 to TD1CON.0. When a Timer D1 overflow interrupt occurs and is serviced by

the CPU, the pending condition is cleared automatically by hardware or must be cleared by software.

To enable the Timer D1 match/capture interrupt (IRQ3, vector DCh), write a 1 to TD1CON.1. To detect a match/capture interrupt pending condition, the application software polls INTPND.3. When a 1 is detected, a Timer D1 match or capture interrupt is pending. When the interrupt request has been serviced, the pending condition must be cleared by software by writing a 0 to the Timer D1 match/capture interrupt pending bit, INTPND.5.

Timer D1 Function Description

This section describes the features and functions of the Timer D1 interrupt.

Timer D1 Interrupts

The Timer D1 can generate two interrupts: the Timer D1 overflow interrupt (TD1OVF), and the Timer D1 match/capture interrupt (TD1INT). TD1OVF is associated to interrupt level IRQ3, vector DEh. TD1INT also associates to interrupt level IRQ3, but is assigned the separate vector address, DCh.

A Timer D1 overflow interrupt pending condition is automatically cleared by hardware when it has been serviced, or should be cleared by software in the interrupt service routine by writing a 0 to the INTPND.4 interrupt pending bit. However, the Timer D1 match/capture interrupt pending condition must be cleared by the application's interrupt service routine by writing a 0 to the INTPND.5 interrupt pending bit.

Timer D1 Interval Timer Mode

In Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer D1 Reference Data Register, TD1DATAH/TD1DATAL. The match signal generates a Timer D1 match interrupt (TD1INT, vector DCh) and clears the counter.

If, for example, you write the value 1087h to TD1DATAH/TD1DATAL, the counter will increment until it reaches 1087h. At this point, the Timer D1 interrupt request is generated, the counter value is reset, and counting resumes. With each match, the level of the signal at the Timer D1 output pin is inverted; see Figure 82.

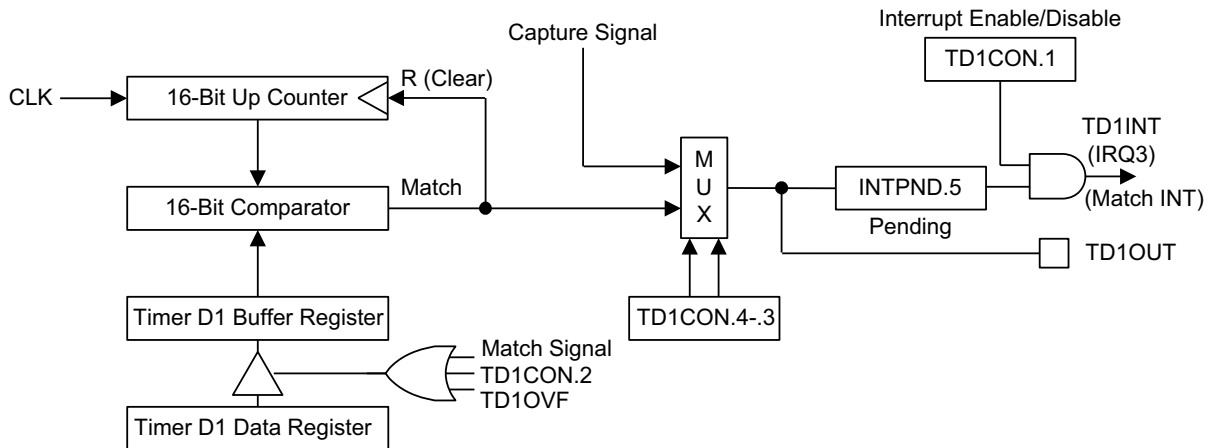


Figure 82. Simplified Timer D1 Function Diagram: Interval Timer Mode

Timer D1 Pulse Width Modulation Mode

Pulse Width Modulation (PWM) Mode lets you program the width (duration) of the pulse that is output at the TD1PWM pin. As in Interval Timer Mode, a match signal is generated when the counter value is identical to the value written to the Timer D1 Data Register. In PWM Mode, however, the match signal does not clear the counter. Instead, it runs continuously, overflowing at $FFFFh$, then continues incrementing from $0000h$.

Although you can use the match signal to generate a Timer D1 overflow interrupt, interrupts are not typically used in PWM-type applications. Instead, the pulse at the TD1PWM pin is held Low as long as the reference data value is less than or equal to (\leq) the counter value; the pulse is then held High for as long as the data value is greater than ($>$) the counter value. One pulse width is equal to $t_{CLK} \times 65536$; see Figure 83.

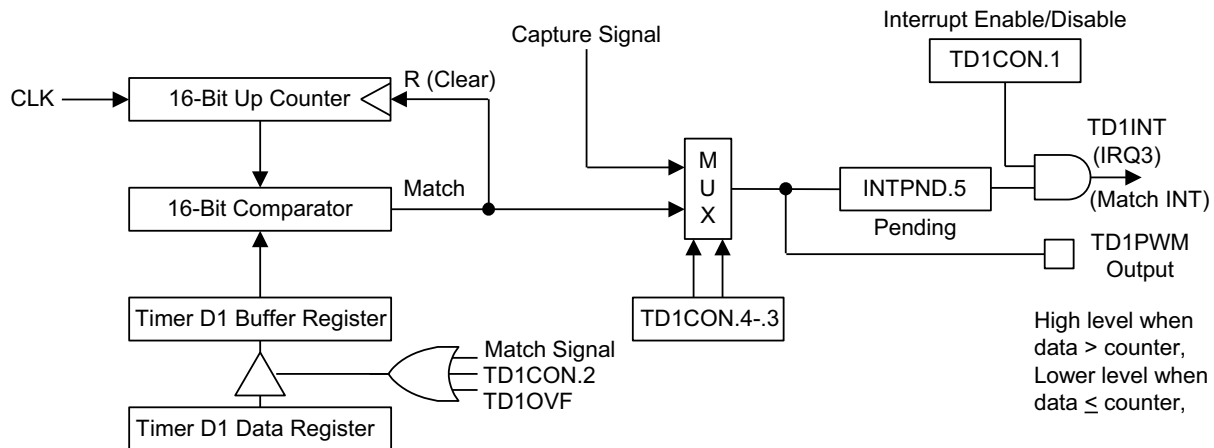


Figure 83. Simplified Timer D1 Function Diagram: PWM Mode

Timer D1 Capture Mode

In Capture Mode, a signal edge that is detected at the TD1CAP pin opens a gate and loads the current counter value into the Timer D1 Data Register. Select rising or falling edges to trigger this operation.

Timer D1 also provides a capture input source: the signal edge at the TD1CAP pin. Select the capture input by setting the values of the Timer D1 capture input selection bits in the Port 1 Control Register, P1CONH.3–.2 (Set1, Bank1, E0h). When P1CONH.3–.2 is 00, the TD1CAP input is selected.

Both kinds of Timer D1 interrupts can be used in Capture Mode: the Timer D1 overflow interrupt is generated whenever a counter overflow occurs, and the Timer D1 match/capture interrupt is generated whenever the counter value is loaded into the Timer D1 Data Register.

By reading the captured data value in TD1DATAH/TD1DATAL, and assuming a specific value for the Timer D1 clock frequency, you can calculate the pulse width (duration) of the signal that is being input at the TD1CAP pin; see Figure 84.

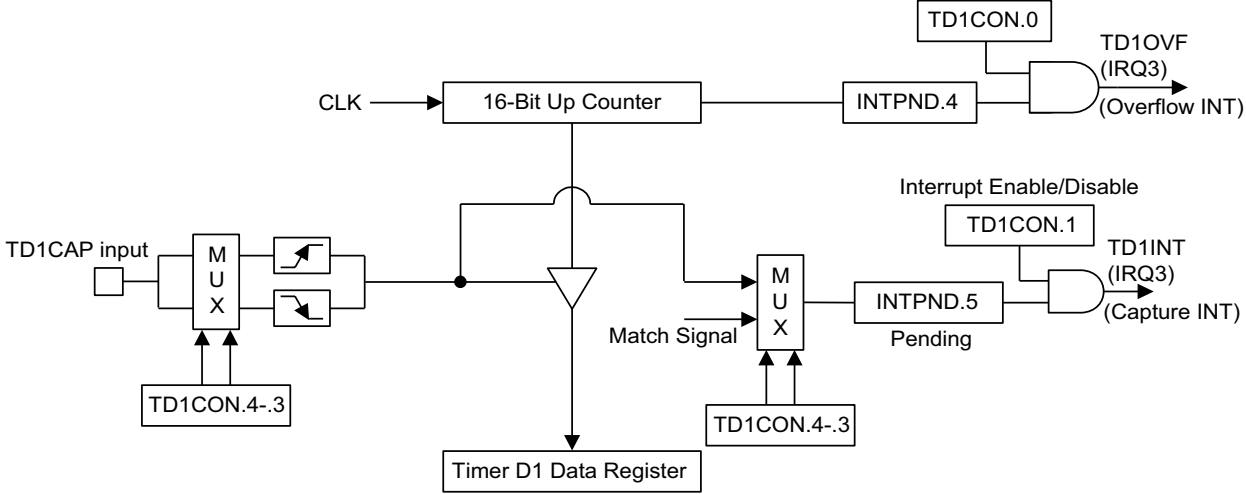


Figure 84. Simplified Timer D1 Function Diagram: Capture Mode

Watch Timer

The watch timer functions include programmable periodic interrupts, programmable frequency buzzer output, and a clock source for the LCD controller. The time base input for the watch timer can be set to either the main clock divided by 128 or the 32.768kHz sub-clock.

To start watch timer operation, set bit 1 of the Watch Timer Control Register, WTCN.1, to 1. To enable the watch timer overflow interrupt (IRQ4, vector E6h), set WTCN.0 to 1. After the watch timer starts and the time selected by WTCN.3-.2 elapses, the watch timer interrupt pending bit (INTPND.7) is automatically set to 1, and interrupt requests continue to occur in 1.995 ms, 0.125 s, 0.25 s and 0.5 s intervals.

The watch timer can also generate a programmable frequency for the BUZ output pin for a buzzer function. WTCN.3 and WTCN.2 must be set to 11b, thereby selecting 1.995 ms, and the output frequency can then be selected from 0.5kHz, 1kHz, 2kHz, or 4kHz with WTCN.4 and .5.

The watch timer supplies the clock frequency for the LCD controller (f_{LCD}). Therefore, if the watch timer is disabled, the LCD controller does not operate.

The watch timer provides the following features:

- Periodic interrupt generation (1.995 ms, 0.125 s, 0.25 s or 0.5 s)
- Selectable main clock or subclock for time base
- Provides clock source generation for the LCD controller (f_{LCD})
- I/O pin for buzzer output frequency generator (BUZ)
- Watch timer overflow interrupt (IRQ4, vector E6h) generation
- Watch Timer Control (WTCN) Register (Set1, Bank1, FEh, read/write)

Figure 85 presents a block diagram of the watch timer circuit.

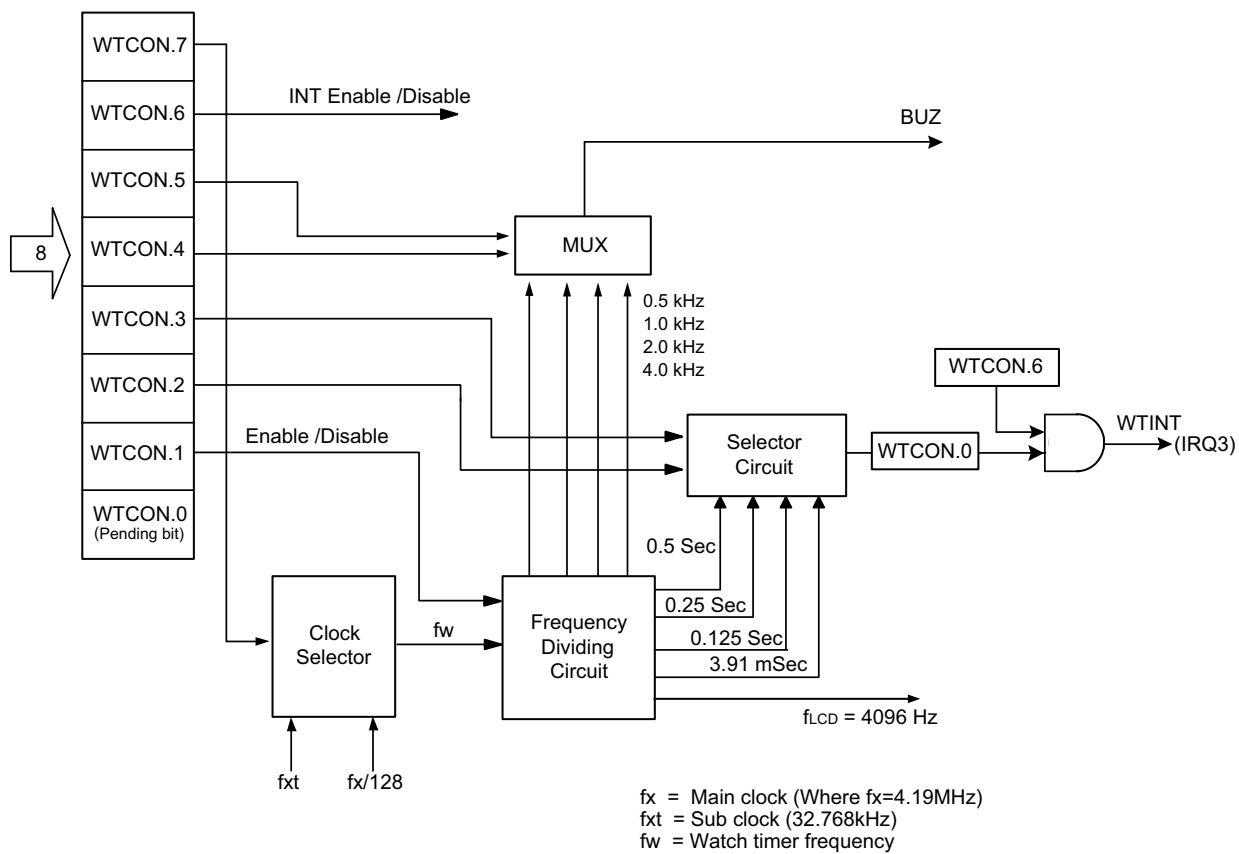


Figure 85. Watch Timer Circuit Block Diagram

Watch Timer Control Register

The Watch Timer Control (WTC0N) Register, shown in Table 72, is used to select the watch timer interrupt time and buzzer signal to enable or disable the watch timer function. It is located in Set1, Bank1 at address FEh, and is read/write addressable using Register Addressing Mode.

Table 72. Watch Timer Control Register (WTCN; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	FEh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7:6]	<p>Watch Timer Clock Selection Bits</p> <p>00: Select main clock divided by 2^7 ($f_{XX}/128$). 01: Select main clock divided by 2^8 ($f_{XX}/256$). 10: Select subclock. 11: Not available.</p>
[5:4]	<p>Buzzer Signal Selection Bits</p> <p>00: 0.5kHz. 01: 1kHz. 10: 2kHz. 11: 4kHz.</p>
[3:2]	<p>Watch Timer Speed Selection Bits</p> <p>00: Set watch timer interrupt to 0.5s. 01: Set watch timer interrupt to 0.25s. 10: Set watch timer interrupt to 0.125s. 11: Set watch timer interrupt to 0.391s.</p>
[1]	<p>Watch Timer Enable Bit</p> <p>0: Disable watch timer; clear frequency dividing circuits. 1: Enable watch timer.</p>
[0]	<p>Watch Timer Interrupt Enable Bit</p> <p>0: Disable watch timer interrupt. 1: Enable watch timer interrupt.</p>
Note: Refer to bit 7 of the INTPND Register for the watch timer pending bit.	

A reset clears WTCN to 00h, thereby disabling the watch timer. Therefore, to use the watch timer, write the appropriate value to WTCN.

LCD Controller/Driver

The S3F8S5A microcontroller can directly drive a 18-segment x 8-common LCD panel up to 144 dots. Its LCD block features the following components:

- LCD controller/driver
- Display RAM (00h–15h) for storing display data in Page 3
- 4 common/segment output pins (COM4/SEG16–COM7/SEG19)
- 18 segment output pins (SEG0–SEG15/SEG20–SEG21)
- 4 common output pins (COM0–COM3)
- LCD bias by voltage-dividing resistors

The LCD Control (LCON) Register, shown in Table 73, is used to turn the LCD display on and off and to select the frame frequency, LCD duty, and bias. Data written to LCD display RAM can be automatically transferred to the segment signal pins without any program control. When a subsystem clock is selected as the LCD clock source, the LCD display is enabled even in the main clock stop or idle modes.

LCD data stored in display RAM locations are transferred to the segment signal pins automatically without program control.

Table 73. LCD Control Register (LCON; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	F5h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	COM Pins High Impedance Control Bit 0: Display off. 1: Turn Display on.

Bit	Description (Continued)
[6:4]	LCD Clock Selection Bits 000: $f_W/28$ (128Hz). 001: $f_W/27$ (256Hz). 010: $f_W/26$ (512Hz). 011: $f_W/25$ (1024Hz). 100: $f_W/24$ (2048Hz). 101–111: Not available.
[3:1]	LCD Duty and Bias Selection Bits 000: 1/8 duty, 1/4 bias. 001: 1/4 duty, 1/3 bias. 010: 1/3 duty, 1/3 bias. 011: 1/3 duty, 1/2 bias. 1xx: 1/2 duty, 1/2 bias.
[0]	LCD Display Control Bits 0: Display off. 1: Turn display on.

Note: The clock and duty cycle for the LCD controller/driver are automatically initialized by hardware whenever the LCON Register data value is rewritten. As a result, the LCON Register does not rewrite frequently.

Figure 86 presents a block diagram of the LCD function.

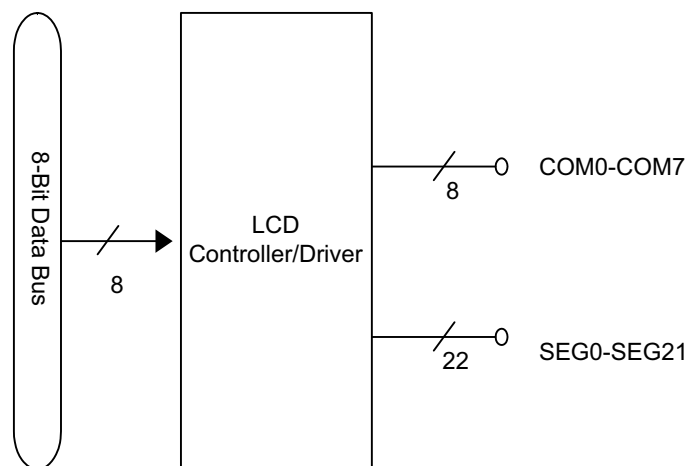


Figure 86. LCD Function Diagram

Figure 87 presents a diagram of the LCD circuit.

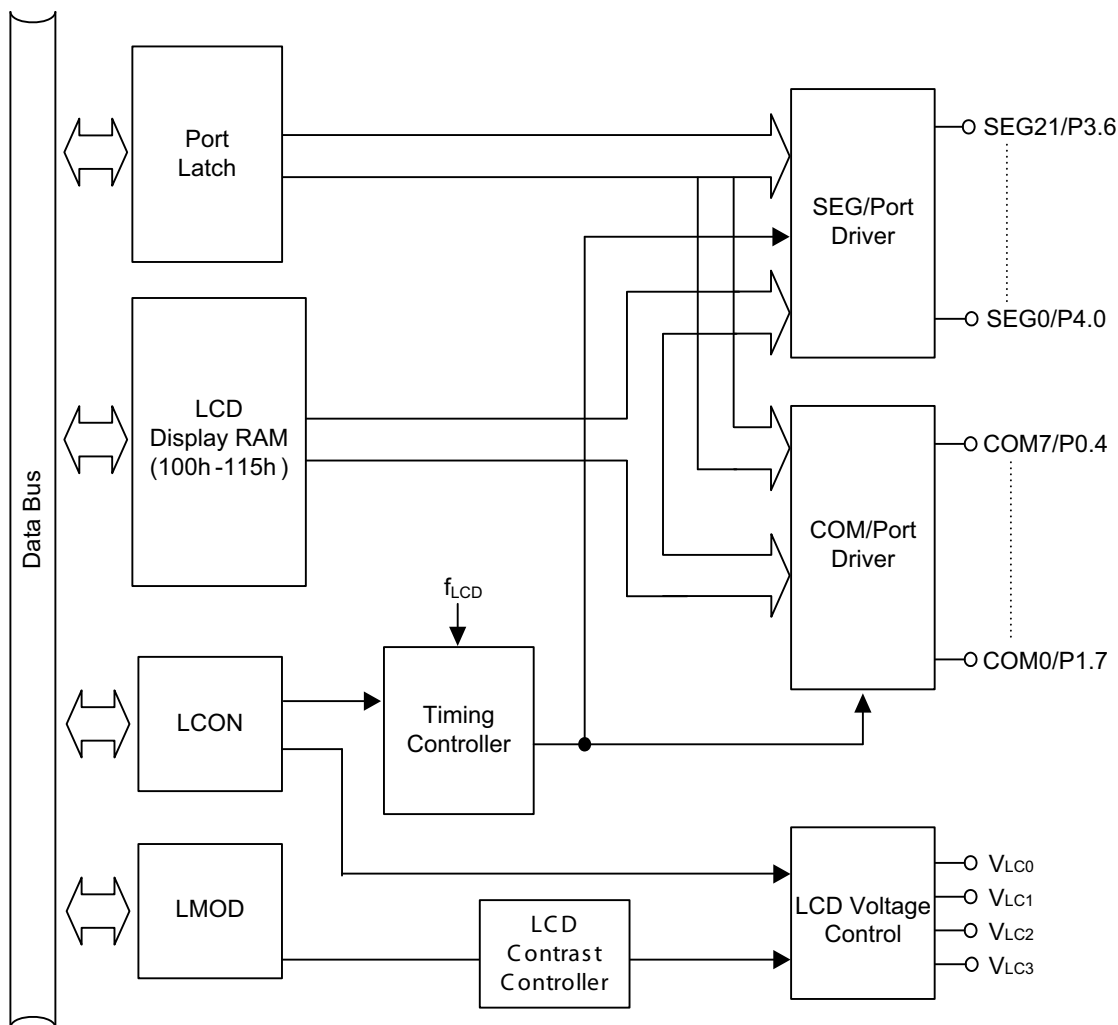


Figure 87. LCD Circuit

LCD RAM Address Area

RAM addresses of 00h–15h in Page 3 are used as LCD data memory. These locations can be addressed by 1-bit or 8-bit instructions. When the bit value of a display segment is 1, the LCD display is turned on; when the bit value is 0, the display is turned off.

Display RAM data are sent out through the segment pins, SEG0–SEG21, using a direct memory access (DMA) method that is synchronized with the f_{LCD} signal. RAM addresses

in this location that are not used for LCD display can be allocated to general-purpose use; see Table 74.

Table 74. LCD Display Data RAM Organization

COM	Bit	SEG0	SEG1	SEG2	SEG3	SEG4	–	SEG20	SEG21
COM0	.0								
COM1	.1								
COM2	.2								
COM3	.3								
COM4	.4	300h	301h	302h	303h	304h	–	314h	315h
COM5	.5								
COM6	.6								
COM7	.7								

LCD Control Register

The LCD Control (LCON) Register, shown in Table 75, is located in Set1, Bank1 at address F9h, and is read/write addressable using Register Addressing Mode. This register features the following control functions:

- LCD duty and bias selection
- LCD clock selection
- LCD display control

The LCON Register is used to turn the LCD display on/off, to select duty and bias, to select the LCD clock. A reset clears the LCON Register to 00h, thereby turning off the LCD display, selecting 1/8 duty and 1/4 bias, and selecting 128Hz for the LCD clock.

The LCD clock signal determines the frequency of the COM signal scan of each segment output; also referred to as the *LCD frame frequency*. Because the LCD clock is generated by the watch timer clock (f_W), the watch timer should be enabled when the LCD display is turned on.

► **Note:** The clock and duty for the LCD controller/driver is automatically initialized by hardware whenever the LCON Register data value is rewritten. Therefore, the LCON Register does not rewrite frequently.

Table 75. LCD Control Register (LCON; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	FAh							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7]	COM Pins High Impedance Control Bit 0: COMs signal output. 1: COM pins high impedance output.
[6:4]	LCD Clock Selection Bits 000: $f_W/2^8$ (128Hz). 001: $f_W/2^7$ (256Hz). 010: $f_W/2^6$ (512Hz). 011: $f_W/2^5$ (1024Hz). 100: $f_W/2^4$ (2048Hz). 101–111: Not available.
[3:1]	LCD Duty and Bias Selection Bits 000: 1/8 duty, 1/4 bias. 001: 1/4 duty, 1/3 bias. 010: 1/3 duty, 1/3 bias. 011: 1/3 duty, 1/2 bias. 1xx: 1/2 duty, 1/2 bias.
[0]	LCD Display Control Bits 0: All LCD signals are low. 1: Turn display on.

Note: The clock and duty cycle for the LCD controller/driver are automatically initialized by hardware whenever the LCON Register data value is rewritten. As a result, the LCON Register does not rewrite frequently.

Internal Resistor Bias

Figure 88 shows the internal bias connections.

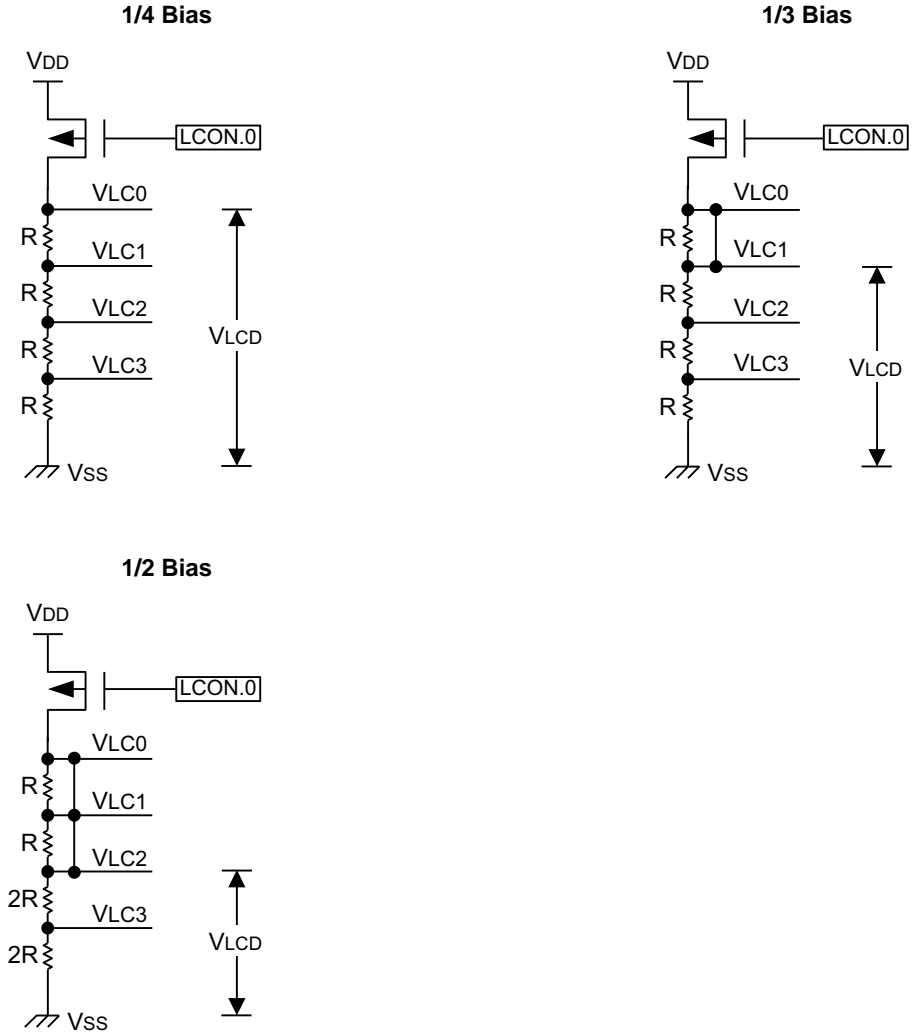


Figure 88. Internal Resistor Bias Pin Connections

► **Note:** In Figure 88, V_{LC0} and V_{LC1} should be connected at 1/3 bias; V_{LC0} , V_{LC1} , and V_{LC2} should be connected at 1/2 bias.

Common Signals

The common signal (COM) output pin selection varies according to the selected duty cycle, as follows:

- In 1/8 Duty Mode, COM0–COM7 (SEG0–SEG15/SEG20–SEG21) pins are selected
- In 1/4 Duty Mode, COM0–COM3 (SEG0–SEG21) pins are selected
- In 1/3 Duty Mode, COM0–COM2 (SEG0–SEG21) pins are selected
- In 1/2 Duty Mode, COM0–COM1 (SEG0–SEG21) pins are selected

Segment Signals

The 22 LCD segment signal pins are connected to their corresponding display RAM locations at Page 3. The bits of the display RAM are synchronized with the common signal output pins.

When the bit value of a display RAM location is 1, a select signal is sent to the corresponding segment pin. When the display bit is 0, a *no-select signal* is sent to the corresponding segment pin. See Figures 89 and 90.

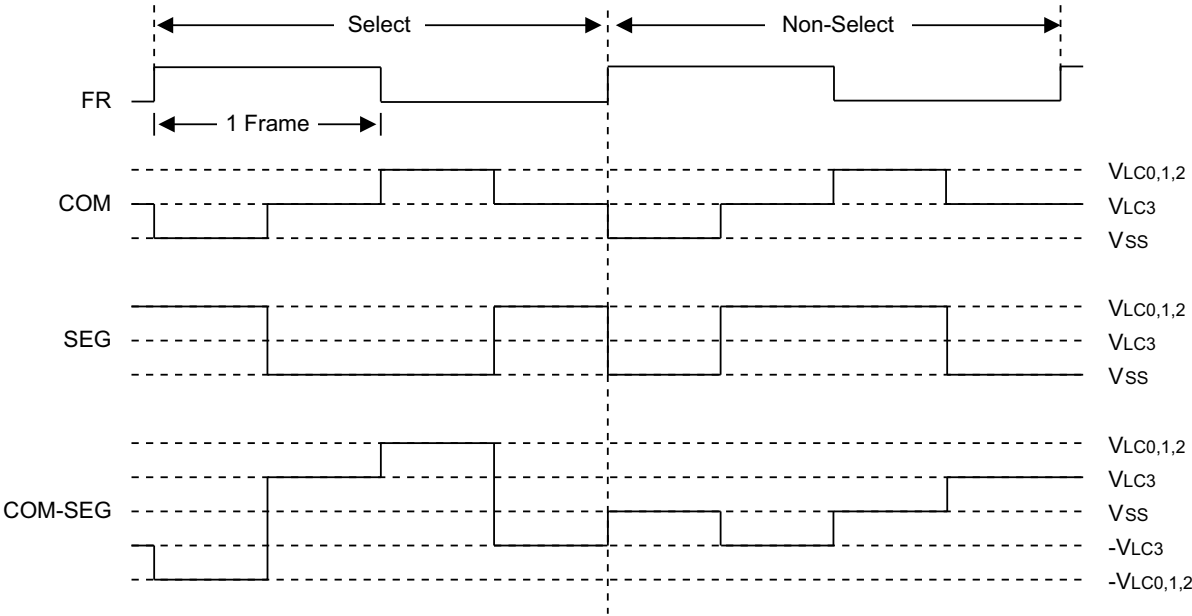


Figure 89. Select/No-Select Signal in 1/2 Duty, 1/2 Bias Display Mode

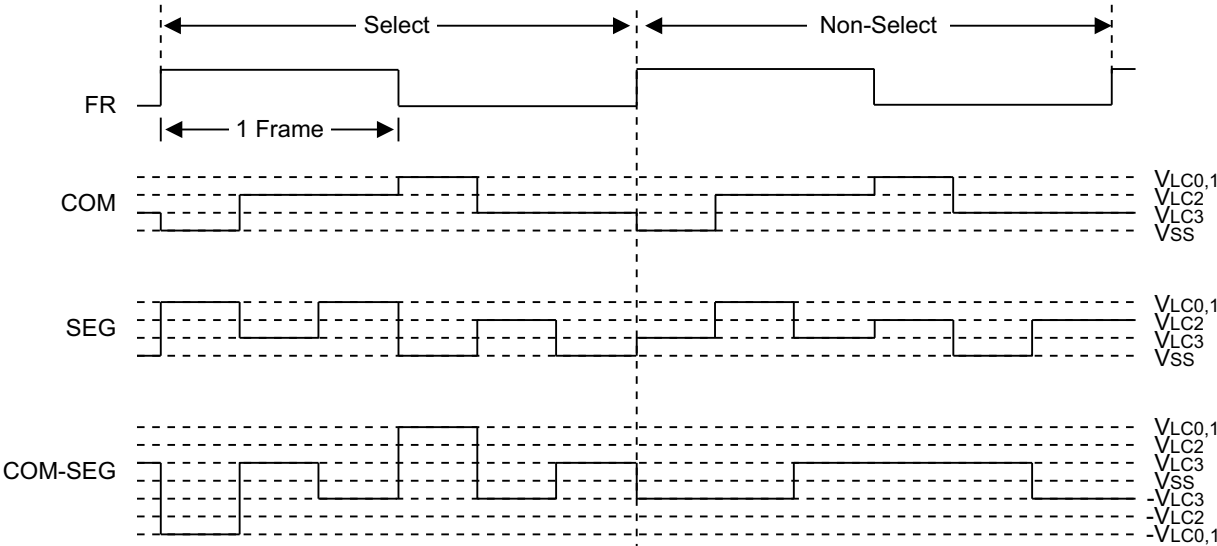


Figure 90. Select/No-Select Signal in 1/3 Duty, 1/3 Bias Display Mode

Figures 91 through 95 present waveforms of the LCD signal for differing duty and bias configurations.

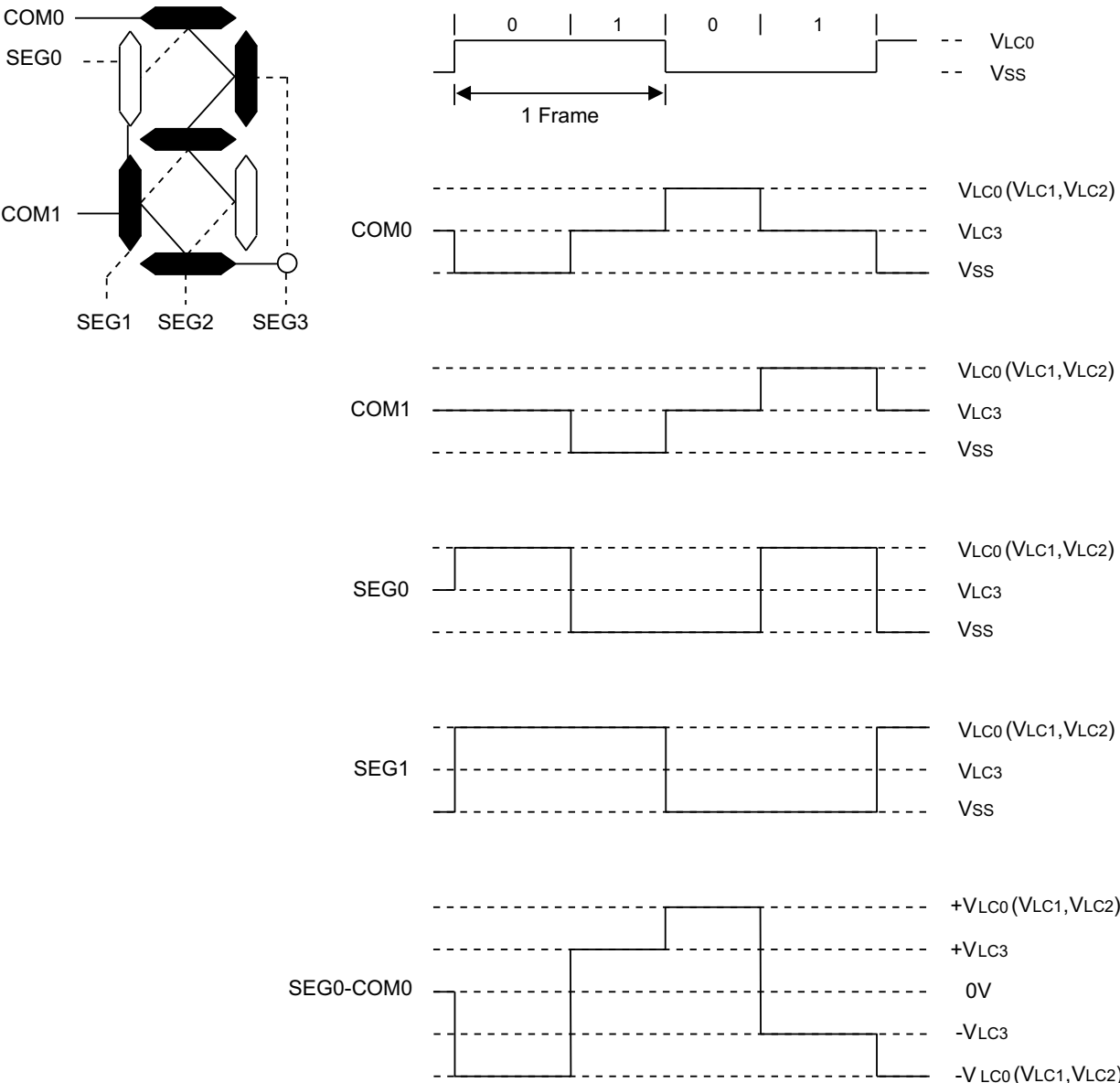


Figure 91. LCD Signal Waveforms: 1/2 Duty, 1/2 Bias

► **Note:** In Figure 91, $V_{LC0} = V_{LC1}, V_{LC2}$.

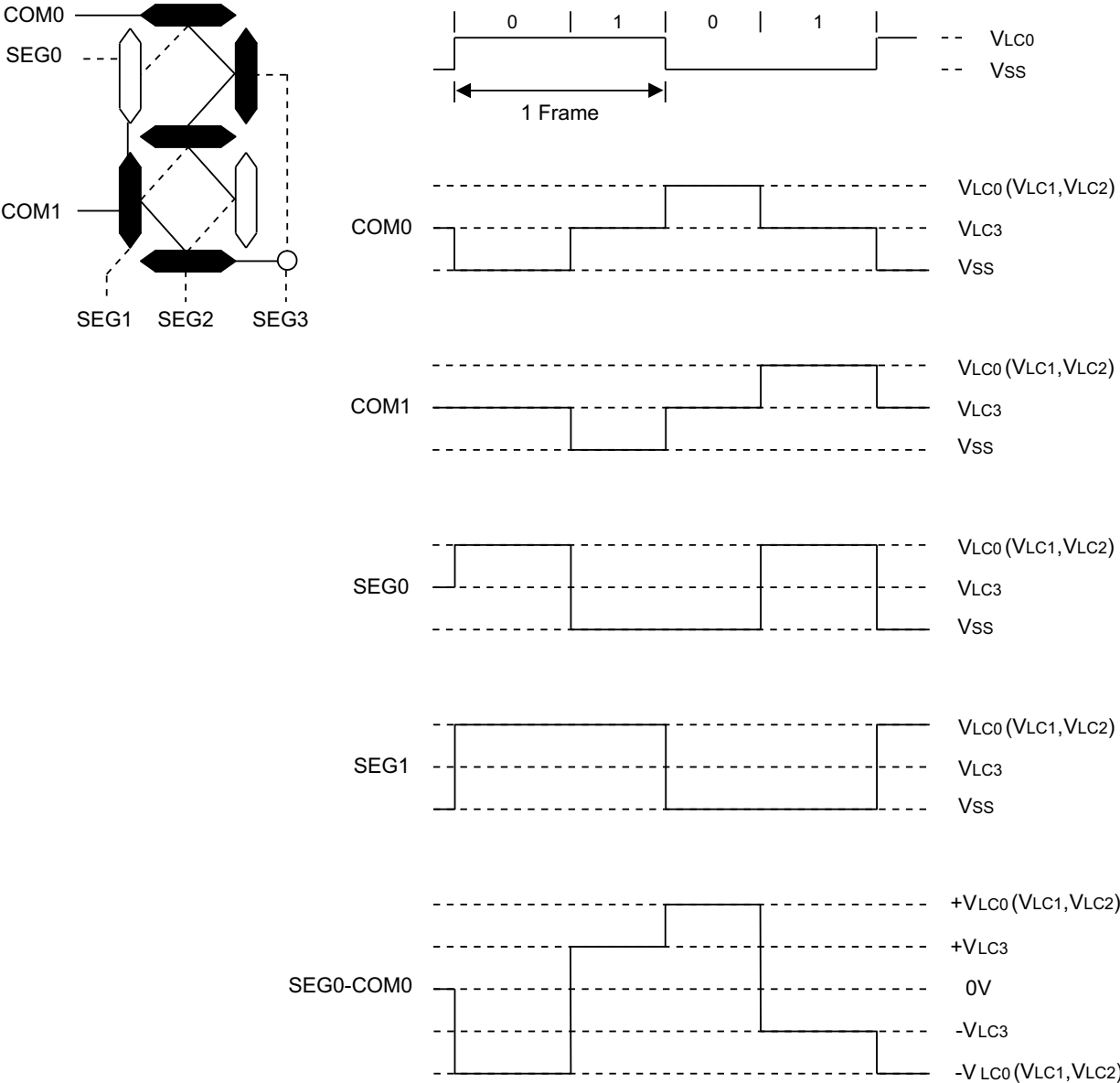


Figure 92. LCD Signal Waveforms: 1/3 Duty, 1/3 Bias

► **Note:** In Figure 92, $V_{LC0} = V_{LC1}$.

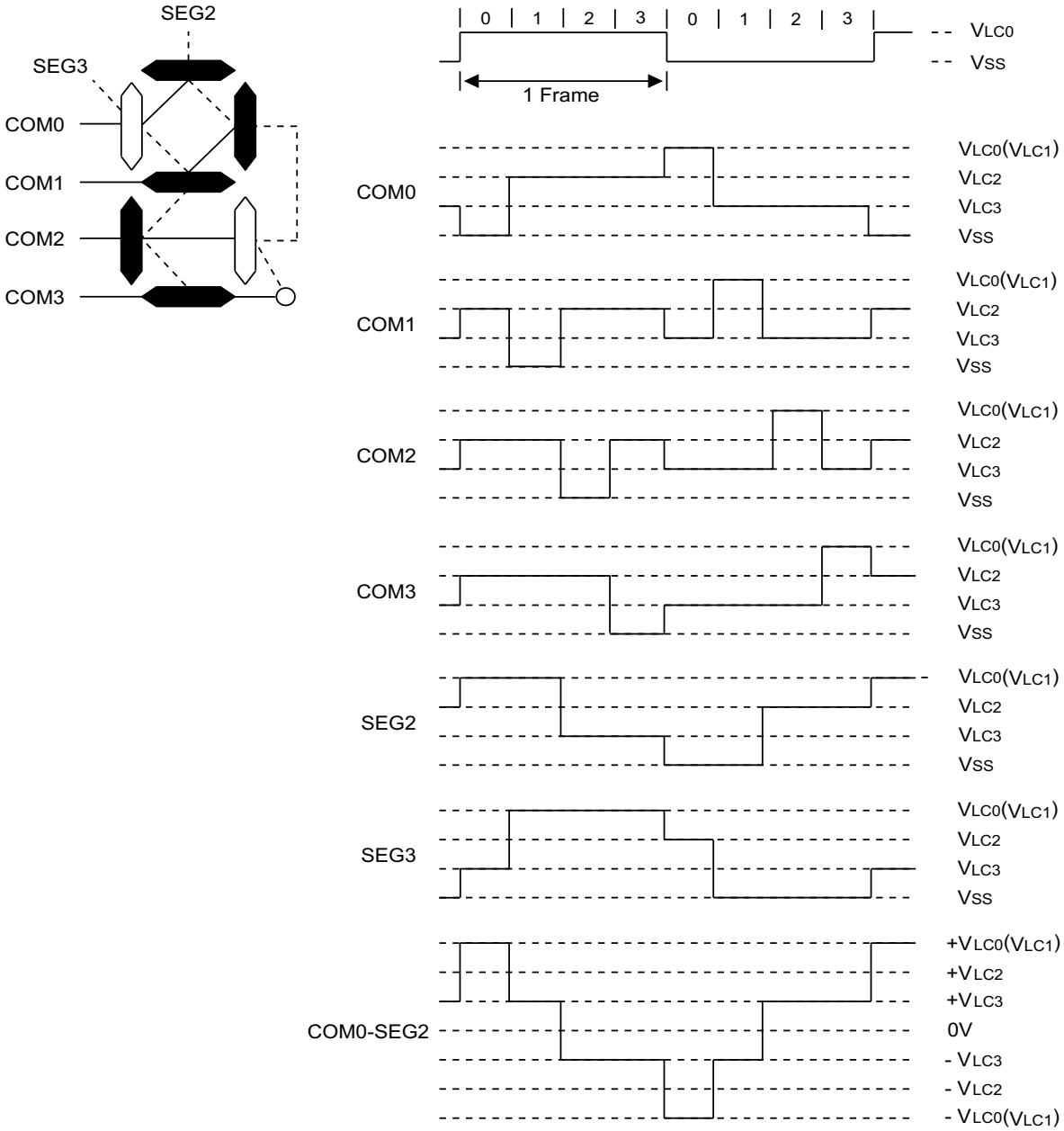


Figure 93. LCD Signal Waveforms: 1/4 Duty, 1/3 Bias

► **Note:** In Figure 93, $V_{LC0} = V_{LC1}$.

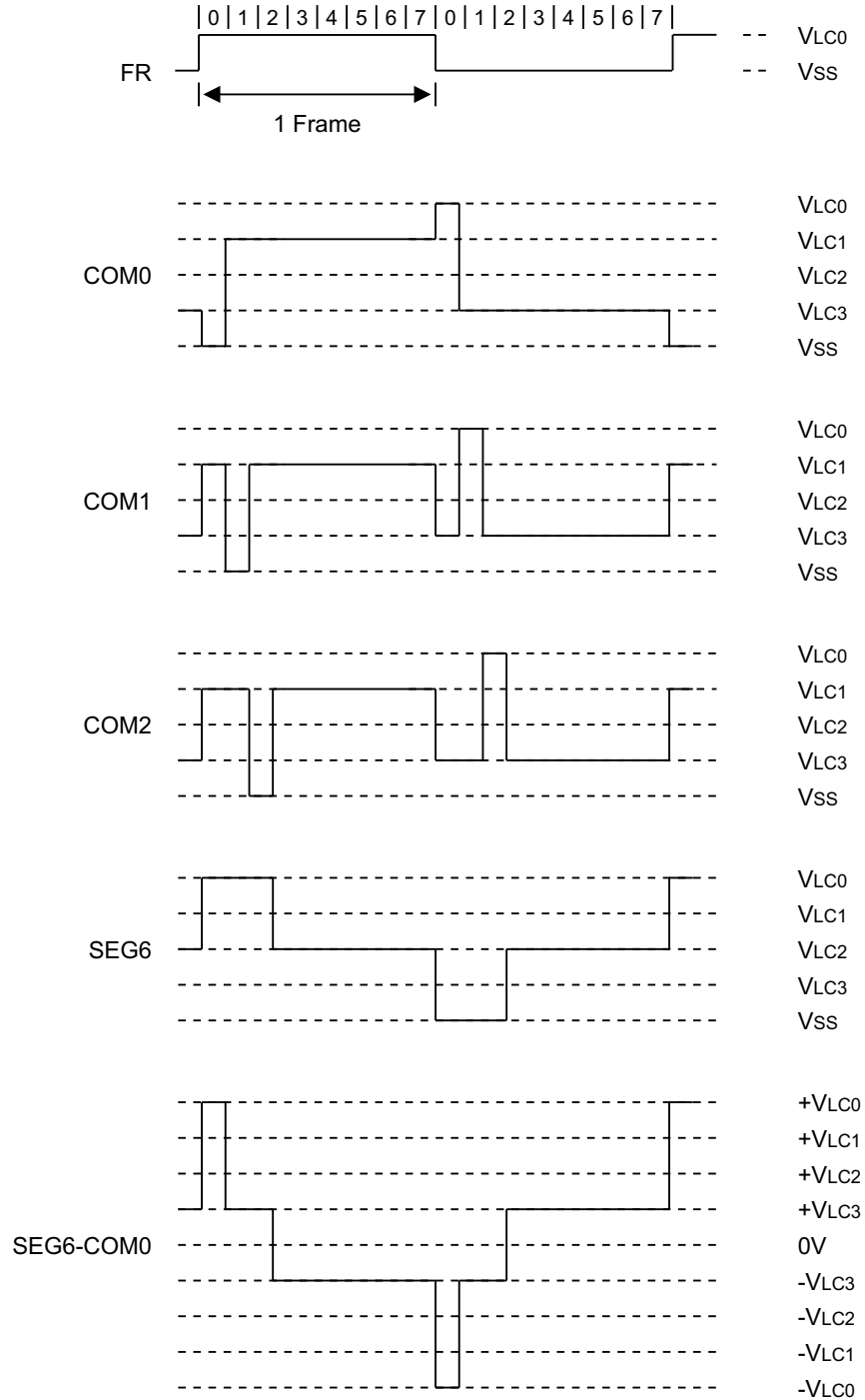
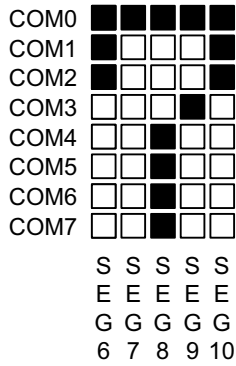


Figure 94. LCD Signal Waveforms: 1/8 Duty, 1/4 Bias, #1 of 2

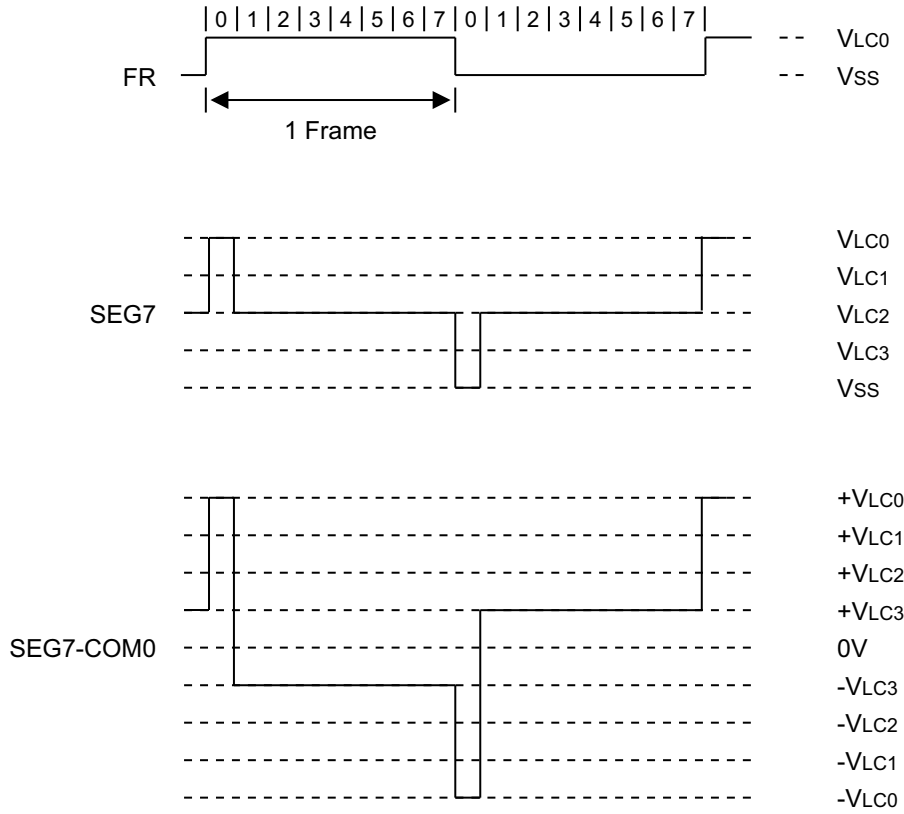


Figure 95. LCD Signal Waveforms: 1/8 Duty, 1/4 Bias, #2 of 2

10-Bit Analog-to-Digital Converter

The 10-bit A/D converter (ADC) module uses successive approximation logic to convert analog levels entering at one of the eight input channels to equivalent 10-bit digital values. The analog input level must lie between the AV_{REF} and V_{SS} values.

The A/D converter features the following components:

- Analog comparator with successive approximation logic
- D/A converter logic (resistor string type)
- ADC Control (ADCON) Register
- Eight multiplexed analog data input pins (AD0–AD7)
- 10-bit A/D conversion data output register (ADDATAH/ADDATAL)
- 8-bit digital input port (alternatively, I/O port)
- AV_{REF} and V_{SS} pins

Function Description

To initiate an analog-to-digital conversion procedure, set the ADCEN signal for ADC input enable at Ports 0/1; the pin set with the alternative function can be used for ADC analog input. Next, write the channel selection data in ADCON.4–.6 to select one of the eight analog input pins (AD0–AD7), then set the conversion start or disable bit, ADCON.0. The read/write ADCON Register (see [Table 76](#) on page 281) is located in Set1, Bank0 at address D2h. The pins that are not used for ADC can be used for normal I/O.

During a normal conversion, ADC logic initially sets the successive approximation register to 200h (the approximate halfway point of a 10-bit register). This register is then updated automatically during each conversion step. The successive approximation block performs 10-bit conversions for one input channel at a time. Different channels can be dynamically selected by manipulating the channel selection bit value (ADCON.6–.4) in the ADCON Register. To start the A/D conversion, set the start bit, ADCON.0. When a conversion is completed, ADCON.3, the end-of-conversion (EOC) bit, is automatically set to 1, and the result is dumped into the ADDATAH/ADDATAL registers (see [Tables 77 and 78 on page 282](#)), where it can be read. The A/D converter then enters an idle state. Remember to read the contents of ADDATAH/ADDATAL before another conversion starts; otherwise, the previous result will be overwritten by the next conversion result.

-
- **Note:** Because the A/D converter has no sample-and-hold circuitry, it is very important that fluctuation in the analog level at the AD0–AD7 input pins during a conversion procedure be kept to an absolute minimum. Any change in the input level, perhaps due to noise, will invalidate the result. If the chip enters the STOP or IDLE modes in this conversion process, there will be a leakage current path in the A/D block. Therefore, use the STOP or IDLE modes after ADC operation is finished.
-

Conversion Timing

The A/D conversion process requires four steps (i.e., 4 clock edges) to convert each bit and 10 clocks to set up an A/D conversion. Therefore, total of 50 clocks are required to complete a 10-bit conversion: When $f_{XX}/8$ is selected for conversion clock with an 8MHz f_{XX} clock frequency, one clock cycle is 1 μ s.

Each bit conversion requires 4 clocks; the conversion rate is calculated as follows:

$$4 \text{ clocks/bit} \times 10 \text{ bits} + \text{set-up time} = 50 \text{ clocks}$$

$$50 \text{ clocks} \times 1 \mu\text{s} = 50 \mu\text{s at } 1 \text{ MHz}$$

A/D Converter Control Register

The A/D Converter Control (ADCON) Register, shown in Table 76, is located at address D2h in Set1, Bank0, and provides the following functions:

- Analog input pin selection (ADCON.6–.4)
- End-of-conversion status detection (ADCON.3)
- ADC clock selection (ADCON.2–.1)
- A/D operation start or disable (ADCON.0)

After a reset, the start bit is turned off; only one analog input channel at a time can be selected. Other analog input pins (AD0–AD7) can be selected dynamically by manipulating the ADCON.4–.6 bits; analog input pins that remain unused can be used for normal I/O functions.

Table 76. A/D Converter Control Register (ADCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R	R/W	R/W	R/W
Address	D2h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	Reserved; Always Logic 0
[6:4]	A/D Input Pin Selection Bits 000: AD0. 001: AD1. 010: AD2. 011: AD3. 100: AD4. 101: AD5. 110: AD6. 111: AD7.
[3]	End-of-Conversion Bit (Read Only) 0: Conversion not complete. 1: Conversion complete.
[2:1]	Clock Source Selection Bits 00: $f_{XX}/16$. 01: $f_{XX}/8$. 10: $f_{XX}/4$. 11: $f_{XX}/1$.
[0]	Start or Disable Bit 0: Disable operation. 1: Start operation.

A/D Converter Data Registers

The contents of the A/D Converter Data High and Low Byte (ADDATAH/ADDATA) Register are shown in Tables 77 and 78.

Table 77. A/D Converter Data High Byte Register (ADDATAH; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R	R	R	R	R	R	R	R
Address	D0h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Table 78. A/D Converter Control Register (ADDATA; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R	R	R	R	R	R	R	R
Address	D1h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Internal Reference Voltage Levels

In the ADC function block, the analog input voltage level is compared to the reference voltage. This voltage level must remain within the V_{SS} -to- AV_{REF} range; usually, $AV_{REF} \leq V_{DD}$.

Different reference voltage levels are generated internally along the resistor tree during the analog conversion process for each conversion step. The reference voltage level for the first conversion bit is always $1/2 AV_{REF}$.

Figure 96 presents a block diagram of the A/D Converter function.

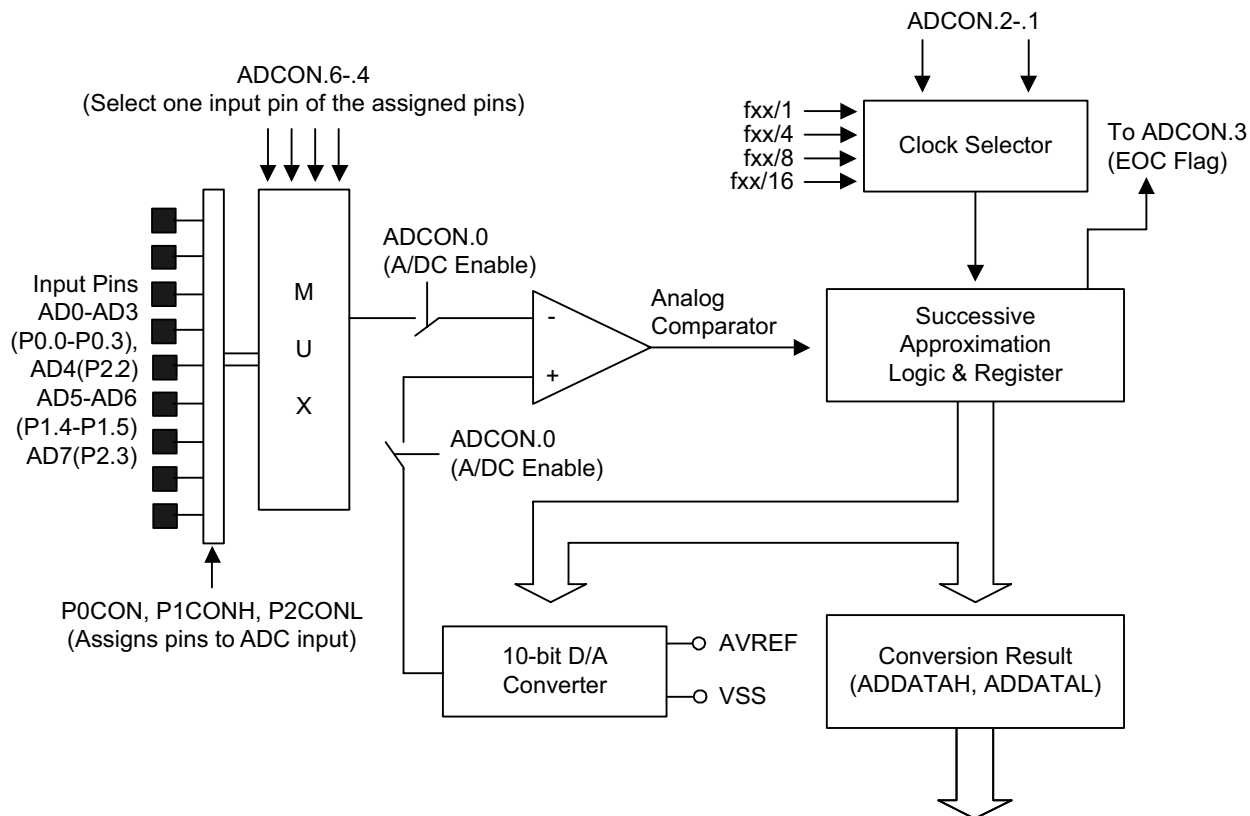


Figure 96. A/D Converter Functional Block Diagram

Figure 97 presents a diagram of the recommended A/D Converter circuit.

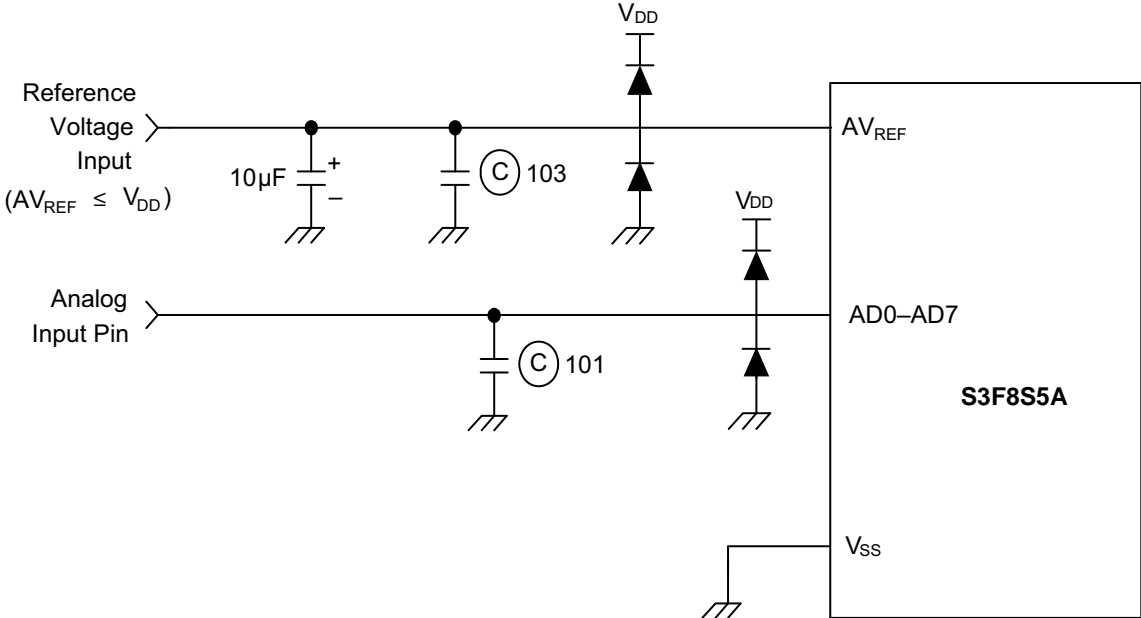


Figure 97. Recommended A/D Converter Circuit for Highest Absolute Accuracy

Serial I/O Interface

The serial I/O (SIO) module can interface with various types of external devices that require serial data transfers. The components of each SIO function block are:

- 8-bit control register (SIOCON)
- Clock selector logic
- 8-bit data buffer (SIODATA)
- 8-bit prescaler (SIOPS)
- 3-bit serial clock counter
- Serial data I/O pins (SI, SO)
- Serial clock input/output pins (SCK)

The SIO module can transmit or receive 8-bit serial data at a frequency determined by its corresponding control register settings. To ensure flexible data transmission rates, you can select an internal or external clock source.

Programming Procedure

To program the SIO modules, observe the following basic steps:

1. Configure the I/O pins at port (SO, SCK, SI) by loading the appropriate value to the P2CONH and P2CONL registers, if necessary.
2. Load an 8-bit value to the SIOCON Control Register to properly configure the serial I/O module. In this operation, SIOCON.2 must be set to 1 to enable the data shifter.
3. For interrupt generation, set the serial I/O interrupt enable bit (SIOCON.1) to 1.
4. When transmitting data to the serial buffer, write data to SIODATA and set SIOCON.3 to 1; the shift operation starts.
5. When the shift operation (transmit/receive) is completed, the SIO pending bit (SIOCON.0) is set to 1 and an SIO interrupt request is generated.

SIO Control Register

The control register for the serial I/O interface module, SIOCON, shown in Table 79, is located at E7h in Set1, Bank0. This register provides the following control settings for the SIO module:

- Clock source selection (internal or external) for shift clock
- Interrupt enable
- Edge selection for shift operation
- Clear 3-bit counter and start shift operation
- Shift operation (transmit) enable
- Mode selection (transmit/receive or receive-only)
- Data direction selection (MSB-first or LSB-first)

Table 79. SIO Control Register (SIOCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	E7h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	SIO Shift Clock Selection Bit 0: Internal clock (P.S clock). 1: External clock (SCK).
[6]	Data Direction Control Bit 0: MSB-First Mode. 1: LSB-First Mode.
[5]	SIO Mode Selection Bit 0: Receive-Only Mode. 1: Transmit/Receive Mode.
[4]	Shift Clock Edge Selection Bit 0: Tx at falling edges; Rx at rising edges. 1: Tx at rising edges, Rx at falling edges.
[3]	SIO Counter Clear and Shift Start Bit 0: No action. 1: Clear 3-bit counter and start shifting.
[2]	SIO Shift Operation Enable Bit 0: Disable shifter and clock counter. 1: Enable shifter and clock counter.

Bit	Description (Continued)
[1]	SIO Interrupt Enable Bit 0: Disable SIO interrupt. 1: Enable SIO interrupt.
[0]	SIO Interrupt Pending Bit 0: No interrupt is pending when read; clear pending condition when write. 1: Interrupt is pending.

A reset clears the SIOCON value to 00h, thereby configuring the corresponding module with an internal clock source at the SCK, selecting a receive-only operating mode, and clearing the 3-bit counter. The data shift operation and the interrupt are disabled. The selected data direction is MSB-first.

SIO Prescaler Register

The control register for the serial I/O interface module, SIOPS, is located at E9h in Set1, Bank0. The value stored in this SIOPS Register lets you determine the SIO clock rate (baud rate) as follows:

$$\text{Baud rate} = \text{Input clock } (f_{XX}/4) / (\text{Prescaler value} + 1), \text{ or SCK input clock, in which the input clock is } f_{XX}/4$$

The contents of the SIO Prescaler (SIOPS) Register are shown in Table 80.

Table 80. SIO Prescaler Register (SIOPS; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Address	E9h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	SIO Prescaler Configuration Bits Baud rate = $(f_{XX} / 4) / (\text{SIOPS} + 1)$.

Figure 98 presents a block diagram of the SIO function.

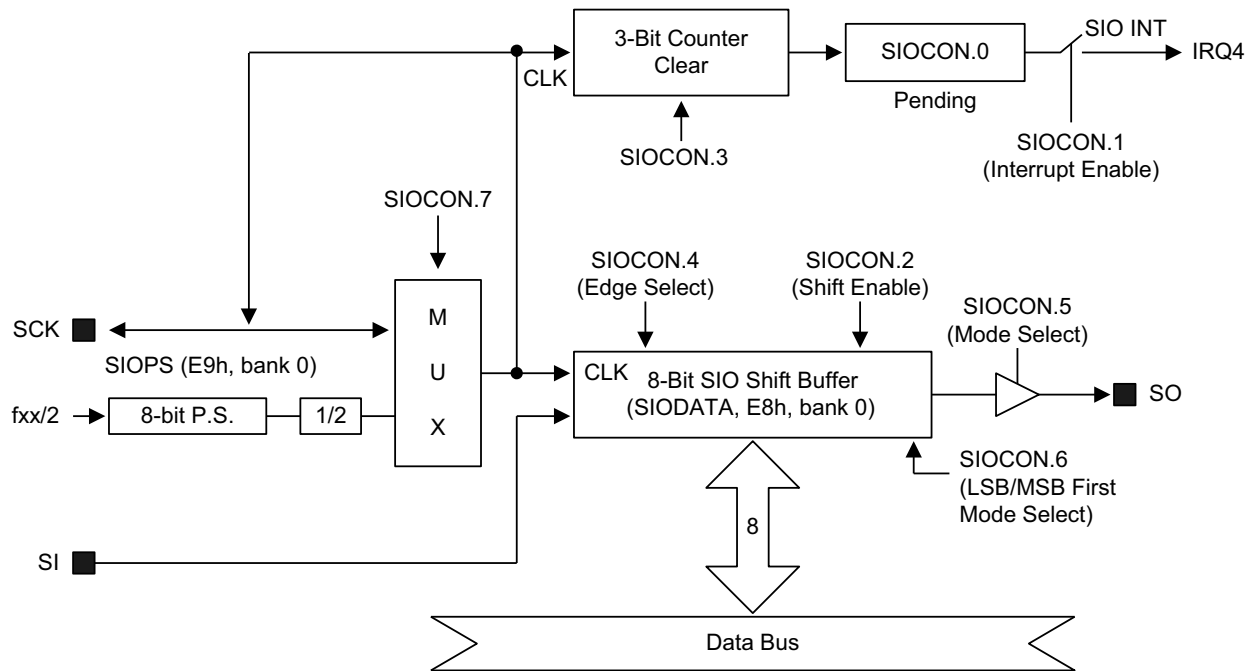


Figure 98. SIO Functional Block Diagram

SIO Serial Timing

Figure 99 presents a timing diagrams for Transmit/Receive Mode operation at the falling edge.

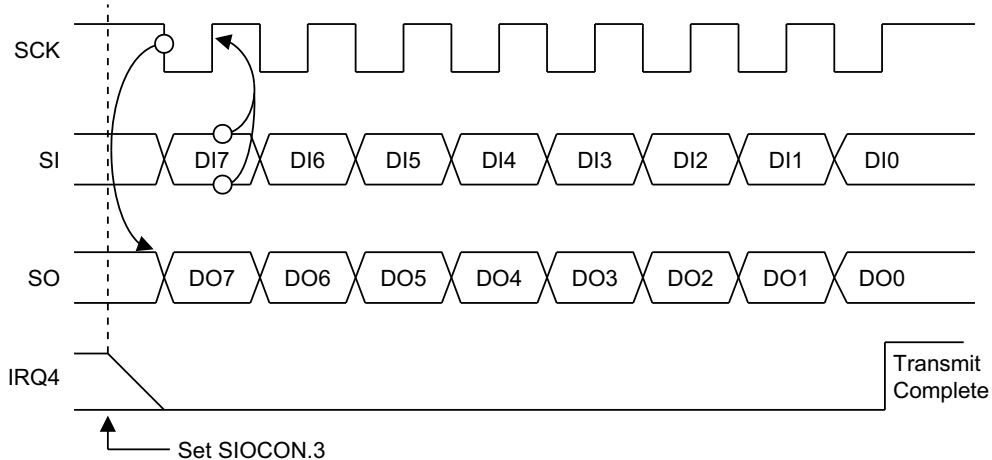


Figure 99. Serial I/O Timing in Transmit/Receive Mode (T_x at Falling Edge; SIOCON.4 = 0)

Figure 100 presents a timing diagrams for Transmit/Receive Mode operation at the falling edge.

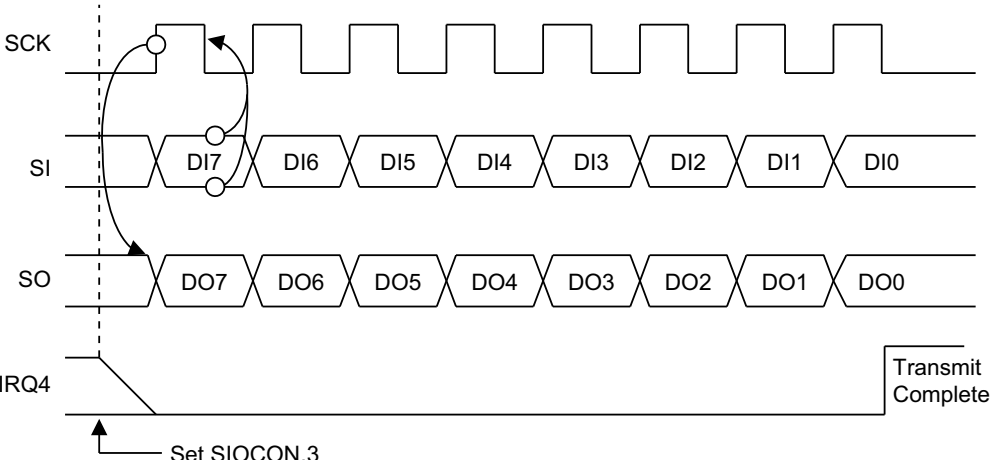


Figure 100. Serial I/O Timing in Transmit/Receive Mode (T_x at at Rising Edge; SIOCON.4 = 1)

UART0

The UART0 block features a full-duplex serial port with the following four programmable operating modes – one synchronous mode and three Universal Asynchronous Receiver/Transmitter (UART) modes:

- Serial I/O with baud rate of $f_U/(16 \times (\text{BRDATA0}+1))$
- 8-bit UART Mode; variable baud rate
- 9-bit UART Mode; $f_U/16$
- 9-bit UART Mode, variable baud rate

The UART0 receive and transmit buffers are both accessed via the UDATA0 Data Register, and are located in Set1, Bank0 at address F0h. Writing to the UART data register loads the transmit buffer; reading the UART0 data register accesses a physically separate receive buffer.

When accessing a receive data buffer (i.e., the shift register), reception of the next byte can begin before the previously received byte has been read from the receive register. However, if the first byte has not been read by the time the next byte has been completely received, one of the bytes will be lost.

In all operating modes, transmission begins when any instruction (usually a write operation) uses the UDATA0 Register as its destination address. In Mode 0, serial data reception starts when the receive interrupt pending bit (UART0CONH.0) is 0 and the receive enable bit (UART0CONH.4) is 1. In modes 1, 2, and 3, reception starts whenever an incoming start bit (0) is received and the receive enable bit (UART0CONH.4) is set to 1.

Programming Procedure

To program the UART0 modules, observe the following basic steps:

1. Configure P2.6 and P2.7 to alternative function (RxD0 (P2.6), TxD0 (P2.7)) for the UART0 module by setting the P2CONH Register to the appropriate value.
2. Load an 8-bit value to the UART0CONH/UART0CONL control registers to properly configure the UART0 I/O module.
3. For interrupt generation, set the UART0 I/O interrupt enable bit (UART0CONH.1 or UART0CONL.1) to 1.
4. When you transmit data to the UART0 buffer, the data is written to UDATA0, and the shift operation starts.

5. When the shift operation (receive/transmit) is completed, the UART0 pending bit (UART0CONH.0 or UART0CONL.0) is set to 1 and a UART0 interrupt request is generated.

UART0 High-Byte Control Register

The high-byte control register for UART0 is called UART0CONH, and is shown in Table 81. The UART0CONH Register is located at Set1, Bank0 at address EEh, and provides the following control functions:

- Operating mode and baud rate selection
- Multiprocessor communication and interrupt control
- Serial receive enable/disable control
- 9th data bit location for transmit and receive operations (modes 2 and 3 only)
- UART0 receive interrupt control

A reset clears the UART0CONH value to 00h. Therefore, to use the UART0 module, write the appropriate value to UART0CONH.

Table 81. UART0 Control High Byte Register (UART0CONH; Set1,

Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					EEh			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6] MS1:MS0	UART0 Mode Selection Bits¹ 00: Mode 0: Shift Register ($f_U/(16 \times (BRDATA0 + 1))$). 01: Mode 1: 8-bit UART ($f_U/(16 \times (BRDATA0 + 1))$). 10: Mode 2: 9-bit UART ($f_U/16$). 11: Mode 3: 9-bit UART ($f_U/(16 \times (BRDATA0 + 1))$).
[5]	Multiprocessor Communication Enable Bit (modes 2 and 3 only)² 0: Disable. 1: Enable.
[4]	Serial Data Receive Enable Bit 0: Disable. 1: Enable.
[3]	TB8 (only when UART0CONL.7 = 0)³ Location of the 9th data bit to be transmitted in UART0 Mode 2 or 3 (i.e., 0 or 1).
[2]	RB8 (only when UART0CONL.7 = 0)³ Location of the 9th data bit to be received in UART0 Mode 2 or 3 (i.e., 0 or 1).
[1]	UART0 Receive Interrupt Enable Bit 0: Disable Rx interrupt. 1: Enable Rx interrupt.
[0]	UART0 Receive Interrupt Pending Bit 0: No interrupt pending (when read); clear pending bit (when write). 1: Interrupt is pending (when read).

Notes:

1. The descriptions for the 8-bit and 9-bit UART modes do not include start and stop bits for the serial data receive and transmit operations.
2. In modes 2 and 3, if the MCE bit is set to 1, then the receive interrupt will not be activated if the received 9th data bit is 0. In mode 1, if MCE = 1, then the receive interrupt will not be activated if a valid stop bit was not received. In Mode 0, the MCE bit should be 0.
3. If UART0CONL.7 = 1, this bit is a *don't care*.

UART0 Low-Byte Control Register

The low-byte control register for UART0 is called UART0CONL, and is shown in Table 82. The UART0CONL Register is located at Set1, Bank0 at address EFh, and provides the following control functions:

- UART0 transmit and receive parity-bit selection
- UART0 clock selection
- UART0 transmit interrupt control

A reset clears the UART0CONL value to 00h. Therefore, to use UART0 module, write the appropriate value to UART0CONL.

Table 82. UART0 Control Low Byte Register (UART0CONL; Set1,

Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					EFh			
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								
Bit	Description							
[7]	UART0 Transmit Parity Autogeneration Enable Bit (modes 2 and 3 only)¹ 0: Disable parity bit autogeneration. 1: Enable parity bit autogeneration.							
[6]	UART0 Transmit Parity Selection Bit (modes 2 and 3 only)^{1,2} 0: Even parity bit. 1: Odd parity bit.							
[5]	UART0 Receive Parity Selection Bit (modes 2 and 3 only)^{1,2} 0: Even parity bit check. 1: Odd parity bit check.							
[4]	UART0 Receive Parity Error Status Bit (modes 2 and 3 only)^{1,2} 0: No parity bit error. 1: Parity bit error.							
[3:2]	UART0 Clock Selection Bits 00: $f_{XX}/8$. 01: $f_{XX}/4$. 10: $f_{XX}/2$. 11: $f_{XX}/1$.							
[1] TIE	UART0 Transmit Interrupt Enable Bit 0: Disable Tx interrupt. 1: Enable Tx interrupt.							
[0] TIP	UART0 Transmit Interrupt Pending Bit 0: No interrupt pending (when read); clear pending bit (when write). 1: Interrupt is pending (when read).							
Notes:								
1. UART0CONL bits in the range .7–.4 are for modes 2 and 3 only.								
2. If UART0CONL.7 = 0, this bit is a <i>don't care</i> .								

UART0 Interrupt Pending bits

In Mode 0, the receive interrupt pending bit, UART0CONH.0, is set to 1 when the 8th receive data bit has been shifted. In Mode 1, the UART0CONH.0 bit is set to 1 at the half-way point of the stop bit's shift time. In modes 2 or 3, the UART0CONH.0 bit is set to 1 at

the halfway point of the RB8 bit's shift time. When the CPU has acknowledged the receive interrupt pending condition, the UART0CONH.0 bit must then be cleared by software in the interrupt service routine.

In Mode 0, the transmit interrupt pending bit UART0CONL.0 is set to 1 when the 8th transmit data bit has been shifted. In modes 1, 2, or 3, the UART0CONL.0 bit is set at the start of the stop bit. When the CPU has acknowledged the transmit interrupt pending condition, the UART0CONL.0 bit must then be cleared by software in the interrupt service routine.

UART0 Data Register

The UART0 Data (UDATA0) Register is shown in Table 83.

Table 83. UART0 Data Register (UDATA0; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	F0h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	UART0 Data Register Configuration Bits Transmit or Receive data.

UART0 Baud Rate Data Register

The value stored in the UART0 Baud Rate Data (BRDATA0) Register, shown in Table 84, lets you determine the UART0 clock rate (baud rate).

Table 84. UART0 Baud Rate Data Register (BRDATA0; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	F1h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	UART0 Baud Rate Data Register Configuration Bits Transmit or Receive data.

UART0 Baud Rate Calculations

Baud rate calculations for UART0 modes 0 to 3 are described in this section.

Mode 0 Baud Rate Calculation

In Mode 0, the baud rate is determined by the UART0 Baud Rate Data (BRDATA0) Register, which is located at Set1, Bank0 at address F1h. The calculation for this baud rate is:

$$\text{Mode 0 baud rate} = f_U / (16 \times (\text{BRDATA0} + 1))$$

Mode 2 Baud Rate Calculation

The baud rate in Mode 2 is fixed at the f_U clock frequency divided by 16, as follows:

$$\text{Mode 2 baud rate} = f_U / 16$$

Modes 1 and 3 Baud Rate Calculation

In modes 1 and 3, the baud rate is determined by the UART0 Baud Rate Data (BRDATA0) Register, which is located at Set1, Bank0 at address F1h. The calculation for this baud rate is:

$$\text{Mode 1 and 3 baud rate} = f_U / (16 \times (\text{BRDATA0} + 1))$$

Table 85 presents a matrix of commonly used baud rates generated by BRDATA0.

Table 85. Commonly Used Baud Rates Generated by BRDATA0

Mode	Baud Rate	UART Clock (f_U)	BRDATA0	
			Decimal	Hexadecimal
Mode 2	0.5 MHz	8MHz	x	x
	230,400Hz	11.0592MHz	02	02h
	115,200Hz	11.0592 MHz	05	05h
	57,600Hz	11.0592 MHz	11	0Bh
	38,400Hz	11.0592MHz	17	11h
	19,200Hz	11.0592MHz	35	23h
	9,600Hz	11.0592MHz	71	47h
Mode 0	4,800Hz	11.0592MHz	143	8Fh
Mode 1	62,500Hz	10MHz	09	09h
	9,615Hz	10MHz	64	40h
	38,461Hz	8MHz	12	0Ch
	12,500Hz	8MHz	39	27h
	19,230Hz	4MHz	12	0Ch
	9,615Hz	4MHz	25	19h

Figure 101 presents a block diagram of the UART0 function.

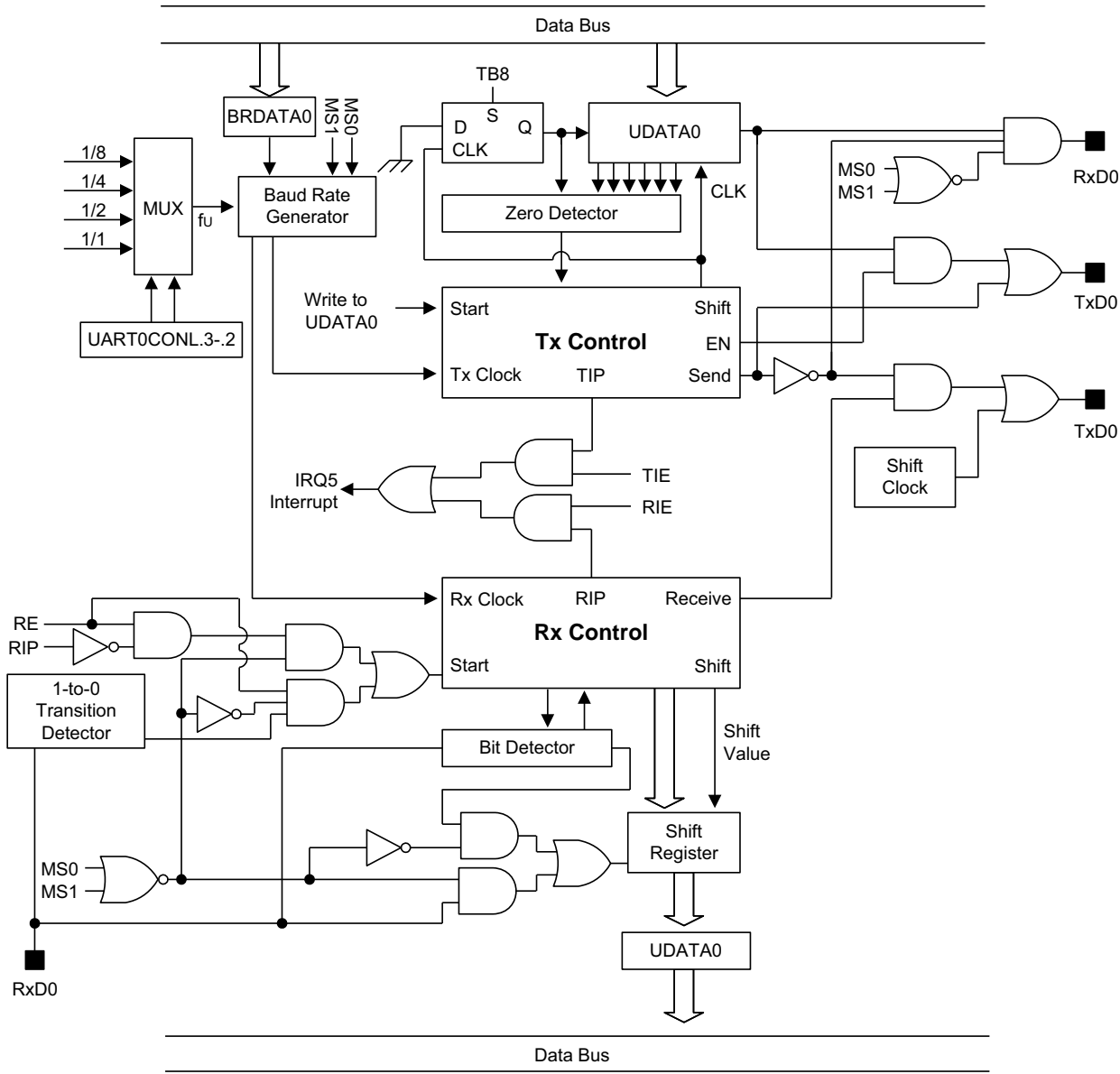


Figure 101. UART0 Functional Block Diagram

UART0 Mode 0 Function Description

In Mode 0, UART0 is input and output through the RxD0 (P2.6) pin, and the TxD0 (P2.7) pin outputs the shift clock. Data is transmitted or received in 8-bit units only. The LSB of the 8-bit value is transmitted (or received) first.

Mode 0 Transmit Procedure

Observe the following procedure to write transmission data via UART0 in Mode 0.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Clear the UART0 transmit parity-bit autogeneration enable bit, UART0CONL.7.
3. Select Mode 0 by setting UART0CONH.7 and .6 to 00b.
4. Write the transmission data to the UDATA0 Shift Register (F0h, Set1, Bank0) to start the transmission operation.

Mode 0 Receive Procedure

Observe the following procedure to read receive data via UART0 in Mode 0.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Clear the UART0 transmit parity-bit autogeneration enable bit, UART0CONL.7.
3. Select Mode 0 by setting UART0CONH.7 and .6 to 00b.
4. Clear the receive interrupt pending bit, UART0CONH.0, by writing a 0 to UART0CONH.0.
5. Set the UART0 receive enable bit, UART0CONH.4, to 1.
6. The shift clock will now be output to the TxD0 (P2.7) pin and will read the data at the RxD0 (P2.6) pin. A UART0 receive interrupt occurs when UART0CONH.1 is set to 1.

Figure 102 shows the timing of the Serial Port Mode 0 operation.

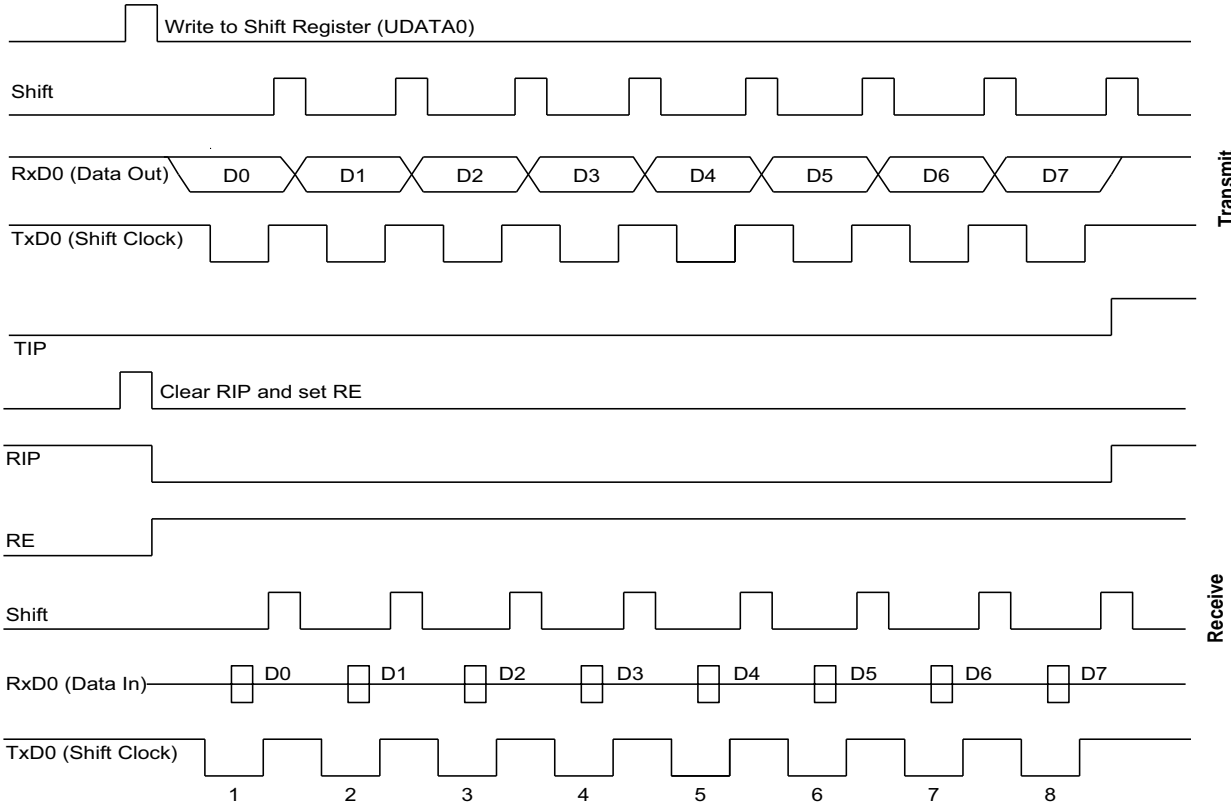


Figure 102. UART0 Serial Port Mode 0 Timing

Serial Port Mode 1 Function Description

In Mode 1, 10 bits are transmitted through the TxD0 (P2.7) pin or received through the RxD0 (P2.6) pin. Each data frame provides three components:

- Start bit (0)
- 8 data bits (LSB first)
- Stop bit (1)

The baud rate for Mode 1 is variable.

Mode 1 Transmit Procedure

Observe the following procedure to write transmission data via UART0 in Mode 1.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Clear the UART0 transmit parity-bit autogeneration enable bit (UART0CONL.7).
3. Select the baud rate to be generated by BRDATA0.
4. Select Mode 1 (8-bit UART) by setting UART0CONH bits 7 and 6 to 01b.
5. Write transmission data to the UDATA0 Shift Register (F0h, Set1, Bank0). The start and stop bits are generated automatically by hardware.

Mode 1 Receive Procedure

Observe the following procedure to read receive data via UART0 in Mode 1.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Clear the UART0 transmit parity-bit autogeneration enable bit, UART0CONL.7.
3. Select the baud rate to be generated by BRDATA0.
4. Select Mode 1 and set the Receive Enable (RE) bit in the UART0CONH Register to 1.
5. The start bit Low (0) condition at the RxD0 (P2.6) pin will cause the UART0 module to start the serial data receive operation.

Figure 103 shows the timing of the Serial Port Mode 1 operation.

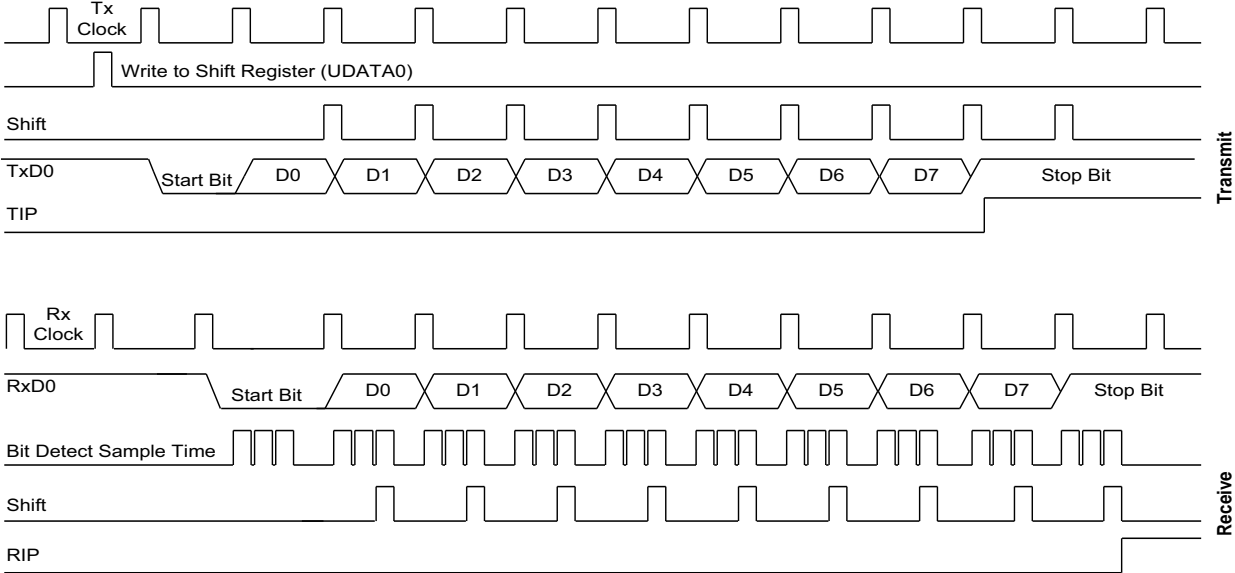


Figure 103. UART0 Serial Port Mode 1 Timing

Serial Port Mode 2 Function Description

In Mode 2, 11 bits are transmitted through the TxD0 (P2.7) pin or received through the RxD0 (P2.6) pin. Each data frame features the following four components:

- Start bit (0)
- 8 data bits (LSB first)
- Programmable 9th data bit
- Stop bit (1)

The 9th data bit to be transmitted can be assigned a value of 0 or 1 by writing the TB8 bit, UART0CONH.3. When receiving, the 9th data bit that is received is written to the RB8 bit, UART0CONH.2, while the stop bit is ignored. The baud rate for mode 2 is $f_U/16$ clock frequency.

Mode 2 Transmit Procedure

Observe the following procedure to write transmission data via UART0 in Mode 2.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Select the UART0 transmit parity-bit autogeneration enable or disable (UART0CONL.7).
3. Select Mode 2 (9-bit UART) by setting UART0CONH bits 7 and 6 to 10b. Additionally, select the 9th data bit to be transmitted by writing TB8 to 0 or 1.
4. Write the transmission data to the UDATA0 Shift Register (F0h, Set1, Bank0) to start the transmit operation.

Mode 2 Receive Procedure

Observe the following procedure to read receive data via UART0 in Mode 2.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Select the UART0 transmit parity-bit autogeneration enable or disable (UART0CONL.7).
3. Select Mode 2 and set the receive enable bit (RE) in the UART0CONH Register to 1.
4. The receive operation starts when the signal at the RxD0 (P2.6) pin goes Low.

Figure 104 shows the timing of the Serial Port Mode 2 operation.

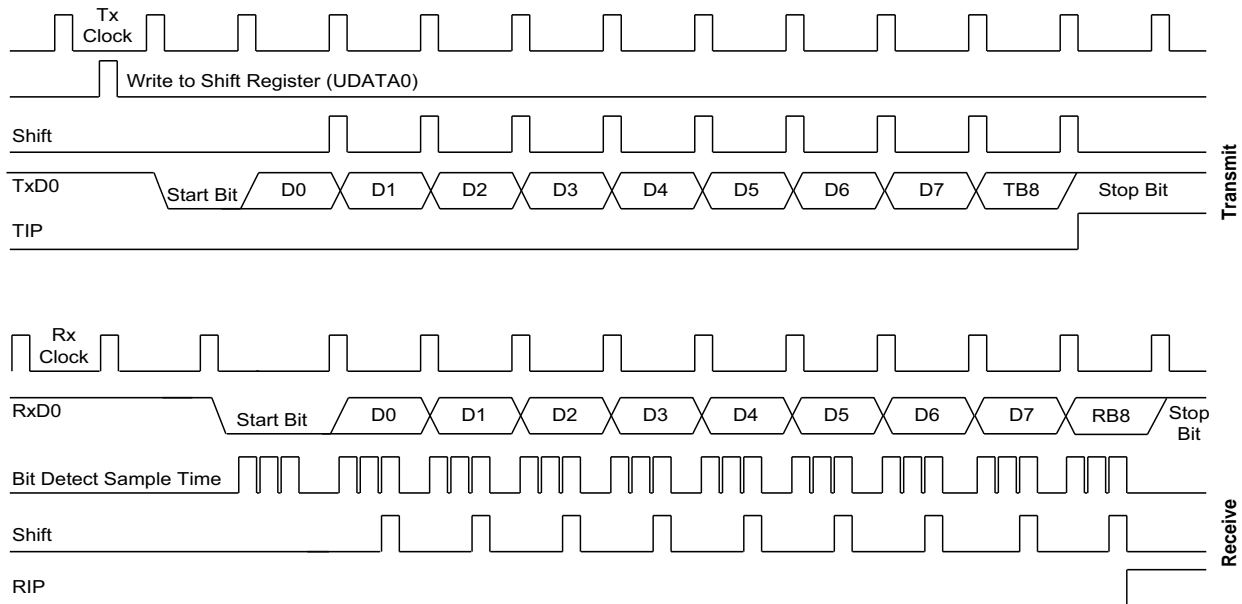


Figure 104. UART0 Serial Port Mode 2 Timing

Serial Port Mode 3 Function Description

In Mode 3, 11 bits are transmitted through the TxD0 (P2.7) pin or received through the RxD0 (P2.6) pin. Mode 3 is identical to Mode 2 except for the baud rate, which is variable. Each data frame features the following four components:

- Start bit (0)
- 8 data bits (LSB first)
- Programmable 9th data bit
- Stop bit (1)

Mode 3 Transmit Procedure

Observe the following procedure to write transmission data via UART0 in Mode 3.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Select the UART0 transmit parity-bit autogeneration enable or disable (UART0CONL.7).

3. Select Mode 3 operation (9-bit UART) by setting UART0CONH bits 7 and 6 to 11b. Additionally, select the 9th data bit to be transmitted by writing UART0CONH.3 (TB8) to 0 or 1.
4. Write transmission data to the UDATA0 Shift Register (F0h, Set1, Bank0), to start the transmit operation.

Mode 3 Receive Procedure

Observe the following procedure to read receive data via UART0 in Mode 3.

1. Select the UART0 clock, UART0CONL.3 and .2.
2. Select the UART0 transmit parity-bit autogeneration enable or disable (UART0CONL.7).
3. Select Mode 3 and set the Receive Enable (RE) bit in the UART0CONH Register to 1.
4. The receive operation will be started when the signal at the RxD0 (P2.6) pin goes Low.

Figure 105 shows the timing of the Serial Port Mode 3 operation.

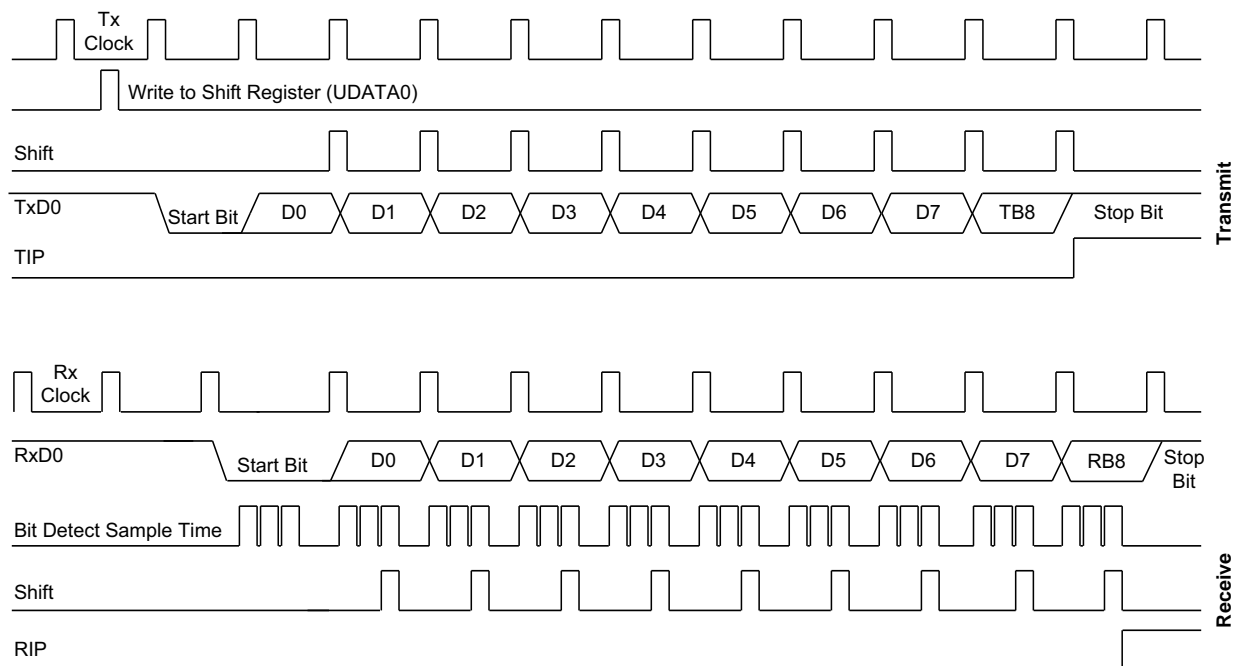


Figure 105. UART0 Serial Port Mode 3 Timing

Serial Communication for Multiprocessor Configurations

The S3F8 Series multiprocessor communication features lets a *master* S3F8S5A MCU send a multiple-frame serial message to a *slave* device in a multi-S3F8S5A configuration without interrupting other slave devices that may be on the same serial line. This feature can be used only in UART modes 2 or 3. In these two modes, 9 data bits are received. The 9th bit value is written to RB8 (UART0CONH.2). The data receive operation is concluded with a stop bit. This function can be programmed such that when the stop bit is received, the serial interrupt will be generated only if RB8 = 1.

To enable this feature, set the MCE bit in the UART0CONH Register. When the MCE bit is 1, serial data frames that are received with the 9th bit = 0 do not generate an interrupt. In this case, the 9th bit simply separates the address from the serial data.

Sample Protocol for Master/Slave Interaction

When the master device transmits a block of data to one of several slaves on a serial line, it first sends out an address byte to identify the target slave. Note that in this case, an address byte differs from a data byte; in an address byte, the 9th bit is 1, and in a data byte, it is 0.

The address byte interrupts all slaves so that each slave can examine the received byte and determine if it is being addressed. The addressed slave then clears its MCE bit and prepares to receive incoming data bytes.

The MCE bits of slaves that were not addressed remain set, and they continue operating normally while ignoring the incoming data bytes.

While the MCE bit setting has no effect in Mode 0, it can be used in Mode 1 to check the validity of the stop bit. For Mode 1 reception, if MCE is 1, the receive interrupt will be issue unless a valid stop bit is received.

Setup Procedure for Multiprocessor Communications

Observe the following steps to configure multiprocessor communications.

1. Set all S3F8S5A devices (masters and slaves) to UART0 Mode 2 or 3.
2. Write the MCE bit of all the slave devices to 1.
3. The master device's transmission protocol is:
 - First byte: the address identifying the target slave device (9th bit = 1)
 - Next bytes: data (9th bit = 0)

- 4. When the target slave receives the first byte, all of the slaves are interrupted because the 9th data bit is 1. The targeted slave compares the address byte to its own address and then clears its MCE bit to receive incoming data. The other slaves continue operating normally.

Figure 106 shows an example of multiprocessor serial data communications.

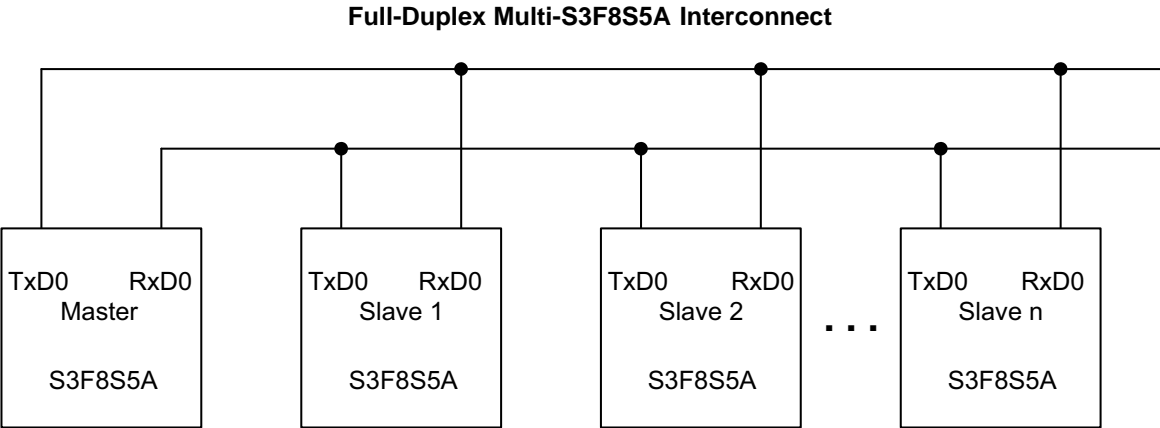


Figure 106. UART0 Multiprocessor Serial Data Communications Example

UART1

The UART1 block features a full-duplex serial port with the following four programmable operating modes – one synchronous mode and three Universal Asynchronous Receiver/Transmitter (UART) modes:

- Serial I/O with baud rate of $f_U/(16 \times (\text{BRDATA1}+1))$
- 8-bit UART Mode; variable baud rate
- 9-bit UART Mode; $f_U/16$
- 9-bit UART Mode, variable baud rate

The UART1 receive and transmit buffers are both accessed via the UDATA1 Data Register, and are located in Set1, Bank0 at address F4h. Writing to the UART1 Data Register loads the transmit buffer; reading the UART1 Data Register accesses a physically separate receive buffer.

When accessing a receive data buffer (i.e., the shift register), reception of the next byte can begin before the previously received byte has been read from the receive register. However, if the first byte has not been read by the time the next byte has been completely received, one of the bytes will be lost.

In all operating modes, transmission is started when any instruction (usually a write operation) uses the UDATA1 Register as its destination address. In Mode 0, serial data reception starts when the receive interrupt pending bit (UART1CONH.0) is 0 and the receive enable bit (UART1CONH.4) is 1. In modes 1, 2, and 3, reception starts whenever an incoming start bit (0) is received and the receive enable bit (UART1CONH.4) is set to 1.

Programming Procedure

To program the UART1 modules, observe the following basic steps.

1. Configure P3.6 and P3.7 to alternative function (RxD1 (P3.6), TxD1 (P3.7)) for the UART1 module by setting the P3CONH Register to an appropriate value.
2. Load an 8-bit value to the UART1CONH/UART1CONL control registers to properly configure the UART1 I/O module.
3. For interrupt generation, set the UART1 I/O interrupt enable bit (UART1CONH.1 or UART1CONL.1) to 1.
4. When transmitting data to the UART1 buffer, write the data to UDATA1; the shift operation starts.

5. When the shift operation (receive/transmit) is completed, the UART1 pending bit (UART1CONH.0 or UART1CONL.0) is set to 1 and an UART1 interrupt request is generated.

UART1 High-Byte Control Register

The control register for UART1 is called UART1CONH, and is shown in Table 86. The UART1CONH Register is located in Set1, Bank0 at address F2h, and provides the following control functions:

- Operating mode and baud rate selection
- Multiprocessor communication and interrupt control
- Serial receive enable/disable control
- 9th data bit location for transmit and receive operations (modes 2 and 3 only)
- UART1 receive interrupt control

A reset clears the UART1CONH value to 00h. Therefore, to use the UART1 module, write the appropriate value to UART1CONH.

Table 86. UART1 Control High Byte Register (UART1CONH; Set1,

Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	F2h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6] MS1:MS0	UART1 Mode Selection Bits¹ 00: Mode 0: Shift Register ($f_U/(16 \times (BRDATA1 + 1))$). 01: Mode 1: 8-bit UART ($f_U/(16 \times (BRDATA1 + 1))$). 10: Mode 2: 9-bit UART ($f_U/16$). 11: Mode 3: 9-bit UART ($f_U/(16 \times (BRDATA1 + 1))$).
[5]	Multiprocessor Communication Enable Bit (modes 2 and 3 only)² 0: Disable. 1: Enable.
[4]	Serial Data Receive Enable Bit 0: Disable. 1: Enable.

Bit	Description (Continued)
[3]	TB8 (only when UART1CONL.7 = 0)³ Location of the 9th data bit to be transmitted in UART1 Mode 2 or 3 (i.e., 0 or 1).
[2]	RB8 (only when UART1CONL.7 = 0)³ Location of the 9th data bit to be received in UART1 Mode 2 or 3 (i.e., 0 or 1).
[1]	UART1 Receive Interrupt Enable Bit 0: Disable Rx interrupt. 1: Enable Rx interrupt.
[0]	UART1 Receive Interrupt Pending Bit 0: No interrupt pending (when read); clear pending bit (when write). 1: Interrupt is pending (when read).

Notes:

1. The descriptions for the 8-bit and 9-bit UART modes do not include start and stop bits for the serial data receive and transmit operations.
2. In modes 2 and 3, if the MCE bit is set to 1, then the receive interrupt will not be activated if the received 9th data bit is 0. In mode 1, if MCE = 1, then the receive interrupt will not be activated if a valid stop bit was not received. In Mode 0, the MCE bit should be 0.
3. If UART1CONL.7 = 1, this bit is a *don't care*.

UART1 Low-Byte Control Register

The control register for the UART1 is called UART1CONL, shown in Table 87. The UART1CONL Register is located in Set1, Bank0 at address F3h, and provides the following control functions:

- UART1 transmit and receive parity-bit selection
- UART1 clock selection
- UART1 transmit interrupt control

A reset clears the UART1CONL value to 00h. Therefore, to use the UART1 module, write the appropriate value to UART1CONL.

Table 87. UART1 Control Low Byte Register (UART1CONL; Set1,

Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address	F3h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7]	UART1 Transmit Parity Autogeneration Enable Bit (modes 2 and 3 only)¹ 0: Disable parity bit autogeneration. 1: Enable parity bit autogeneration.
[6]	UART1 Transmit Parity Selection Bit (modes 2 and 3 only)^{1,2} 0: Even parity bit. 1: Odd parity bit.
[5]	UART1 Receive Parity Selection Bit (modes 2 and 3 only)^{1,2} 0: Even parity bit check. 1: Odd parity bit check.
[4]	UART1 Receive Parity Error Status Bit (modes 2 and 3 only)^{1,2} 0: No parity bit error. 1: Parity bit error.
[3:2]	UART1 Clock Selection Bits 00: $f_{XX}/8$. 01: $f_{XX}/4$. 10: $f_{XX}/2$. 11: $f_{XX}/1$.
[1]	UART1 Transmit Interrupt Enable Bit 0: Disable Tx interrupt. 1: Enable Tx interrupt.
[0]	UART1 Transmit Interrupt Pending Bit 0: No interrupt pending (when read); clear pending bit (when write). 1: Interrupt is pending (when read).

Notes:

1. UART1CONL.bits in the range .7–.4 are for modes 2 and 3 only.
2. If UART1CONL.7 = 0, this bit is a *don't care*.

UART1 Interrupt Pending Bits

In Mode 0, the receive interrupt pending bit, UART0CONH.0, is set to 1 when the 8th receive data bit has been shifted. In Mode 1, the UART0CONH.0 bit is set to 1 at the half-way point of the stop bit's shift time. In modes 2 or 3, the UART0CONH.0 bit is set to 1 at

the halfway point of the RB8 bit's shift time. When the CPU has acknowledged the receive interrupt pending condition, the UART0CONH.0 bit must then be cleared by software in the interrupt service routine.

In Mode 0, the transmit interrupt pending bit, UART1CONL.0, is set to 1 when the 8th transmit data bit has been shifted. In modes 1, 2, or 3, the UART1CONL.0 bit is set at the start of the stop bit. When the CPU has acknowledged the transmit interrupt pending condition, the UART1CONL.0 bit must then be cleared by software in the interrupt service routine.

UART1 Data Register

The UART1 Data (UDATA1) Register is shown in Table 88.

Table 88. UART1 Data Register (UDATA1; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					F4h			
Mode					Register Addressing Mode only			

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	UART1 Data Register Configuration Bits Transmit or Receive data.

UART1 Baud Rate Data Register

The value stored in the UART1 Baud Rate Data (BRDATA1) Register, shown in Table 89, lets you determine the UART1 clock (baud) rate.

Table 89. UART1 Baud Rate Data Register (BRDATA1; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					F5h			
Mode					Register Addressing Mode only			

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	UART1 Baud Rate Data Register Configuration Bits Transmit or Receive data.

UART1 Baud Rate Calculations

Baud rate calculations for UART1 modes 0 to 3 are described below.

Mode 0 Baud Rate Calculation

In Mode 0, the baud rate is determined by the UART1 Baud Rate Data (BRDATA1) Register, which is located at Set1, Bank0 at address F5h. The calculation for this baud rate is:

$$\text{Mode 0 baud rate} = f_U / (16 \times (\text{BRDATA1} + 1))$$

Mode 2 Baud Rate Calculation

The baud rate in Mode 2 is fixed at the f_U clock frequency divided by 16, as follows:

$$\text{Mode 2 baud rate} = f_U / 16$$

Modes 1 and 3 Baud Rate Calculation

In modes 1 and 3, the baud rate is determined by the UART1 Baud Rate Data (BRDATA1) Register, which is located at Set1, Bank0 at address F5h. The calculation for this baud rate is:

$$\text{Mode 1 and 3 baud rate} = f_U / (16 \times (\text{BRDATA1} + 1))$$

Table 90 presents a matrix of commonly used baud rates generated by BRDATA1.

Table 90. Commonly Used Baud Rates Generated by BRDATA1

Mode	Baud Rate	UART Clock (f_U)	BRDATA1	
			Decimal	Hexadecimal
Mode 2	0.5 MHz	8MHz	x	x
	230,400Hz	11.0592MHz	02	02h
	115,200Hz	11.0592 MHz	05	05h
	57,600Hz	11.0592 MHz	11	0Bh
	38,400Hz	11.0592MHz	17	11h
	19,200Hz	11.0592MHz	35	23h
Mode 0	9,600Hz	11.0592MHz	71	47h
Mode 1	4,800Hz	11.0592MHz	143	8Fh
Mode 3	62,500Hz	10MHz	09	09h
	9,615Hz	10MHz	64	40h
	38,461Hz	8MHz	12	0Ch
	12,500Hz	8MHz	39	27h
	19,230Hz	4MHz	12	0Ch
	9,615Hz	4MHz	25	19h

Figure 107 presents a block diagram of the UART1 function.

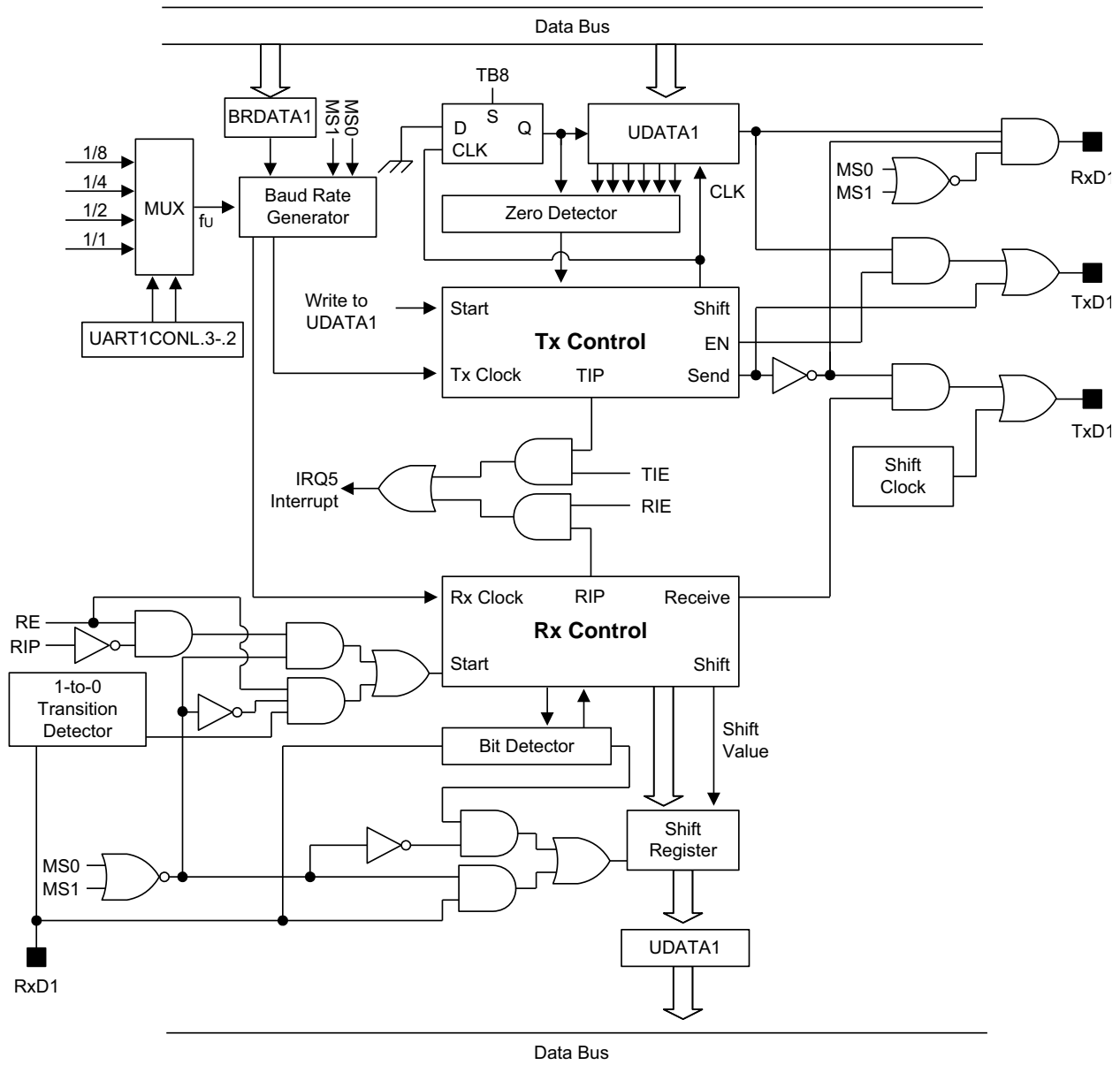


Figure 107. UART1 Functional Block Diagram

UART1 Mode 0 Function Description

In Mode 0, UART1 is input and output through the RxD1 (P3.6) pin, and TxD1 (P3.7) pin outputs the shift clock. Data is transmitted or received in 8-bit units only. The LSB of the 8-bit value is transmitted (or received) first.

Mode 0 Transmit Procedure

Observe the following procedure to write transmission data via UART1 in Mode 0.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Clear the UART1 transmit parity-bit autogeneration enable bit, UART1CONL.7.
3. Select Mode 0 by setting UART1CONH.7 and .6 to 00b.
4. Write the transmission data to the UDATA1 Shift Register (F4h, Set1, Bank0) to start the transmission operation.

Mode 0 Receive Procedure

Observe the following procedure to read receive data via UART1 in Mode 0.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Clear the UART1 transmit parity-bit autogeneration enable bit, UART1CONL.7.
3. Select Mode 0 by setting UART1CONH.7 and .6 to 00b.
4. Clear the receive interrupt pending bit, UART1CONH.0, by writing a 0 to UART1CONH.0.
5. Set the UART1 receive enable bit, UART1CONH.4, to 1.
6. The shift clock will now be output to the TxD1 (P3.7) pin and will read the data at the RxD1 (P3.6) pin. A UART1 receive interrupt occurs when UART1CONH.1 is set to 1.

Figure 108 shows the timing of the UART1 Serial Port Mode 0 operation.

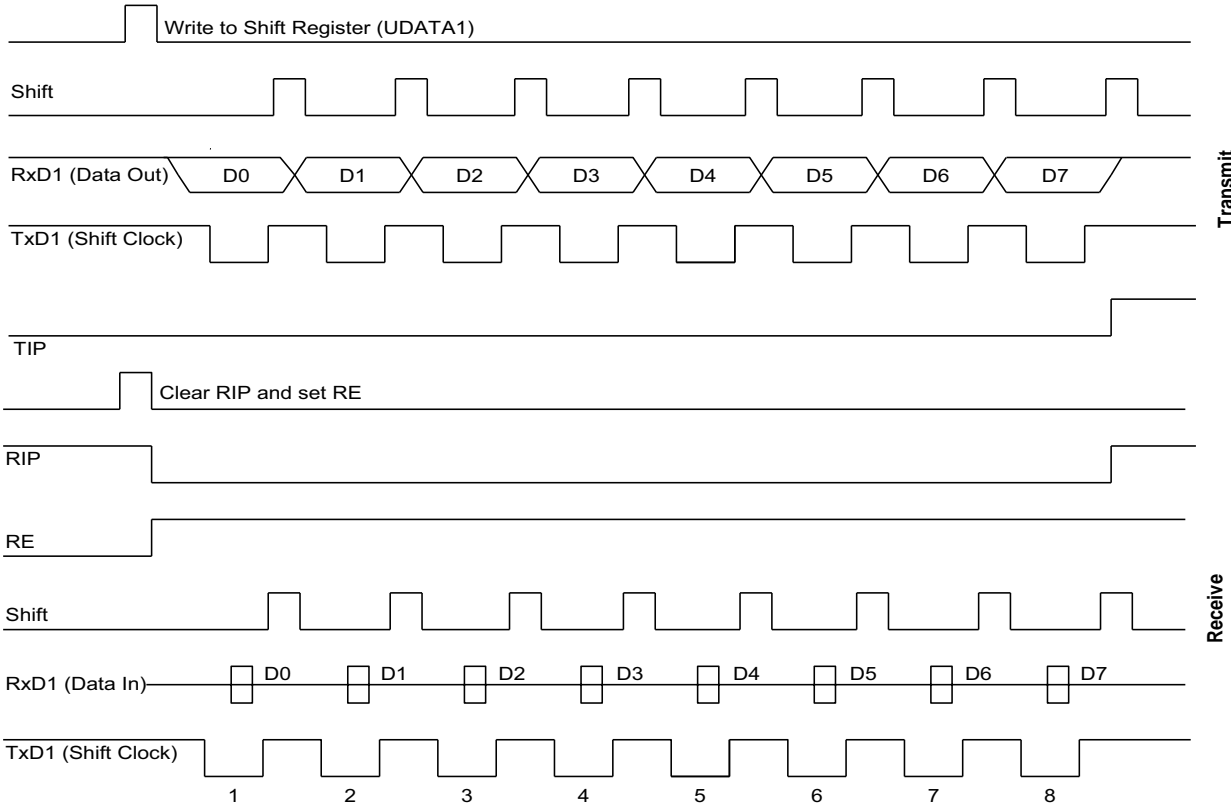


Figure 108. UART1 Serial Port Mode 0 Timing

Serial Port Mode 1 Function Description

In Mode 1, 10-bits are transmitted through the TxD1 (P3.7) pin or received through the RxD1 (P3.6) pin. Each data frame features the following three components:

- Start bit (0)
- 8 data bits (LSB first)
- Stop bit (1)

The baud rate for Mode 1 is variable.

Mode 1 Transmit Procedure

Observe the following procedure to write transmission data via UART1 in Mode 1.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Clear the UART1 transmit parity-bit autogeneration enable bit (UART1CONL.7).
3. Select the baud rate to be generated by BRDATA1.
4. Select Mode 1 (8-bit UART) by setting UART1CONH bits 7 and 6 to 01b.
5. Write transmission data to the UDATA1 Shift Register (F4h, Set1, Bank0). The start and stop bits are generated automatically by hardware.

Mode 1 Receive Procedure

Observe the following procedure to read receive data via UART1 in Mode 1.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Clear the UART1 transmit parity-bit autogeneration enable bit (UART1CONL.7).
3. Select the baud rate to be generated by BRDATA1.
4. Select Mode 1 and set the Receive Enable (RE) bit in the UART1CONH Register to 1.
5. The start bit low (0) condition at the RxD1 (P3.6) pin will cause the UART1 module to start the serial data receive operation.

Figure 109 shows the timing of the UART1 Serial Port Mode 1 operation.

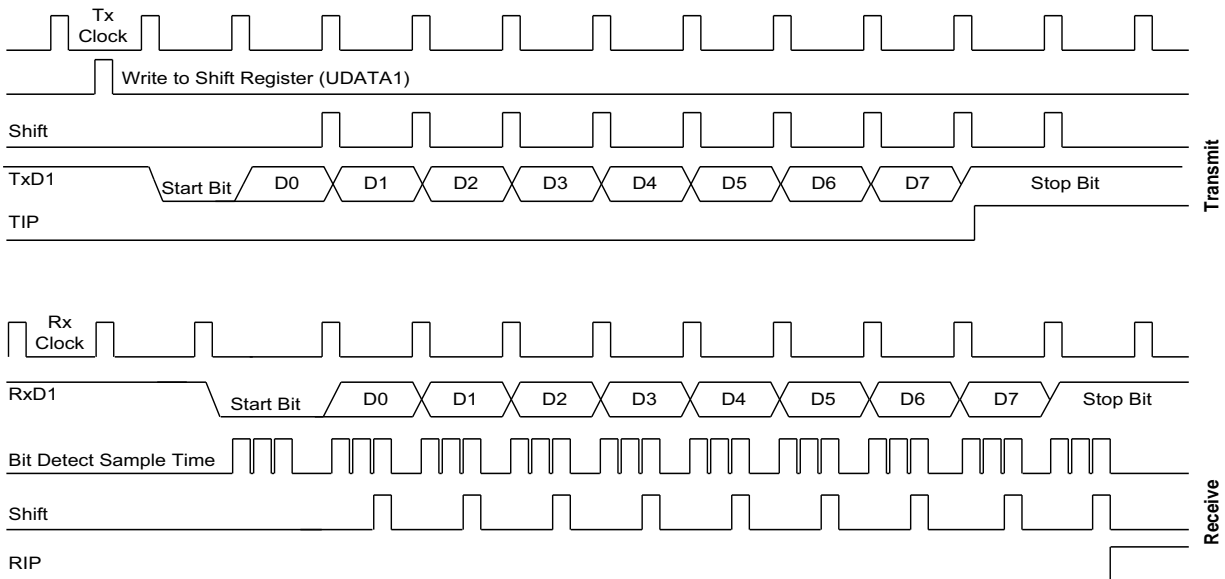


Figure 109. UART1 Serial Port Mode 1 Timing

Serial Port Mode 2 Function Description

In Mode 2, 11 bits are transmitted through the TxD1 (P3.7) pin. Each data frame features the following three components:

- Start bit (0)
- 8 data bits (LSB first)
- Programmable 9th data bit
- Stop bit (1)

The 9th data bit to be transmitted can be assigned a value of 0 or 1 by writing the TB8 bit, UART1CONH.3. When receiving, the 9th data bit that is received is written to the RB8 bit, UART1CONH.2, while the stop bit is ignored. The baud rate for mode 2 is $f_U/16$ clock frequency.

Mode 2 Transmit Procedure

Observe the following procedure to write transmission data via UART1 in Mode 2.

1. Select the UART1 clock, UART0CONL.3 and .2.

2. Select the UART1 transmit parity-bit autogeneration enable or disable (UART0CONL.7).
3. Select Mode 2 (9-bit UART) by setting UART1CONH bits 7 and 6 to 10b. Additionally, select the 9th data bit to be transmitted by writing TB8 to 0 or 1.
4. Write the transmission data to the UDATA1 Shift Register (F4h, Set1, Bank0) to start the transmit operation.

Mode 2 Receive Procedure

Observe the following procedure to read receive data via UART1 in Mode 2.

1. Select the UART1 clock, UART0CONL.3 and .2.
2. Select the UART1 transmit parity-bit autogeneration enable or disable (UART0CONL.7).
3. Select Mode 2 and set the receive enable bit (RE) in the UART1CONH Register to 1.
4. The receive operation starts when the signal at the RxD1 (P1.2) pin goes Low.

Figure 104 shows the timing of the Serial Port Mode 2 operation.

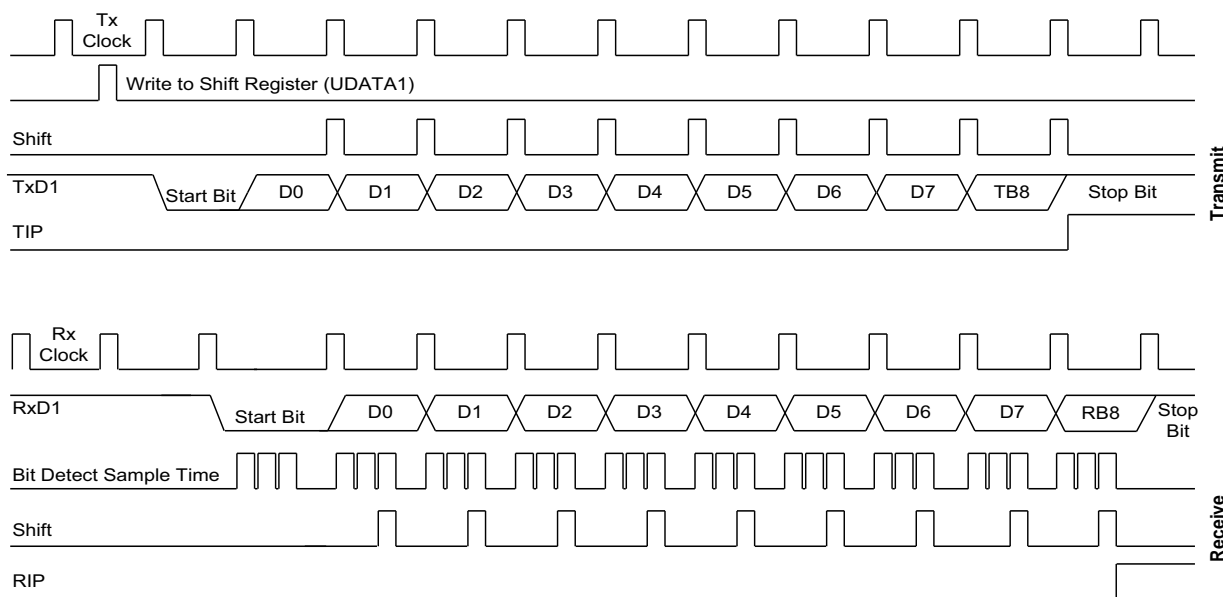


Figure 110. UART1 Serial Port Mode 2 Timing

Serial Port Mode 3 Function Description

In Mode 3, 11 bits are transmitted through the TxD1 (P3.7) pin or received through the RxD0 (P3.6) pin. Mode 3 is identical to Mode 2 except for the baud rate, which is variable. Each data frame features the following four components:

- Start bit (0)
- 8 data bits (LSB first)
- Programmable 9th data bit
- Stop bit (1)

Mode 3 Transmit Procedure

Observe the following procedure to write transmission data via UART1 in Mode 3.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Select the UART1 transmit parity-bit autogeneration enable or disable (UART1CONL.7).
3. Select Mode 3 operation (9-bit UART) by setting UART1CONH bits 7 and 6 to 11b. Additionally, select the 9th data bit to be transmitted by writing UART1CONH.3 (TB8) to 0 or 1.
4. Write transmission data to the UDATA1 Shift Register (F4h, Set1, Bank0), to start the transmit operation.

Mode 3 Receive Procedure

Observe the following procedure to read receive data via UART1 in Mode 3.

1. Select the UART1 clock, UART1CONL.3 and .2.
2. Select the UART1 transmit parity-bit autogeneration enable or disable (UART1CONL.7).
3. Select Mode 3 and set the Receive Enable (RE) bit in the UART1CONH Register to 1.
4. The receive operation will be started when the signal at the RxD1 (P1.2) pin goes Low.

Figure 111 shows the timing of the Serial Port Mode 3 operation.

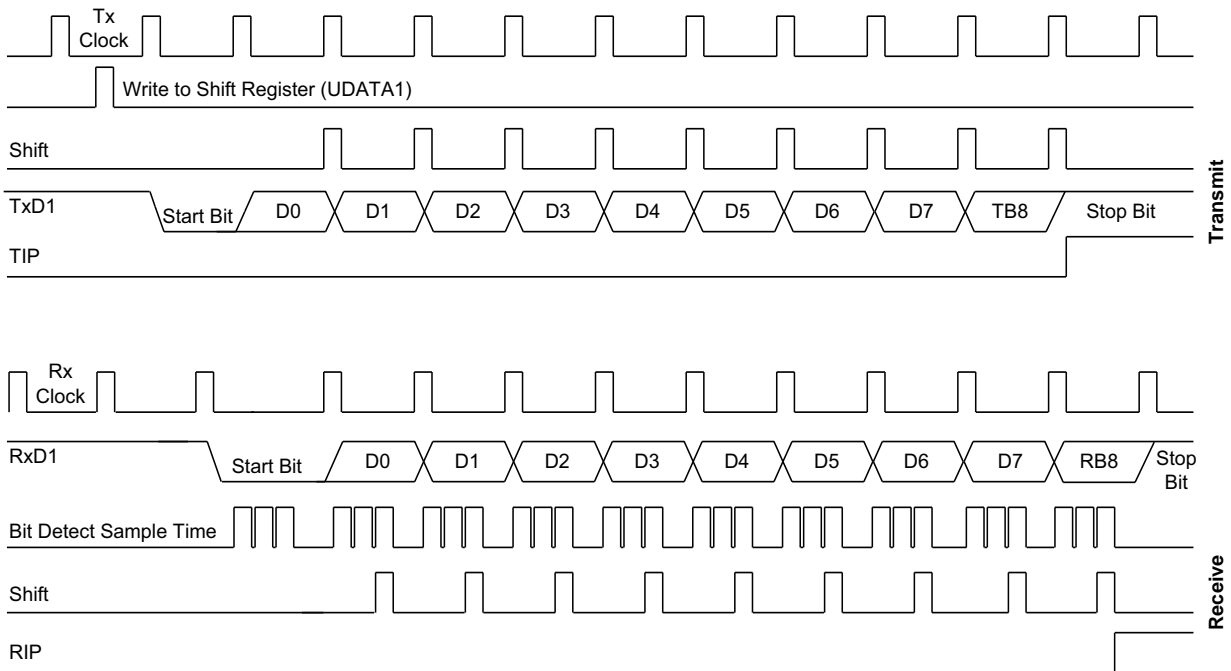


Figure 111. UART1 Serial Port Mode 3 Timing

Serial Communication for Multiprocessor Configurations

The S3F8 Series multiprocessor communication features lets a *master* S3F8S5A MCU send a multiple-frame serial message to a *slave* device in a multi-S3F8S5A configuration without interrupting other slave devices that may be on the same serial line. This feature can be used only in UART modes 2 or 3. In these two modes, 9 data bits are received. The 9th bit value is written to RB8 (UART1CONH.2). The data receive operation is concluded with a stop bit. This function can be programmed such that when the stop bit is received, the serial interrupt will be generated only if RB8 = 1.

To enable this feature, set the MCE bit in the UART1CONH Register. When the MCE bit is 1, serial data frames that are received with the 9th bit = 0 do not generate an interrupt. In this case, the 9th bit simply separates the address from the serial data.

Sample Protocol for Master/Slave Interaction

When the master device transmits a block of data to one of several slaves on a serial line, it first sends out an address byte to identify the target slave. Note that in this

case, an address byte differs from a data byte; in an address byte, the 9th bit is 1, and in a data byte, it is 0.

The address byte interrupts all slaves so that each slave can examine the received byte and determine if it is being addressed. The addressed slave then clears its MCE bit and prepares to receive incoming data bytes.

The MCE bits of slaves that were not addressed remain set, and they continue operating normally while ignoring the incoming data bytes.

While the MCE bit setting has no effect in Mode 0, it can be used in Mode 1 to check the validity of the stop bit. For Mode 1 reception, if MCE is 1, the receive interrupt will be issued unless a valid stop bit is received.

Setup Procedure for Multiprocessor Communications

Observe the following steps to configure multiprocessor communications.

1. Set all S3F8S5A devices (masters and slaves) to UART1 Mode 2 or 3.
2. Write the MCE bit of all the slave devices to 1.
3. The master device's transmission protocol is:
 - First byte: the address identifying the target slave device (9th bit = 1)
 - Next bytes: data (9th bit = 0)
4. When the target slave receives the first byte, all of the slaves are interrupted because the 9th data bit is 1. The targeted slave compares the address byte to its own address and then clears its MCE bit to receive incoming data. The other slaves continue operating normally.

Figure 112 shows an example of multiprocessor serial data communications.

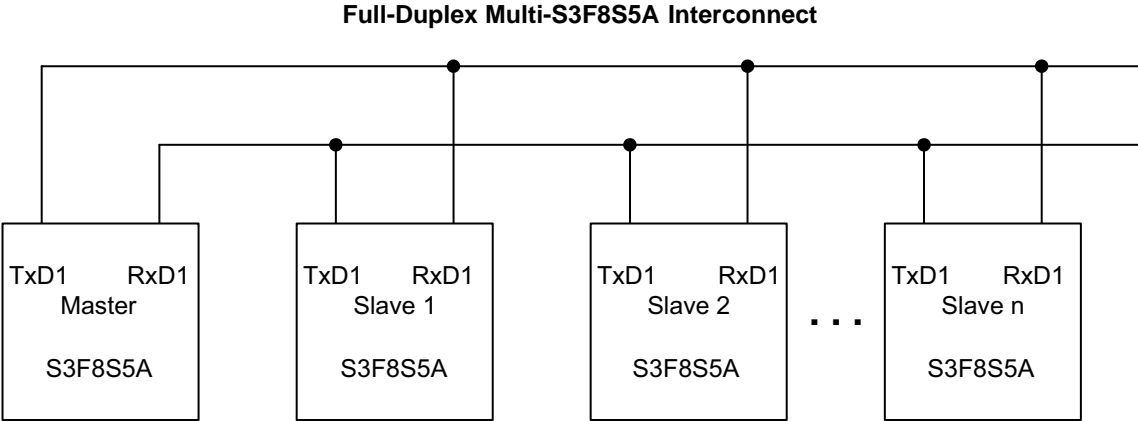


Figure 112. UART1 Multiprocessor Serial Data Communications Example

Pattern Generation Module

Up to 8 bits can be output through P3.0–P3.7 by tracing the sequence shown in Figure 113. First, PGDATA must be changed into a desired output.

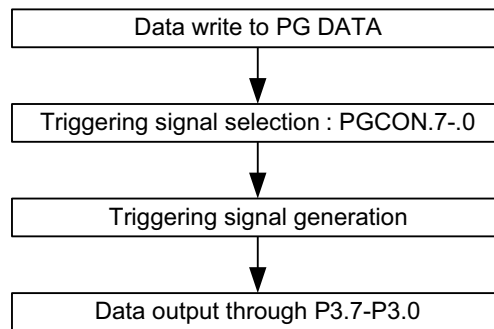


Figure 113. Pattern Generation Flow

Next, the PGCON Register, shown in Table 91, must be set to enable the pattern generation module and select the triggering signal. At this point, the PGDATA bits are in the range P3.0–P3.7 whenever the selected triggering signal occurs.

Table 91. Pattern Generation Module Control Register (PGCON; Set1,

Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	–	–	–	–	0	0	0	0
R/W	–	–	–	–	R/W	R/W	R/W	R/W
Address	F7h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:4]	Reserved
[3]	Software Trigger Start Bit 0: No effect. 1: Software trigger start (auto clear).

Bit	Description (Continued)
[2]	Pattern Generation Operation Disable/Enable Selection Bit 0: Pattern generation disable. 1: Pattern generation enable.
[1:0]	Detection Voltage Selection Bits 00: Timer A match signal triggering. 01: Timer B overflow signal triggering. 10: Timer D0 match signal triggering. 11: Software triggering.

Figure 114 presents a diagram of the pattern generation circuit.

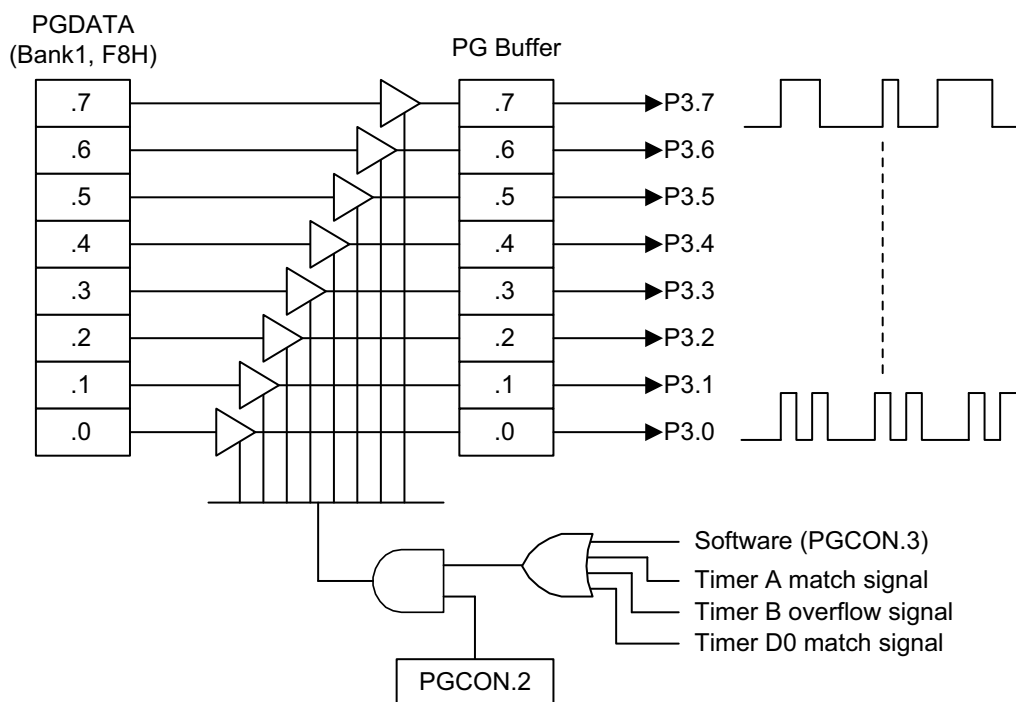


Figure 114. Pattern Generation Circuit Diagram

The following routine presents an example of pattern generation.

```

ORG      0000h
ORG      0100h
INITIAL:
SB0

```

```
LD     SYM, #00h           ; Disable Global/Fast interrupt → SYM
LD     IMR, #01h           ; Enable IRQ0 interrupt
LD     SPH, #0h            ; High byte of stack pointer → SPH
LD     SPL, #0FFh         ; Low byte of stack pointer → SPL
LD     BTCON, #10100011b ; Disable Watchdog
LD     CLKCON, #00011000b; Non-divided (fxx)
SB1
LD     P2CONH,#10101010b ; Enable PG output
LD     P2CONL,#10101010b ; Enable PG output SB0
EI
MAIN:
NOP
NOP
SB1
LD     PGDATA, #10101010b; PG data setting
OR     PGCON, #00000100b ; Triggering by Timer A match then
                                ; pattern data are output
SB0
NOP
NOP
JR     T,MAIN
.END
```

10-Bit Pulse Width Modulation

The S3F8S5A microcontroller features a 10-bit PWM circuit. The operation of all PWM circuits is controlled by a single control register, PWMCON.

The PWM counter is a 10-bit incrementing counter used by the 10-bit PWM circuits. To start the counter and enable these PWM circuits, set PWMCON.2 to 1. If the counter is stopped, it retains its current count value; when restarted, it resumes counting from the retained count value. When clearing the counter is required, set PWMCON.3 to 1.

Select a clock for the PWM counter by setting PWMCON.6–.7. Selectable clocks are $f_{XX}/64$, $f_{XX}/8$, $f_{XX}/2$, and $f_{XX}/1$.

The 10-bit PWM circuits offer the following components:

- 8-bit comparator and extension cycle circuit
- 8-bit reference data register (PWMDATAH .7–.0)
- 2-bit extension data register (PWMDATAL .1–.0)
- PWM output pins (P2.1/PWM)

PWM Counter

To determine the PWM module's base operating frequency, the upper 8 bits of the counter are compared to the PWM data (PWMDATAH .7–.0). To achieve higher resolutions, the lower 2 bits of the PWMDATAL counter can be used to modulate the *stretch cycle*; i.e., to control the *stretching* of the PWM output duty cycle.

PWM Data and Extension Registers

The PWM (duty) data registers, which are located in Set1, Bank1 at addresses FBh–FDh, determine the output value generated by each 10-bit PWM circuit.

To program the required PWM output, load the appropriate initialization values into the 8-bit reference data register (PWMDATAH .7–.0) and the 2-bit extension data register (PWMDATAL .1–.0). To start the PWM counter, or to resume counting, set PWMCON.2 to 1.

A reset operation disables all PWM output. The current counter value is retained when the counter stops. When the counter starts, counting resumes at the retained value.

PWM Clock Rate

The timing characteristics of the PWM output are based on the f_{OSC} clock frequency. The PWM counter clock value is determined by the setting of PWMCON.6–.7; see Table 92.

Table 92. PWM Control and Data Registers

Register Name	Mnemonic	Address	Function
PWM data registers	PWMDATAH .7–.0	FCh, Set1, Bank1	8-bit PWM basic cycle frame value.
	PWMDATAL .1–.0	FDh, Set1, Bank1	2-bit extension ("stretch") value.
PWM control registers	PWMCON	FBh, Set1, Bank1	PWM counter stop/start (resume), and PWM counter clock settings.

PWM Function Description

The PWM output signal toggles to a low level whenever the 8-bit counter matches the PWM-DATAH Reference Data Register. If the value in this register is not zero, an overflow of the 8 counter bits causes the PWM output to toggle to a high level. In effect, the reference value written to the reference data register determines the module's base duty cycle.

The value in the lower 2 bits of the PWMDATAL counter is compared with the extension settings in the 2-bit Extension Data Register, PWMDATAL .1–.0. These lower 2 bits of the counter value, together with extension logic and the PWM module's Extension Data Register, is then used to *stretch* the duty cycle of the PWM output. This *stretch value* is one extra clock period at specific intervals, or cycles; see Table 93.

Table 93. PWM Output Stretch Values for the Extension Data Register (PWMDATAL .1–.0)

PWMDATAL Bit (bit[1]–bit[0])	"Stretched" Cycle Number
00	–
01	2
10	1,3
11	1,2,3

If, for example, the value in the PWMDATAH Extension Register is 00b and the value in the PWMDATAL Register is 01b, the 2nd cycle will be one pulse longer than the other 3 cycles. If the base duty cycle is 50%, the duty of the 2nd cycle will therefore be stretched to approximately 51% of duty. Furthermore, if you write 10b to the Extension Data Register, all odd-numbered pulses will be one cycle longer. If you write 11h to the Extension Data Register, all pulses will be stretched by one cycle, with the exception of the 4th pulse. PWM output goes to

an output buffer and then to the corresponding PWM output pin. In effect, high output resolution can be obtained at high frequencies. See Figures 115 and 116.

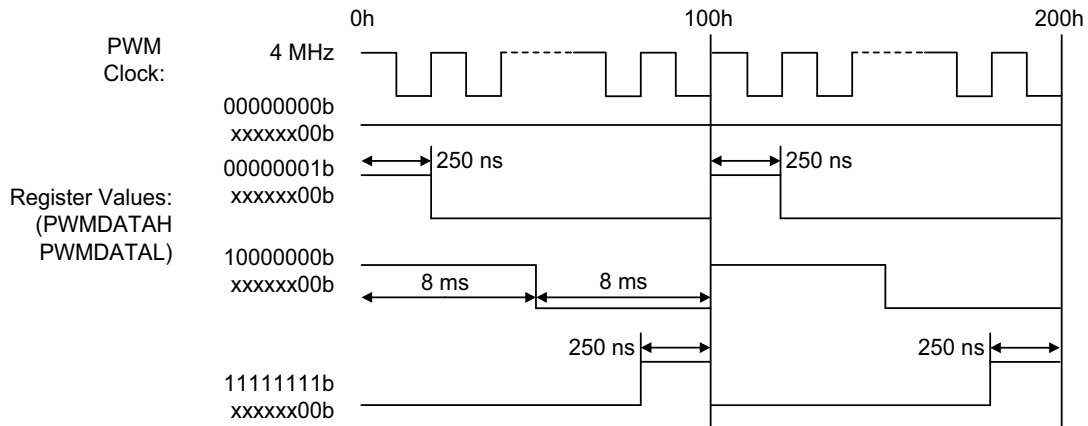


Figure 115. 10-Bit PWM Basic Waveform

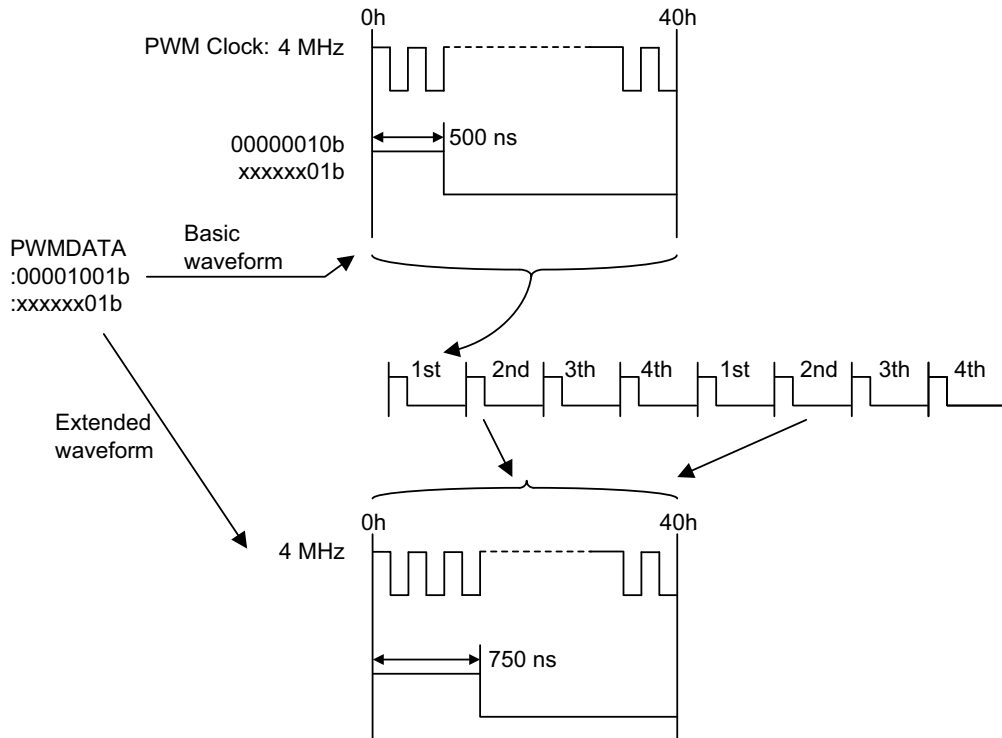


Figure 116. 10-Bit Extended PWM Waveform

PWM Control Register

The control register for the PWM module, PWMCON, shown in Table 94, is located at register address FBh. PWMCON is used for the 10-bit PWM modules. Bit settings in the PWMCON Register control the following functions:

- PWM counter clock selection
- PWM data reload interval selection
- PWM counter clear
- PWM counter stop/start (or resume) operation
- PWM counter overflow (10-bit counter overflow) interrupt control

A reset clears all PWMCON bits to logic zero, thereby disabling the entire PWM module.

Table 94. PWM Control Register (PWMCON; Set1, Bank1)

Bit	7	6	5	4	3	2	1	0
Reset	0	–	–	0	0	0	0	0
R/W	R/W	R/W	–	R/W	R/W	R/W	R/W	R/W
Address	FBh							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:6]	PWM Input Clock Selection Bits 00: $f_{XX}/64$. 01: $f_{XX}/8$. 10: $f_{XX}/2$. 11: $f_{XX}/1$.
[5]	Reserved
[4]	PWMDATA Reload Interval Selection Bit 0: Reload from the 10-bit upcounter overflow. 1: Reload from the 8-bit upcounter overflow.
[3]	PWM Counter Clear Bit 0: No effect. 1: Clear the PWM counter.
[2]	PWM Counter Enable Bit 0: Stop counter. 1: Start/resume counting.

Bit	Description (Continued)
[1]	PWM OVF Interrupt Enable Bit 0: Disable interrupt. 1: Enable interrupt.
[0]	PWM OVF Interrupt Pending Bit 0: No interrupt is pending when read; clear pending condition when write. 1: An interrupt is pending.

Figure 117 presents a block diagram of the PWM function.

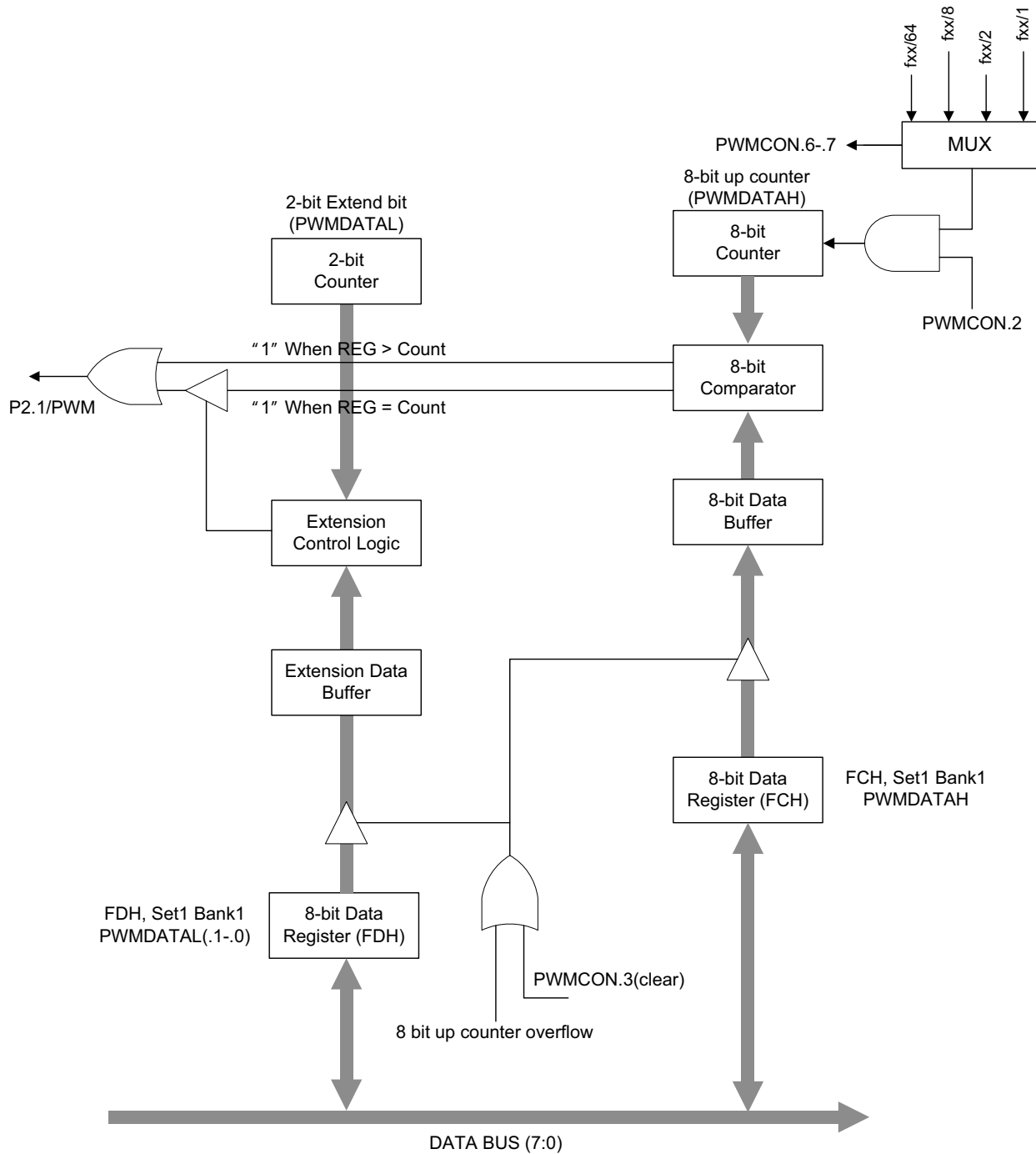


Figure 117. PWM Functional Block Diagram

The following routine presents an example for programming the PWM module to sample specifications.

```

;-----<< Interrupt Vector Address >>
    ORG      0000h
    VECTOR  0DAh,INT_PWM

;-----<< Initialize System and Peripherals >>
    ORG      0100h
RESET:    DI                ; disable interrupt
          LD BTCON,#10100011b ; Watchdog disable
.
.
    LD P2CONL,#00000100b    ; Configure P2.1 PWM output
    LD PWMCON,#00000110b    ; fOSC/64, counter/interrupt enable
    LD PWMDATAH,,#80h
    LD PWMDATAL,#0
.
.
    EI                ; Enable interrupt
;-----<< Main loop >>
Main:
.
.
    JR      t,MAIN
;-----<< Interrupt Service Routines >>
INT_PWM:                ; PWM interrupt service routine
.
.
    AND PWMCON,#11111110b    ; pending bit clear IRET
.
.
END

```

Embedded Flash Memory Interface

The S3F8S5A MCU features internal on-chip Flash memory instead of masked ROM. This Flash memory is accessed by an LDC instruction. With sector erase and byte-programmable Flash, data can be programmed into a Flash memory space at any time. The S3F8S5A MCU's embedded 48KB of memory offers the following two operating features:

- User Program Mode
- Tool Program Mode – see the [S3F8S5A Flash MCU](#) chapter on page 363

User Program Mode

User Program Mode supports sector erase, byte programming, byte read, and one protection mode, Hard Lock protection; read protection is available only in Tool Program Mode. To read-protect the chip, select a read protection option when you initially program your code in Tool Program Mode by using a programming tool.

The S3F8S5A MCU also features an internal pumping circuit; therefore, 12.5V into a V_{pp} (test) pin is not required. To program Flash memory in this mode, several control registers are used. There are four functions: programming, reading, sector erase, and hard lock protection.

-
- **Note:**
1. User Program Mode cannot be used when the CPU operates with the subsystem clock.
 2. Be sure to execute the DI instruction before starting User Program Mode, which checks the Interrupt Request Register (IRQ). If an interrupt request is generated, User Program Mode is stopped.
 3. User Program Mode is also stopped by an interrupt request that is masked even in the DI status. To prevent this situation, disable the interrupt by using the each peripheral interrupt enable bit.
-

Flash Memory Control Registers

This section describes the use of the Flash Memory Control (FMCON), Flash Memory User Programming Enable, and Flash Memory Sector Address registers when operating in User Program Mode.

Flash Memory Control Register

The Flash Memory Control (FMCON) Register, shown in Table 95, is available only in User Program Mode to select the operational mode of Flash memory, as well as the sector erase and byte programming functions, and to protect the Flash memory space with the Hard Lock function.

Table 95. Flash Memory Control Register (FMCON; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	–	–	0
R/W	R/W	R/W	R/W	R/W	R	–	–	R/W
Address	F9h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:4]	Flash Memory Mode Selection Bits 0001–0100: Reserved. 0101: Programming Mode. 0110: Hard Lock Mode. 0111–1001: Reserved. 1010: Sector Erase Mode. 1011–1111: Reserved.
[3]	Sector Erase Status Bit (Read Only) 0: Sector erase success. 1: Sector erase failure.
[2:1]	Reserved
[0]	Flash Operation Start Bit* 0: Operation stop. 1: Operation start.

Note: *FMCON.0 will be cleared automatically immediately after the corresponding operation has completed.

Bit 0 of the FMCON Register, FMCON.0, is a start bit for both the Erase and Hard Lock operation modes. Therefore, operation of the Erase and Hard Lock modes is activated when setting FMCON.0 to 1. Additionally, a waiting period for the Erase (sector erase) or Hard Lock modes to complete their operations must occur before performing a byte programming or byte read operation of the same sector area by with the LDC instruction. When reading or programming a byte data from or into Flash memory, this bit is not required to be manipulated.

The sector erase status bit is read only. Even if the IMR bits are 0, the interrupt is serviced during the operation of a sector erase, when each peripheral interrupt enable bit is set to 1,

and when the interrupt pending bit is set to 1. If an interrupt is requested during a sector erase operation, the operation of this sector erase is discontinued, and the interrupt is serviced by the CPU. Therefore, the sector erase status bit should be checked after executing a sector erase. The sector erase operation is successful if the bit is logic 0, and is a failure if the bit is logic 1.



Caution: When the A5h ID code is written to the FMUSR Register, it is possible that the sector erase, user program, and hard lock modes may be executed; therefore caution is necessary.

Flash Memory User Programming Enable Register

The Flash Memory User Programming Enable (FMUSR) Register, shown in Table 96, manages the safe operation of Flash memory. This register will protect undesired erase or program operations from CPU malfunctions caused by electrical noise. After reset, User Program Mode is disabled because the value of FMUSR is 00000000b as a result of the reset operation. If it is necessary to operate Flash memory, enable User Program Mode by setting the value of FMUSR to 10100101b. Any value written to FMUSR other than 10100101b disables User Program Mode.

Table 96. Flash Memory User Programming Enable Register (FMUSR; Set1,

Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W					R/W			
Address					F8h			
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	Flash Memory User Programming Enable Bits 00000001–10100100: Disable User Program Mode. 10100101: Enable User Program Mode. 10100110–11111111: Disable User Program Mode.

Flash Memory Sector Address Registers

There are two sector address registers used to select a particular sector. The Flash Memory Address Sector High Byte (FMSECH) Register and the Flash Memory Sector Address

Low Byte (FMSECL) Register are combined to generate the most significant bits of the 16-bit base address for the sector to be selected. FMSECH represents the bits 8 through 15 of the 16-bit address, and FMSECL represents bit 7 of the 16-bit base address. The S3F8S5A MCU provides 384 sectors, and each sector is 128 bytes, in effect meaning that the lower 7 bits of FMSECL have no effect; see the example in Figure 118.

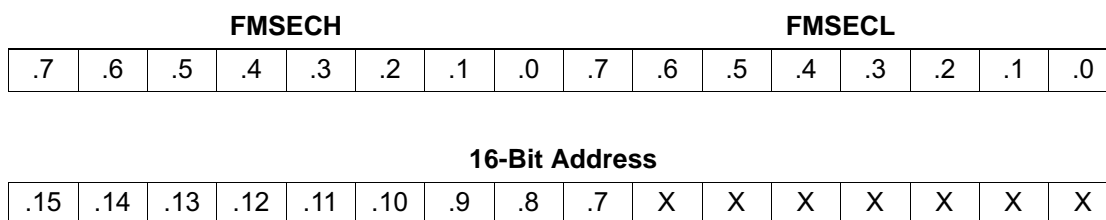


Figure 118. Flash Memory Sector Addressing

As shown in Tables 97 and 98, the Flash Memory Sector Address Register High Byte (FMSECH) Register indicates the high byte of the sector address, and the Flash Memory Sector Address Register Low Byte (FMSECL) Register indicates the low byte of the sector address.

Table 97. Flash Memory Sector Address Register High Byte Register (FMSECH; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	F6h							
Mode	Register Addressing Mode only							

Note: R = read only; R/W = read/write.

Bit	Description
[7:0]	Flash Memory Sector Address (High Byte) The 15th–8th bits to select a sector of Flash ROM.

Note: The high-byte Flash memory sector address pointer value is the upper eight bits of the 16-bit pointer address.

Table 98. Flash Memory Sector Address Register Low Byte Register (FMSECL; Set1, Bank0)

Bit	7	6	5	4	3	2	1	0
Reset	0	0	0	0	0	0	0	0
R/W	R/W							
Address	F7h							
Mode	Register Addressing Mode only							
Note: R = read only; R/W = read/write.								

Bit	Description
[7]	Flash Memory Sector Address (Low Byte) The 7th bit to select a sector of Flash ROM.
[6:0]	Don't Care

Note: The low-byte Flash memory sector address pointer value is the lower eight bits of the 16-bit pointer address.

When programming Flash memory, write the data after loading the sector base address located in the target address into the FMSECH and FMSECL registers. If the next operation is also a data write operation, check to determine if the next address is located in the same sector. In the case of other sectors, you must load the sector address to the FMSECH and FMSECL registers according to the sector.

ISP™ Onboard Programming Sector

ISP™ sectors located in the program memory space can store onboard program software (i.e., boot program code for upgrading application code by interfacing with an I/O port pin). These ISP™ sectors cannot be erased or programmed by an LDC instruction for the safety of onboard program software.

ISP sectors are available only when the ISP enable/disable bit is set to 0, i.e., ISP is enabled using the Smart Option. If you prefer not to use the ISP sector method, this area can be used as normal program memory (i.e., it can be erased or programmed using the LDC instruction) by setting the ISP disable bit (1) with the Smart Option. Even if the ISP sector is selected, the ISP sector can be erased or programmed in Tool Program Mode using a serial programming tool.

The size of the ISP sector can be adjusted using Smart Option settings; see Figure 119. Additionally, refer to [Table 100](#) on page 340 to choose an appropriate ISP sector size according to the size of the onboard program software.

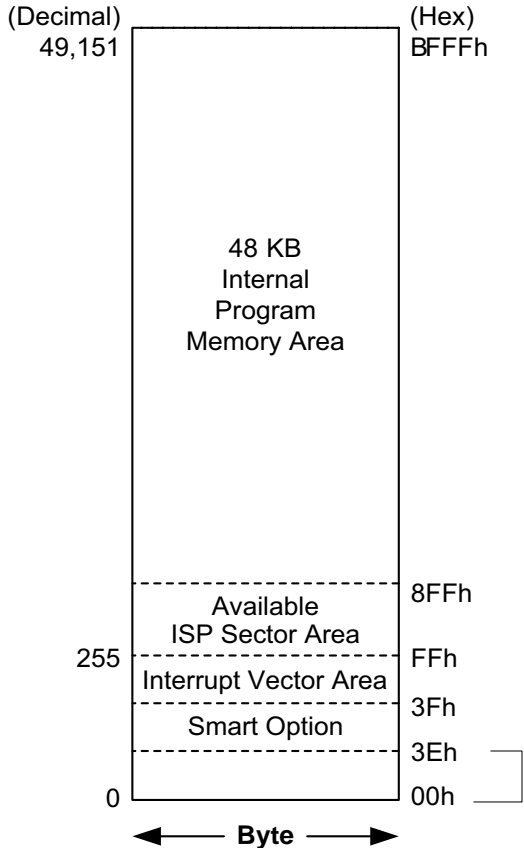


Figure 119. Program Memory Address Space

ISP Reset Vector and ISP Sector Size

If you use ISP sectors by setting the ISP enable/disable bit to 0 and the reset vector selection bit to 0 at the Smart Option (see [Figure 15](#) on page 21), you can choose the reset vector address of the CPU as shown in Table 99 by setting the ISP reset vector address selection bits; also see the list of ISP sector sizes in Table 100.

Table 99. Reset Vector Address

Smart Option (003Eh) ISP Reset Vector Address Selection Bit			Reset Vector Address after POR	Usable Area for ISP Sector	
Bit 7	Bit 6	Bit 5		ISP Sector	ISP Sector Size
1	x	x	0100h	0	0
0	0	0	0200h	100h–1FFh	256 bytes
0	0	1	0300h	100h–2FFh	512 bytes
0	1	0	0400h	100h–4FFh	1024 bytes
0	1	1	0500h	100h–8FFh	2048 bytes

Note: The selection of the ISP reset vector address by Smart Option (003Eh.7–003Eh.5) is not dependent of the selection of ISP sector size by Smart Option (003Eh.2–003Eh.0).

Table 100. ISP Sector Size

Smart Option (003Eh) ISP Size Selection Bit			Area of ISP Sector	ISP Sector Size
Bit 2	Bit 1	Bit 0		
1	x	x	0	0
0	0	0	100h–1FFh (256 bytes)	256 bytes
0	0	1	100h–2FFh (512 bytes)	512 bytes
0	1	0	100h–4FFh (1024 bytes)	1024 bytes
0	1	1	100h–8FFh (2048 bytes)	2048 bytes

Note: The area of the ISP sector selected by Smart Option bits (003Eh.2–003Eh.0) cannot be erased and programmed by the LDC instruction in User Program Mode.

Sector Erase Operations

Flash memory can be partially erased by using the sector erase functions in User Program Mode only. Sectors are the only units of Flash memory that can be erased in User Program Mode.

Program memory on the S3F8S5A MCU is divided into 384 sectors for erase and program operations; every sector is 128 bytes. Each sector should be first be erased prior to programming a new data byte into Flash memory. A minimum of 10ms delay time is required prior to an erase and after setting the sector address and triggering the erase start bit (FMCON.0). The sector erase function is not supported in Tool Program modes (i.e., when using an MDS mode too or programming tool).

Figure 120 portrays how sectors are mapped in User Program Mode.

Sector 383 (128 byte)	BFFFh BF80h
⋮	
Sector 14 (128 byte)	0780h 077Fh
Sector 13 (128 byte)	0700h
Sector 12 (128 byte)	0680h
Sector 11 (128 byte)	0600h
Sector 10 (128 byte)	0580h
Sector 0-9 (128 byte x 10)	0500h 04FFh 0000h

S3F8S5A

Figure 120. Sector Configurations in User Program Mode

The Sector Erase Procedure in User Program Mode

Observe the following procedure to perform a sector erase in User Program Mode.

1. If the sector erase procedure must be stopped by any interrupt, set the appropriate bit in the Interrupt Mask Enable Register (IMR) and the appropriate peripheral interrupt enable bit. Otherwise, clear all bits in the Interrupt Mask Enable Register (IMR) and all peripheral interrupt enable bits.
2. Set the Flash Memory User Programming Enable (FMUSR) Register to 10100101b.
3. Set the Flash Memory Sector Address (FMSECH and FMSECL) registers.
4. Check the user's ID code (written by user).

5. Set the Flash Memory Control (FMCON) Register to 10100001b.
6. Set the Flash Memory User Programming Enable (FMUSR) Register to 00000000b.
7. Check the sector erase status bit to determine if the sector erase is successful.

The following routine presents an example of a successful sector erase.

```

•
•
SB0
reErase: LD FMUSR,Temp0      ; User Program mode enable
                                ; Temp0 = #0A5H
                                ; Temp0 variable is must be setting
                                ; another routine

LD      FMSECH,#10h
LD      FMSECL,#00h        ; Set sector address (1000h-107Fh)
CP UserID_Code,#User_value ; Check user's ID code (written by
                                ; user)
                                ; User_value is any value by user
JR      NE,Not_ID_Code     ; If not equal, jump to Not_ID_Code
LD      FMCON,Temp1        ; Start sector erase
                                ; Temp1 = #0A1h
                                ; Temp1 variable is must be setting
                                ; another routine

NOP      ; Dummy instruction - required
NOP      ; Dummy instruction - required
LD      FMUSR,#0           ; User Program Mode disable
TM FMCON,#00001000b       ; Check "sector erase status bit"
JR      NZ,reErase        ; Jump to reErase if fail
•
•
•
•
Not_ID_Code:
SB0
LD      FMUSR,#0           ; User Program Mode disable
LD      FMCON,#0          ; Sector Erase Mode disable
•
•
•
•

```

► **Note:** In the case of Flash User Mode, the Temp0 to Temp1 data values must set another routine. Temp0 to Temp(n) variables should be defined by the user.

Program Operations

After a sector erase, Flash memory is programmed in one-byte units. For the sake of programming safety, FMSECH and FMSECL must each be set to the Flash memory sector value.

Programming in User Program Mode

Observe the following procedure to program Flash memory in User Program Mode.

1. Erase all target sectors before programming.
2. Set the Flash Memory User Programming Enable (FMUSR) Register to 10100101b.
3. Set the Flash Memory Sector Address registers (FMSECH and FMSECL) to the sector base address of the destination address to write data.
4. Load the Flash memory upper address into the upper register of the working register pair.
5. Load the Flash memory lower address into the lower register of the working register pair.
6. Load transmission data into a working register.
7. Check the user's ID code (written by user).
8. Set the Flash Memory Control Register (FMCON) to 01010001b.
9. Load transmission data to a Flash memory location using the LDC instruction via Indirect Addressing Mode.
10. Set the Flash Memory User Programming Enable (FMUSR) Register to 00000000b.

The following routine presents an example of a successful programming operation.

```
•  
•  
SB0  
LD      FMUSR,Temp0      ; User Program Mode enable  
                          ; Temp0 = #0A5H  
                          ; Temp0 variable is must be setting  
                          ; another routine
```

```

LD      FMSECH,#17h
LD      FMSECL,#80h      ; Set sector address (1780h-17FFh)
LD      R2,#17h         ; Set a ROM address in the same sector
                          ; 1780h-17FFh

LD      R3,#84h
LD      R4,#78h         ; Temporary data
CP      UserID_Code,#User_value ; Check user's ID code (written
                          ; by user)
                          ; User_value is any value by user

JR      NE,Not_ID_Code  ; If not equal, jump to Not_ID_Code
LD      FMCON,Temp1     ; Start program
                          ; Temp1 = #51H
                          ; Temp1 variable is must be setting
                          ; another routine

LDC     @RR2,R4         ; Write the data to a address of same
                          ; sector(1784h)

NOP
LD      FMUSR,#0        ; User Program Mode disable
.
.
.
.
Not_ID_Code:
SB0
LD      FMUSR,#0        ; User Program Mode disable
LD      FMCON,#0       ; Programming Mode disable

```

► **Note:** In the case of Flash User Mode, the Temp0 to Temp1 data values must set another routine. Temp0 to Temp(n) variables should be defined by the user.

Read Operations

The read operation is initiated by the LDC instruction. Observe the following procedure to program read operations in User Program Mode.

1. Load an upper Flash memory address into the upper register of the working register pair.
2. Load a lower Flash memory address into the lower register of the working register pair.

3. Load the receive data from the Flash memory space using the LDC instruction via Indirect Addressing Mode.

The following example shows how to perform read programming.

```
•
•
LD      R2,#3h          ; Load Flash memory upper address
                          ; to upper of pair working register
LD      R3,#0          ; Load Flash memory lower address
                          ; to lower pair working register
LOOP:   LDC R0,@RR2     ; Read data from Flash memory location
                          ; (Between 300h and 3FFh)

INC     R3
CP      R3,#0h
JP      NZ,LOOP
•
•
•
•
```

Hard Lock Protection

The Hard Lock Protection function prevents changes to data in Flash memory. It can be set by writing 0110b to FMCON.7–4. If this function is enabled, the user cannot write or erase the data within Flash memory. This protection can be released by executing a chip erase in Tool Program Mode.

Hard Lock Protection can be enabled by the application software when User Program Mode is enabled, or with a Serial Programmer while in Tool Program Mode. Refer to the documentation that accompanies the Serial Programmer you are using to enable Hard Lock Protection in Tool Program Mode.

To enable Hard Lock protection with application software, observe the following procedure.

1. Set the Flash Memory User Programming Enable (FMUSR) Register to 10100101b.
2. Check the user's ID code (written by user).
3. Set the Flash Memory Control (FMCON) Register to 01100001b.
4. Set the Flash Memory User Programming Enable (FMUSR) Register to 00000000b.

The following example shows how to set Hard Lock protection.

```
SB0
```

```

LD      FMUSR,Temp0      ; User Program Mode enable
                        ; Temp0 = #0A5h
                        ; Temp0 variable is must be setting
                        ; another routine
CP      UserID_Code,#User_value ; Check user's ID code (written
                        ; by user)
                        ; User_value is any value by user
JR      NE,Not_ID_Code  ; If not equal, jump to Not_ID_Code
LD      FMCON,Temp1     ; Hard Lock Mode set & start
                        ; Temp1 = #61H
                        ; Temp1 variable is must be setting
                        ; another routine
NOP                                           ; Dummy Instruction - required
LD      FMUSR,#0        ; User Program Mode disable
.
.
.
.
Not_ID_Code:
SB0
LD      FMUSR,#0        ; User Program Mode disable
LD      FMCON,#0       ; Hard Lock Protection Mode disable
.
.
.
.

```

► **Note:** In the case of Flash User Mode, the Temp0 to Temp1 data values must set another routine. Temp0 to Temp(n) variables should be defined by the user.

Electrical Characteristics

In this chapter, the S3F8S5A MCU's electrical characteristics are presented in tables and charts. This information is arranged in the following order:

1. Absolute Maximum Ratings – see Table 101
2. DC Electrical Characteristics – see Table 102
3. AC Electrical Characteristics – see [Table 103](#) on page 350
4. Input Timing for External Interrupts, Ports 0 and 2 – see [Figure 121](#) on page 351
5. Input Timing for Reset (nRESET Pin) – see [Figure 122](#) on page 351
6. Input/Output Capacitance – see [Table 104](#) on page 351
7. Data Retention Supply Voltage – see [Table 105](#) on page 351
8. Stop Mode Release Timing Initiated by nRESET – see [Table 105](#) on page 351
9. Stop Mode Release Timing Initiated by Interrupts – see [Table 105](#) on page 351
10. A/D Converter Electrical Characteristics – see [Table 106](#) on page 353
11. Low Voltage Reset Electrical Characteristics – see [Table 107](#) on page 353
12. Low Voltage Reset Timing – see [Figure 125](#) on page 354
13. Synchronous SIO Electrical Characteristics – see [Table 108](#) on page 354
14. Serial Data Transfer Timing – see [Figure 126](#) on page 355
15. UART Timing Characteristics in Mode 0 – see [Table 109](#) on page 355
16. Waveform for UART Timing Characteristics – see [Figure 127](#) on page 356
17. Timing Waveform for the UART Module – see [Figure 128](#) on page 356
18. Main Oscillator Characteristics – see [Table 110](#) on page 357
19. Suboscillation Characteristics – see [Table 111](#) on page 357
20. Main Oscillation Stabilization Time – see [Table 112](#) on page 358
21. Clock Timing Measurement at X_{IN} – see [Figure 129](#) on page 358
22. Suboscillation Stabilization Time – see [Table 113](#) on page 358
23. Clock Timing Measurement at X_{TIN} – see [Figure 130](#) on page 359
24. Operating Voltage Range – see [Figure 131](#) on page 359
25. Internal Flash ROM Electrical Characteristics – see [Figure 114](#) on page 360

Table 101. Absolute Maximum Ratings ($T_A = 25^\circ\text{C}$)

Parameter	Symbol	Conditions	Rating TBD	Unit
Supply Voltage	V_{DD}	–	–0.3 to +6.5	V
Input Voltage	V_I	Ports 0–4	–0.3 to $V_{DD} + 0.3$	V
Output Voltage	V_O	–	–0.3 to $V_{DD} + 0.3$	V
Output Current High	I_{OH}	One I/O pin active	–5	mA
		All I/O pins active	–60	
Output Current Low	I_{OL}	One I/O pin active	+30 (peak value)	mA
		Total pin current for ports	+100 (peak value)	
Operating Temperature	T_A	–	–40 to +85	$^\circ\text{C}$
Storage Temperature	T_{STG}	–	–65 to +150	$^\circ\text{C}$

Table 102. DC Electrical Characteristics ($T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)¹

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Operating Voltage	V_{DD}	$f_X = 0.4\text{--}4.2\text{MHz}$	1.8	–	5.5	V
		$f_X = 0.4\text{--}12.0\text{MHz}$	2.2	–	5.5	V
Input High Voltage	V_{IH1}	All ports except for V_{IH2}	$0.8V_{DD}$	–	V_{DD}	V
	V_{IH2}	$X_{IN}, X_{OUT}, X_{TIN}, X_{TOUT}$	$V_{DD}-0.1$	–	V_{DD}	V
Input Low Voltage	V_{IL1}	All ports except V_{IL2}	–	–	$0.2V_{DD}$	V
	V_{IL2}	$X_{IN}, X_{OUT}, X_{TIN}, X_{TOUT}$	–	–	0.1	–
Output High Voltage	V_{OH1}	$V_{DD} = 2.4\text{V}$; P1.0–P1.1, P3.4–P3.6; $I_{OH} = -1\text{mA}$	$V_{DD}-0.7$	$V_{DD}-0.7$	–	V
	V_{OH2}	$V_{DD} = 5\text{V}$; P2; $I_{OH} = -4\text{mA}$	$V_{DD}-1.0$	$V_{DD}-1.0$	–	V
	V_{OH3}	$V_{DD} = 5\text{V}$; the other ports; $I_{OH} = -1\text{mA}$	$V_{DD}-1.0$	$V_{DD}-1.0$	–	V
Output Low Voltage	V_{OL1}	$V_{DD} = 2.4\text{V}$; P1.0–P1.1, P3.4–P3.6; $I_{OL} = 12\text{mA}$	–	0.3	0.5	V
	V_{OL2}	$V_{DD} = 5\text{V}$; P2; $I_{OL} = 15\text{mA}$	–	0.4	2.0	V
	V_{OL3}	$V_{DD} = 5\text{V}$; the other ports; $I_{OL} = 4\text{mA}$	–	0.4	2.0	V

Notes:

1. Every value in this table is measured when bits 4–3 of the System Clock Control Register (CLKCON.4–.3) is set to 11b.
2. Supply current does not include current drawn through internal pull-up resistors, LCD voltage-dividing resistors, the LVR block, and external output current loads.
3. I_{DD1} and I_{DD2} include a power consumption of subclock oscillation.
4. I_{DD3} and I_{DD4} are the current when the main clock oscillation stops and the subclock is used.
5. I_{DD5} is the current when the main and subclock oscillation stops.

Table 102. DC Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)¹

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	
Input High Leakage Current	I_{LIH1}	$V_{IN} = V_{DD}$; all input pins except for I_{LIH2}	–	–	3	μA	
	I_{LIH2}	$V_{IN} = V_{DD}$; X_{IN} , X_{OUT} , X_{TIN} , X_{TOUT}	–	–	20	μA	
Input Low Leakage Current	I_{LIL1}	$V_{IN} = 0\text{V}$; all input pins except for nRESET, I_{LIL2}	–	–	–3	μA	
	I_{LIL2}	$V_{IN} = 0\text{V}$; X_{IN} , X_{OUT} , X_{TIN} , X_{TOUT}	–	–	–20		
Output High Leakage Current	I_{LOH}	$V_{OUT} = V_{DD}$; all output pins	–	–	3	μA	
Output Low Leakage Current	I_{LOL}	$V_{OUT} = 0\text{V}$; all output pins	–	–	–3	μA	
Pull-Up Resistors	R_{L1}	$V_I = 0\text{V}$; $T_A = 25^{\circ}\text{C}$, Ports 0–4	$V_{DD} = 5\text{V}$	25	50	100	$\text{k}\Omega$
			$V_{DD} = 3\text{V}$	50	100	150	$\text{k}\Omega$
	R_{L2}	$V_{IN} = 0\text{V}$, $T_A = 25^{\circ}\text{C}$, nRESET	$V_{DD} = 5\text{V}$	150	250	400	$\text{k}\Omega$
			$V_{DD} = 3\text{V}$	300	500	700	$\text{k}\Omega$
Oscillator Feedback Resistors	R_{OSC1}	$V_{DD} = 5\text{V}$, $T_A = 25^{\circ}\text{C}$, $X_{IN} = V_{DD}$, $X_{OUT} = 0\text{V}$	420	850	1700	$\text{k}\Omega$	
	R_{OSC2}	$V_{DD} = 5\text{V}$, $T_A = 25^{\circ}\text{C}$, $X_{IN} = V_{DD}$, $X_{TIN} = V_{DD}$, $X_{OUT} = 0\text{V}$	2200	4500	9000	$\text{k}\Omega$	
LCD Voltage Dividing Resistor	R_{LCD}	$T_A = 25^{\circ}\text{C}$	45	75	100		
VLCD-COM _i Voltage Drop ($i = 0$ to 7)	V_{DC}	$-15\mu\text{A}$ per common pin	–	–	120		
V _{LCD} -SEG _x Voltage Drop ($x = 0$ –18)	V_{DS}	$-15\mu\text{A}$ per segment pin	–	–	120	mV	

Notes:

1. Every value in this table is measured when bits 4–3 of the System Clock Control Register (CLKCON.4–3) is set to 11b.
2. Supply current does not include current drawn through internal pull-up resistors, LCD voltage-dividing resistors, the LVR block, and external output current loads.
3. I_{DD1} and I_{DD2} include a power consumption of subclock oscillation.
4. I_{DD3} and I_{DD4} are the current when the main clock oscillation stops and the subclock is used.
5. I_{DD5} is the current when the main and subclock oscillation stops.

Table 102. DC Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)¹

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit	
Middle Output Voltage	V_{LC1}	$V_{DD} = 2.7\text{V}$ to 5.5V , LCD clock = 0Hz , $V_{LC0} = V_{DD}$, $\frac{1}{4}$ Bias		0.75	$0.75 V_{DD}$	0.75	V	
	V_{LC2}			$V_{DD}-0.2$		$V_{DD}+0.2$		
	V_{LC3}			0.5	$0.5 V_{DD}$	0.5	V	
				$V_{DD}-0.2$		$V_{DD}+0.2$		
				0.25	$0.25 V_{DD}$	0.25	V	
				$V_{DD}-0.2$		$V_{DD}+0.2$		
Supply Current ²	I_{DD1} ³	Run Mode; $V_{DD} = 5.0\text{V}$; crystal oscillator $C1 = C2 = 22\text{pF}$	4.2MHz	–	1.2	2.0	mA	
			12.0MHz	–	2.2	4.0	mA	
	I_{DD2} ³	Idle Mode; $V_{DD} = 5.0\text{V}$; crystal oscillator $C1 = C2 = 22\text{pF}$	$V_{DD} = 3.0\text{V}$	4.2MHz	–	0.8	1.5	mA
				4.2MHz	–	0.8	1.5	mA
				12.0MHz	–	1.3	2.3	mA
	I_{DD3} ⁴	Suboperating Mode; 32,768Hz crystal oscillator, $V_{DD} = 3.0\text{V}$, $T_A = 25^{\circ}\text{C}$	4.2MHz	–	0.4	0.8	mA	
			–	80.0	120.0	μA		
I_{DD4} ⁴	Subidle Mode; 32,768Hz crystal oscillator, $V_{DD} = 3.0\text{V}$, $T_A = 25^{\circ}\text{C}$		–	6.0	15.0	μA		
I_{DD5} ⁵	Stop Mode; $V_{DD} = 5.0\text{V}$		–	0.3	6.0	μA		

Notes:

1. Every value in this table is measured when bits 4–3 of the System Clock Control Register (CLKCON.4–.3) is set to 11b.
2. Supply current does not include current drawn through internal pull-up resistors, LCD voltage-dividing resistors, the LVR block, and external output current loads.
3. I_{DD1} and I_{DD2} include a power consumption of subclock oscillation.
4. I_{DD3} and I_{DD4} are the current when the main clock oscillation stops and the subclock is used.
5. I_{DD5} is the current when the main and subclock oscillation stops.

Table 103. AC Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

Parameter	Symbol	Conditions	Min.*	Typ.	Max.	Unit
Interrupt input high, low width (P3.0–P3.7)	t_{INTH}	All interrupt, $V_{DD} = 5\text{V}$	500	–	–	ns
	t_{INTL}					
nRESET input low width	t_{RSL}	Input, $V_{DD} = 5\text{V}$	10	–	–	ns

Note: If the width of the interrupt or reset pulse is greater than the minimum value, the pulse is always recognized as a valid pulse.

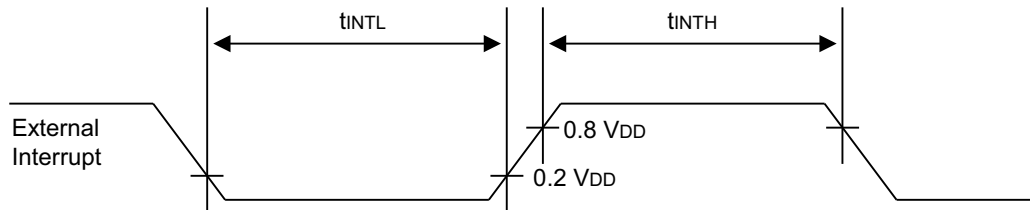


Figure 121. Input Timing for External Interrupts

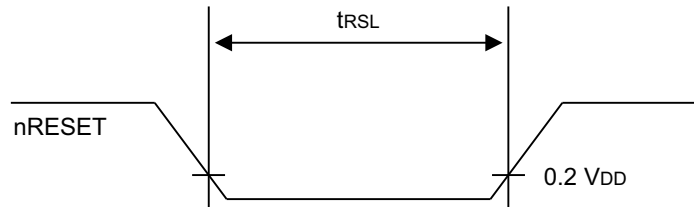


Figure 122. Input Timing for nRESET

Table 104. Input/Output Capacitance ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 0\text{V}$)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input capacitance	C_{IN}	$f = 1\text{ MHz}$; unmeasured pins are returned to V_{SS}	–	–	10	pF
Output capacitance	C_{OUT}	–	–	–	–	–
I/O capacitance	C_{IO}	–	–	–	–	–

Table 105. Data Retention Supply Voltage in Stop Mode ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Data retention supply voltage	V_{DDDR}	–	1.8	–	5.5	V
Data retention supply current	I_{DDDR}	Stop Mode, $T_A = 25^{\circ}\text{C}$, $V_{DDDR} = 1.8\text{V}$	–	–	1	μA

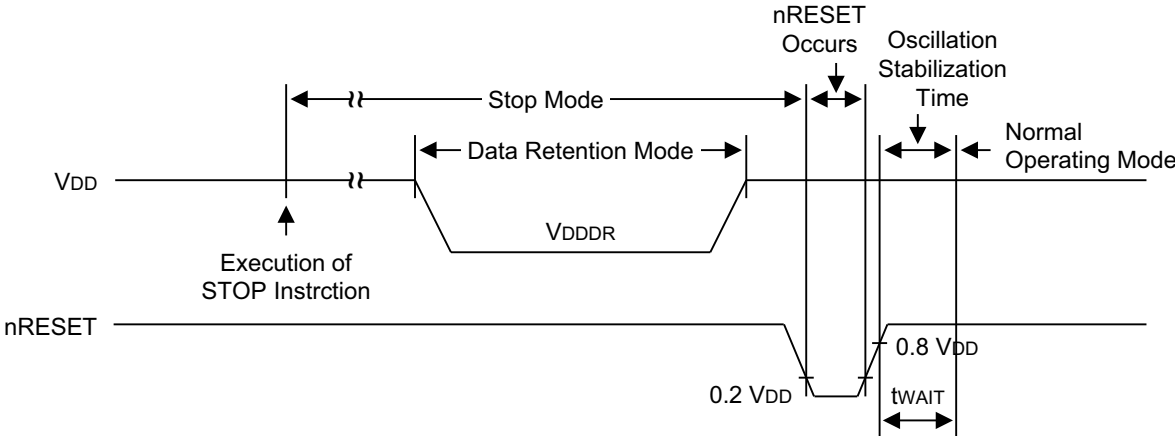


Figure 123. Stop Mode Release Timing Initiated by nRESET

► **Note:** In Figure 123, t_{WAIT} is the same as $4096 \times 16 \times 1 \div f_{XX}$.

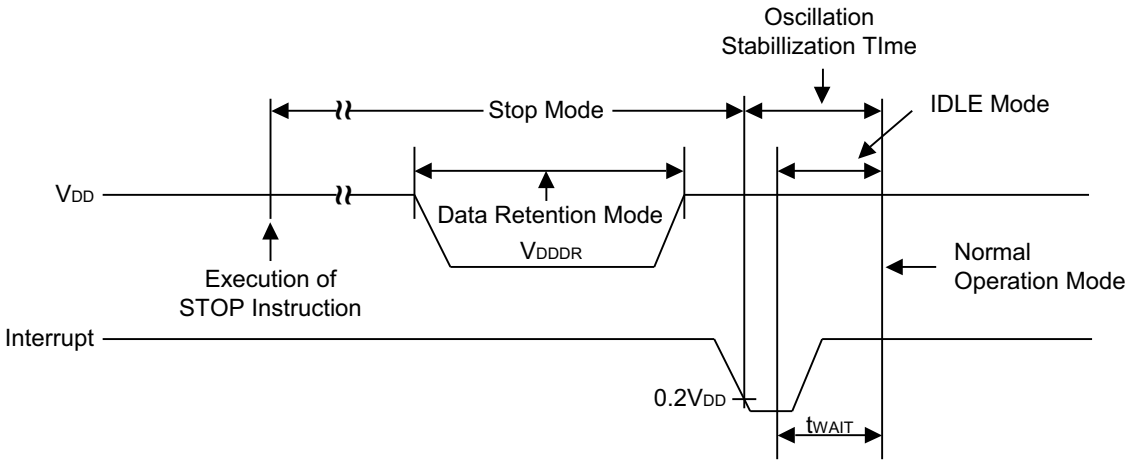


Figure 124. Stop Mode Release Timing Initiated by Interrupts

► **Note:** In Figure 124, t_{WAIT} is the same as $16 \times 1 / f_{BT}$; f_{BT} = the basic timer clock selection.

Table 106. A/D Converter Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V , $V_{SS} = 0\text{V}$)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Resolution	–	–	–	10	–	bit
Total accuracy	–	–	–	–	± 3	LSB
Integral linearity error	ILE	$V_{DD} = 5.120\text{V}$	–	–	± 2	LSB
Differential linearity error	DLE	$V_{SS} = 0\text{V}$ CPU clock = 12.0MHz	–	–	± 1	LSB
Offset error of top	EOT	–	–	–	± 3	LSB
Offset error of bottom	EOB	–	–	–	± 3	LSB
Conversion time ¹	T_{CON}	–	25	–	–	μs
Analog input voltage	V_{IAN}	–	V_{SS}	–	AV_{REF}	V
Analog input impedance	R_{AN}	–	2	1000	–	M Ω
Analog reference voltage	AV_{REF}	–	1.8	–	V_{DD}	V
Analog input current	I_{ADIN}	$V_{DD} = 5.0\text{V}$	–	–	10	μA
Analog block current ²	I_{ADC}	$V_{DD} = 5.0\text{V}$ $V_{DD} = 5.0\text{V}$ when in Power Down Mode	–	0.5	1.5	mA
			–	100	500	nA

Notes:

1. Conversion time is the time required from the moment a conversion operation starts until it ends.
2. I_{ADC} is an operating current during A/D converter.

Table 107. Low Voltage Reset Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)*

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Voltage of LVR	V_{LVR}	$T_A = 25^{\circ}\text{C}$	1.8	1.9	2.0	V
			2.6	2.8	3.0	V
V_{DD} voltage rising time	t_R	–	10	–	–	μs
V_{DD} voltage off time	t_{OFF}	–	0.5	–	–	s
Hysteresis	ΔV	–	–	50	150	mV
Current consumption of LVR	I_{LVR}	$V_{DD} = 3.0\text{V}$	–	30	60	μA

Note: *The current of the LVR circuit is consumed when LVR is enabled by the Smart Option.



Figure 125. Low Voltage Reset Timing

Table 108. Synchronous SIO Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
SCK cycle time	t_{KCY}	External SCK source	1000	–	–	ns
		Internal SCK source	1000	–	–	ns
SCK high, low width	t_{KH}, t_{KL}	External SCK source	500	–	–	ns
		Internal SCK source	$t_{KCY}/2-50$	–	–	ns
SI setup time to SCK high	t_{SIK}	External SCK source	250	–	–	ns
		Internal SCK source	250	–	–	ns
SI hold time to SCK high	t_{KSI}	External SCK source	400	–	–	ns
		Internal SCK source	400	–	–	ns
Output delay for SCK to SO	t_{KSO}	External SCK source	–	–	300	ns
		Internal SCK source	–	–	250	ns

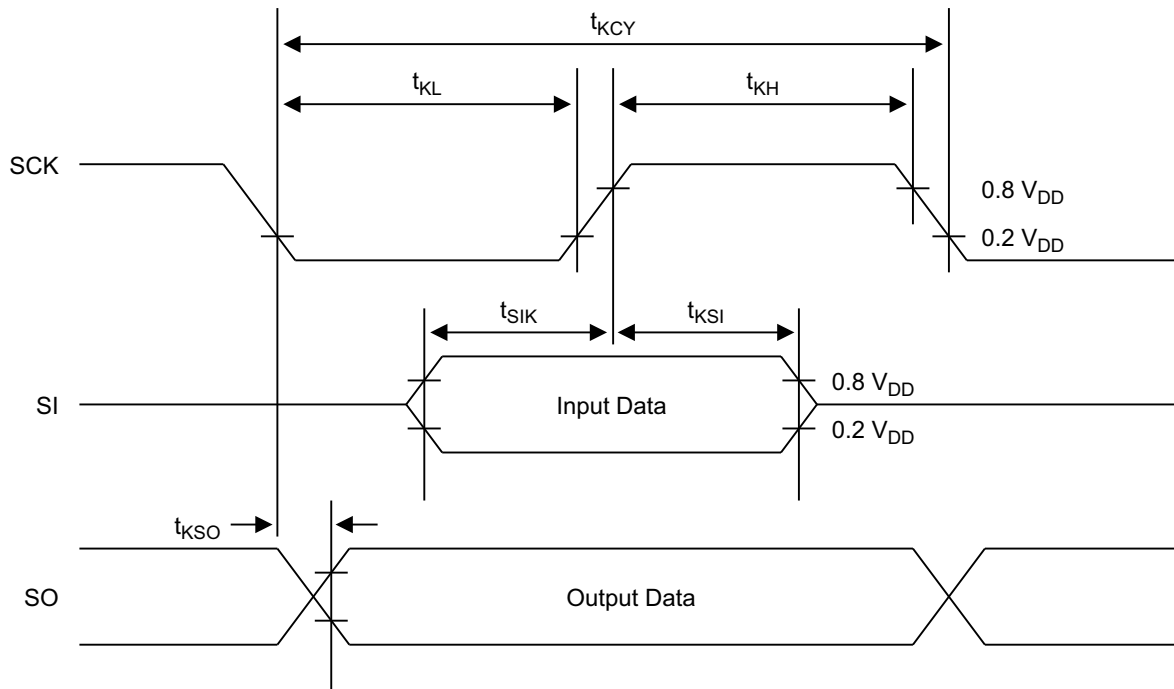


Figure 126. Serial Data Transfer Timing

Table 109. UART Timing Characteristics in Mode 0¹
(12.0 MHz; $T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V ; Load Capacitance = 80pF)

Parameter	Symbol	Min.	Typ.	Max.	Unit
Serial port clock cycle time ²	t_{SCK}	1160	$t_{CPU} \times 16$	1500	ns
Output data setup to clock rising edge	t_{S1}	500	$t_{CPU} \times 13$	–	ns
Clock rising edge to input data valid	t_{S2}	–	–	500	ns
Output data hold after clock rising edge ²	t_{H1}	$t_{CPU} - 50$	t_{CPU}	–	ns
Input data hold after clock rising edge	t_{H2}	0	–	–	ns
Serial port clock High, Low level width ²	t_{HIGH}, t_{LOW}	450	$t_{CPU} \times 8$	890	ns

Notes:

1. All timings are in nanoseconds (ns) and assume a 12.0MHz CPU clock frequency.
2. $t_{CPU} = 1$ UART clock period.

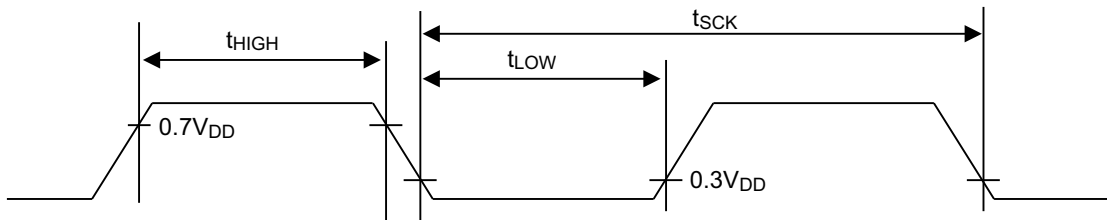


Figure 127. Waveform for UART Timing Characteristics

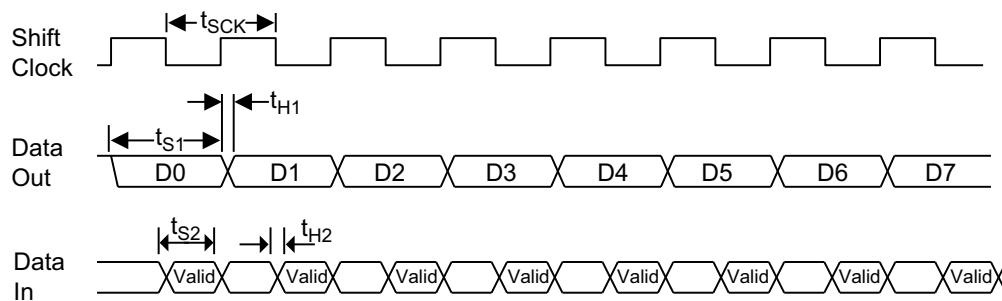


Figure 128. Timing Waveform for the UART Module

► **Notes:** The symbols shown in Figure 128 are defined as:

- f_{SCK} = Serial port clock cycle time.
- t_{S1} = Output data setup to clock rising edge.
- t_{S2} = Clock rising edge to input data valid.
- t_{H1} = Output data hold after clock rising edge.
- t_{H2} = Input data hold after clock rising edge.

Table 110. Main Oscillator Characteristics ($T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

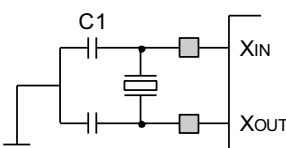
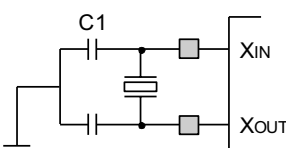
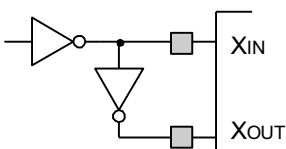
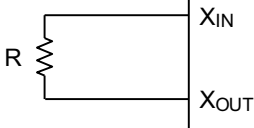
Oscillator	Clock Configuration	Parameter	Test				Unit
			Condition	Min.	Typ.	Max.	
Crystal		Main oscillation frequency	2.2V–5.5V	0.4	–	12.0	MHz
			1.8V–5.5V	0.4	–	4.2	MHz
Ceramic oscillator		Main oscillation frequency	2.2V–5.5V	0.4	–	12.0	MHz
			1.8V–5.5V	0.4	–	4.2	MHz
External clock		X_{IN} input frequency	2.2V–5.5V	0.4	–	12.0	MHz
			1.8V–5.5V	0.4	–	4.2	MHz
RC oscillator		Frequency	5.0V	0.4	–	2.0	MHz
			3.0V	0.4	–	1.0	MHz

Table 111. Suboscillation Characteristics ($T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

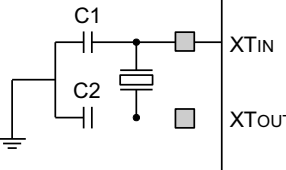
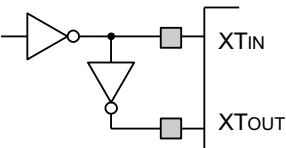
Oscillator	Clock Configuration	Parameter	Test				Unit
			Condition	Min.	Typ.	Max.	
Crystal		Suboscillation frequency	1.8V–5.5V	–	32.768	–	kHz
External clock		X_{TIN} frequency	1.8V–5.5V	32	–	100	kHz

Table 112. Main Oscillation Stabilization Time ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

Parameter	Test Condition	Min.	Typ.	Max.	Unit
Crystal	$f_X > 1\text{ MHz}$; oscillation stabilization occurs when V_{DD} is equal to the minimum oscillator voltage range.	–	–	40	ms
Ceramic		–	–	10	ms
External clock	X_{IN} input high and low width (t_{XH} , t_{XL})	62.5	–	1250	ns

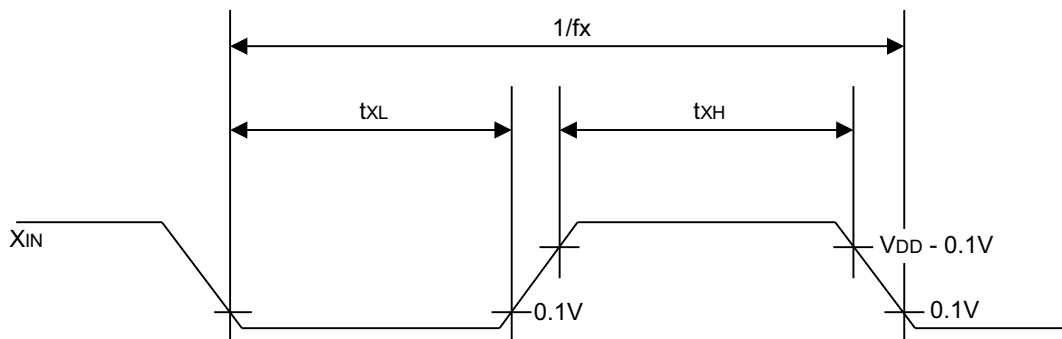


Figure 129. Clock Timing Measurement at X_{IN}

Table 113. Suboscillation Stabilization Time ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

Parameter	Test Condition	Min.	Typ.	Max.	Unit
Crystal	–	–	–	10	s
External clock	X_{TIN} input high and low width (t_{XTH} , t_{XTL})	5	–	15	μs

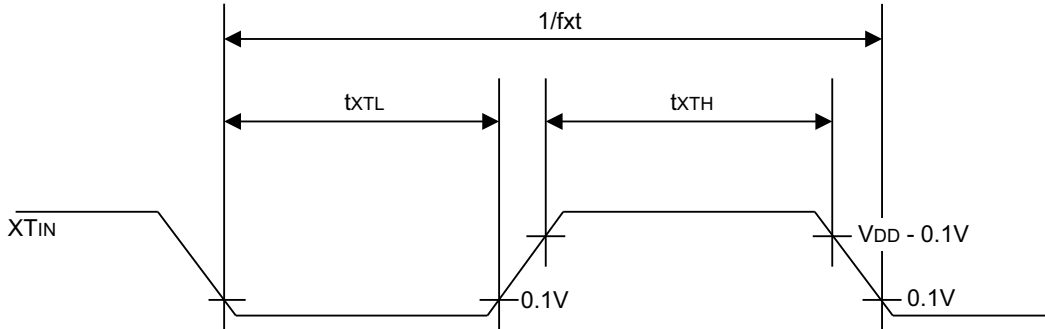


Figure 130. Clock Timing Measurement at XT_{IN}

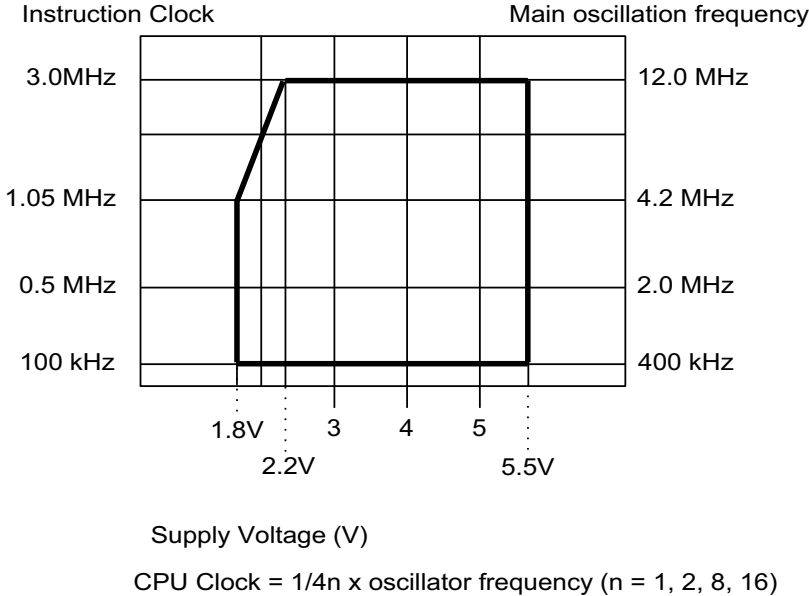


Figure 131. Operating Voltage Range

Table 114. Internal Flash ROM Electrical Characteristics ($T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V}$ to 5.5V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Programming time ¹	Ftp	–	20	25	30	μs
Chip erasing time ²	Ftp1	–	32	50	70	ms
Sector erasing time ³	Ftp2	–	4	8	12	ms
Number of writes/erases	FN_{WE}	–	–	–	10000 ⁴	times

Notes:

1. Programming time = the time during which one byte (8-bit) is programmed.
2. Chip erasing time = the time during which the entire 64KB block is erased.
3. Sector erasing time = the time during which the entire 128-byte block is erased.
4. Chip erasing is available in Tool Program Mode only.

Mechanical Data

The S3F8S5A microcontroller is currently available in 44-pin QFP and 42-pin SDIP packages. A mechanical drawing of the 44-pin QFP package is shown in Figure 132.

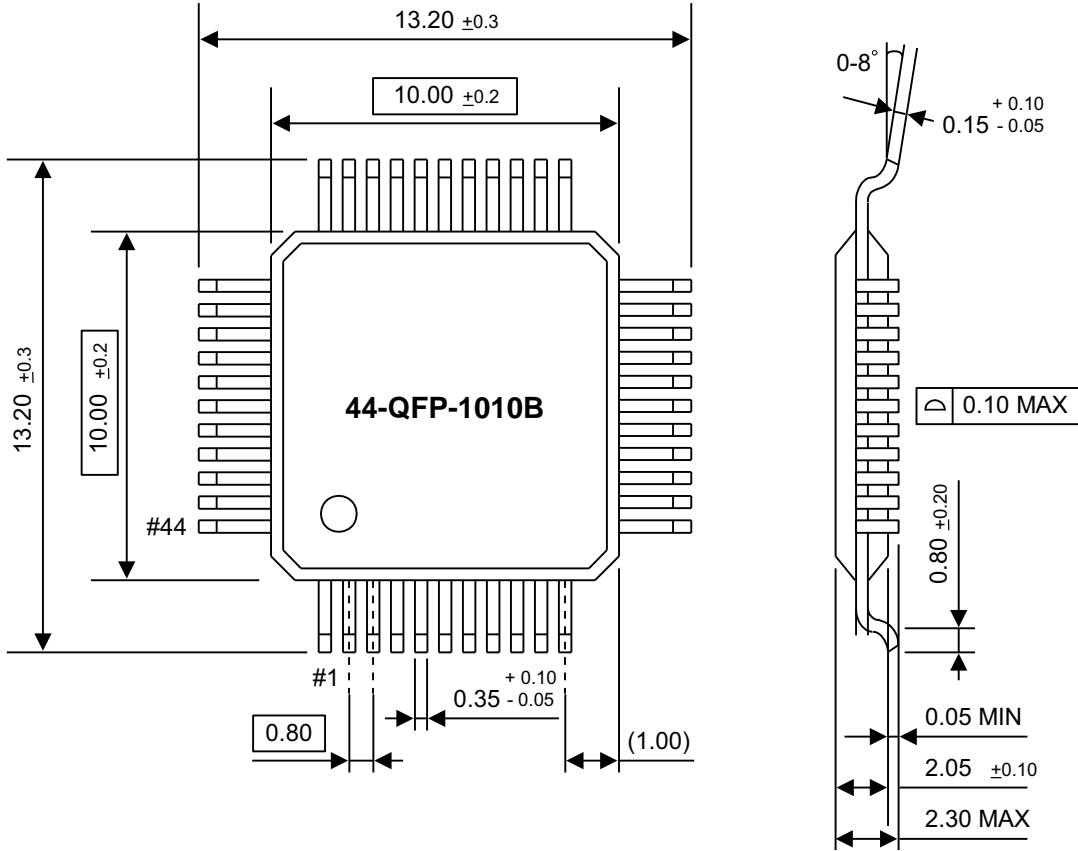


Figure 132. Package Dimensions, 44-Pin QFP Package

► **Note:** Dimensions in Figure 132 are expressed in millimeters.

A mechanical drawing of the 42-pin SDIP package is shown in Figure 133.

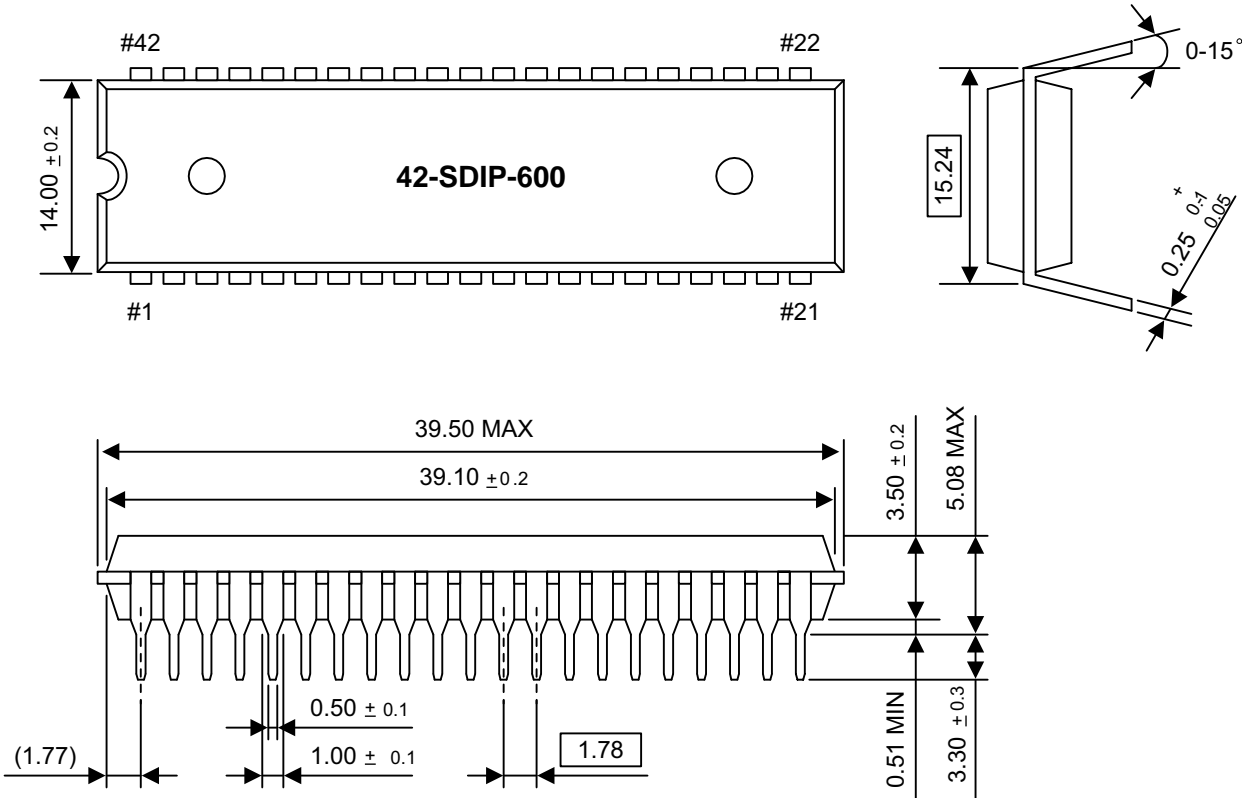


Figure 133. Package Dimensions, 42-pin SDIP Package

► **Note:** Dimensions in Figure 133 are expressed in millimeters.

S3F8S5A Flash MCU

This chapter describes Tool Program Mode operation for the S3F8S5A Flash MCU. To learn more about User Program Mode operation, refer to the [Embedded Flash Memory Interface](#) chapter on page 334.

The S3F8S5A microcontroller features an on-chip Flash MCU ROM which is accessed by serial data format.

Pin assignments for the 44-pin QFP package are shown in Figure 134.

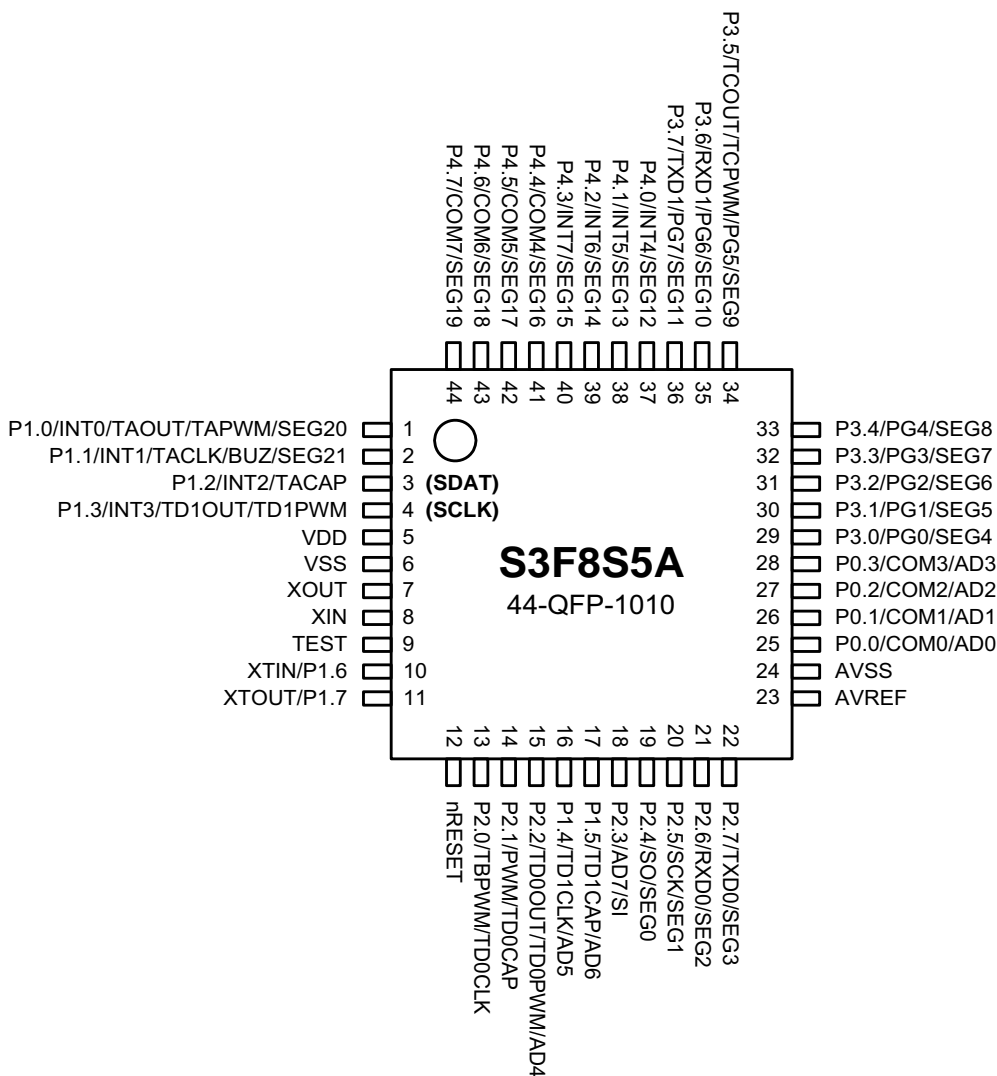


Figure 134. S3F8S5A Pin Assignments, 44-QFP Package

Pin assignments for the 42-pin SDIP package are shown in Figure 135.

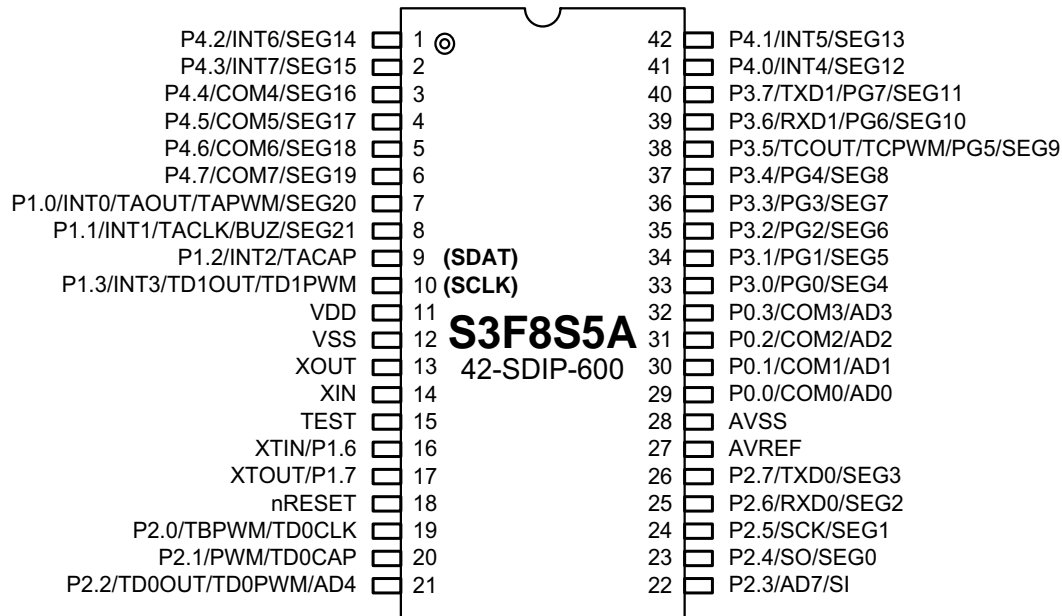


Figure 135. S3F8S5A Pin Assignments, 42-SDIP Package

Table 115. Pins Used to Read/Write the Flash ROM

Main Chip		During Programming			
Pin Name	Pin Name	Pins		I/O	Function
		44-Pin	42-Pin		
P1.2	SDAT	3	9	I/O	Serial data pin; output port when reading and input port when writing. Can be assigned as an input/push-pull output port.
P1.3	SCLK	4	10	I/O	Serial clock pin; input only.
TEST	V _{PP}	9	15	I	Tool Mode selection when TEST/ V _{PP} pin sets logic value 1. If using Flash writer in Tool Mode (e.g., spw2+, etc.), connect the TEST/V _{PP} pin to V _{DD} . The S3F8S5A MCU supplies 12.5V via the internal high-voltage generation circuit.
nRESET	nRESET	12	18	I	Chip initialization.
V _{DD}	V _{DD}	5	11	–	Power supply pin for logic circuit. V _{DD} should be tied to 5V during programming.
V _{SS}	V _{SS}	6	12	–	

Test Pin Voltage

The TEST pin on the socket board for the MTP Writer must be connected to V_{DD} (5.0V) with RC delay as shown in Figure 136 (only when SPW 2+ and GW-pro2 are used). The TEST pin on this socket board must not be connected to V_{PP} (12.5V), which is generated from the MTP Writer. Therefore, the specific socket board for the S3F8S5A MCU must be used when writing or erasing using the MTP Writer.

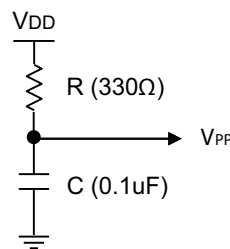


Figure 136. RC Delay Circuit

Onboard Writing

The S3F8S5A requires only six signal lines, including the V_{DD} and V_{SS} pins, for writing internal Flash memory with the serial protocol. Therefore, onboard writing is possible if the writing signal lines are considered when the application board is designed.

Circuit Design Guide

As Flash memory is being written to, the writing tool requires the following six signal lines: V_{SS} , V_{DD} , nRESET, TEST, SDAT, and SCLK. When designing the PCB circuits, consider how these signal lines will be used for onboard writing operations. The TEST pin is normally connected to V_{SS} ; however, in writing mode, a resistor should be inserted between the TEST pin and V_{SS} . The nRESET, SDAT, and SCLK lines should be treated with the same consideration.

when designing your application board, be careful that you design the circuitry related to these signal pins, because the rise and fall timing of the V_{PP} , SCLK, and SDAT lines will be very important for proper programming. See Figure 137.

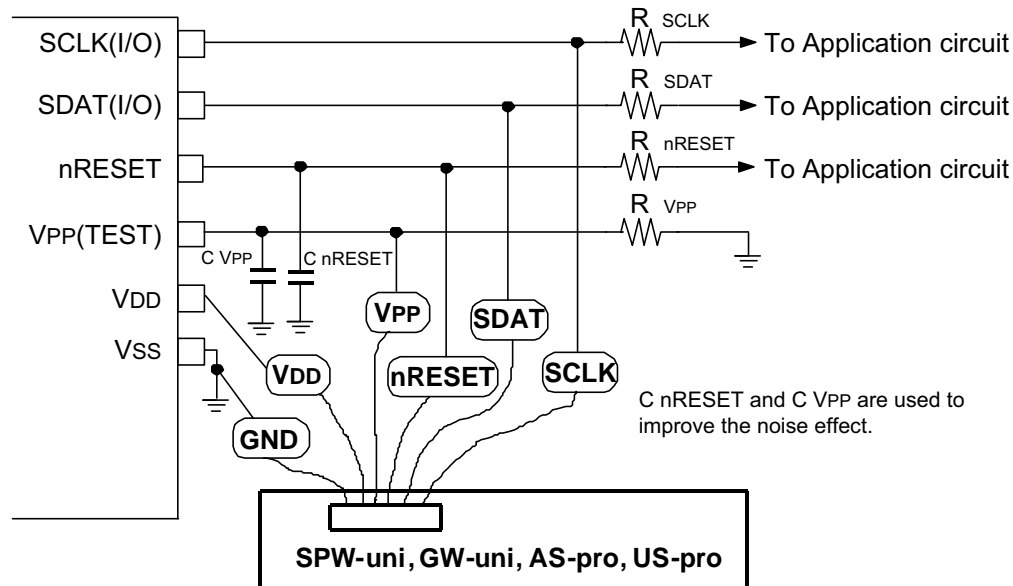


Figure 137. PCB Design Guide for on Board Programming

► **Note:** If the writer tool you are using is the SPW 2+ or the GW-pro2, refer to Figure 136.

Table 116. Circuit Connections

Pin Name	I/O Mode in Application	Resistor Required?	Required Value
V _{PP} (TEST)	Input	Yes	R _{V_{PP}} is 10kΩ to 50kΩ. C _{V_{PP}} is 0.01μF to 0.02μF.
nRESET	Input	Yes	R _{nRESET} is 2kΩ to 5kΩ. C _{nRESET} is 0.01μF to 0.02μF.
SDAT(I/O)	Input	Yes	R _{SDAT} is 2kΩ to 5kΩ.
	Output	No	–
SCLK(I/O)	Input	Yes	R _{SDAT} is 2kΩ to 5kΩ.
	Output	No	–

Note: In Onboard Writing Mode, a very high-speed signal will be provided to the SCLK and SDAT pins that can cause damage to the application circuits connected to the SCLK or SDAT ports if the application circuit is designed for high-speed response, such as a relay control circuit. If possible, the I/O configuration of the SDAT and SCLK pins must set to Input Mode. The value of R, C in this table is the recommended value; this value varies with the system circuitry.

Development Tools

Zilog provides a powerful and easy-to-use development support system on a turnkey basis. This development support system is composed of a host system, debugging tools, and supporting software. For a host system, any standard computer that employs Win95/98/2000/XP as its operating system can be used.

A sophisticated debugging tool is provided in both hardware and software formats: the powerful OPENice-i500/i2000 in-circuit emulator and the SK-1200 SmartKit. Zilog also offers supporting software that includes a debugger, an assembler, and a program for setting options.

Development System Configuration

Figure 138 shows the basic configuration of the development system.

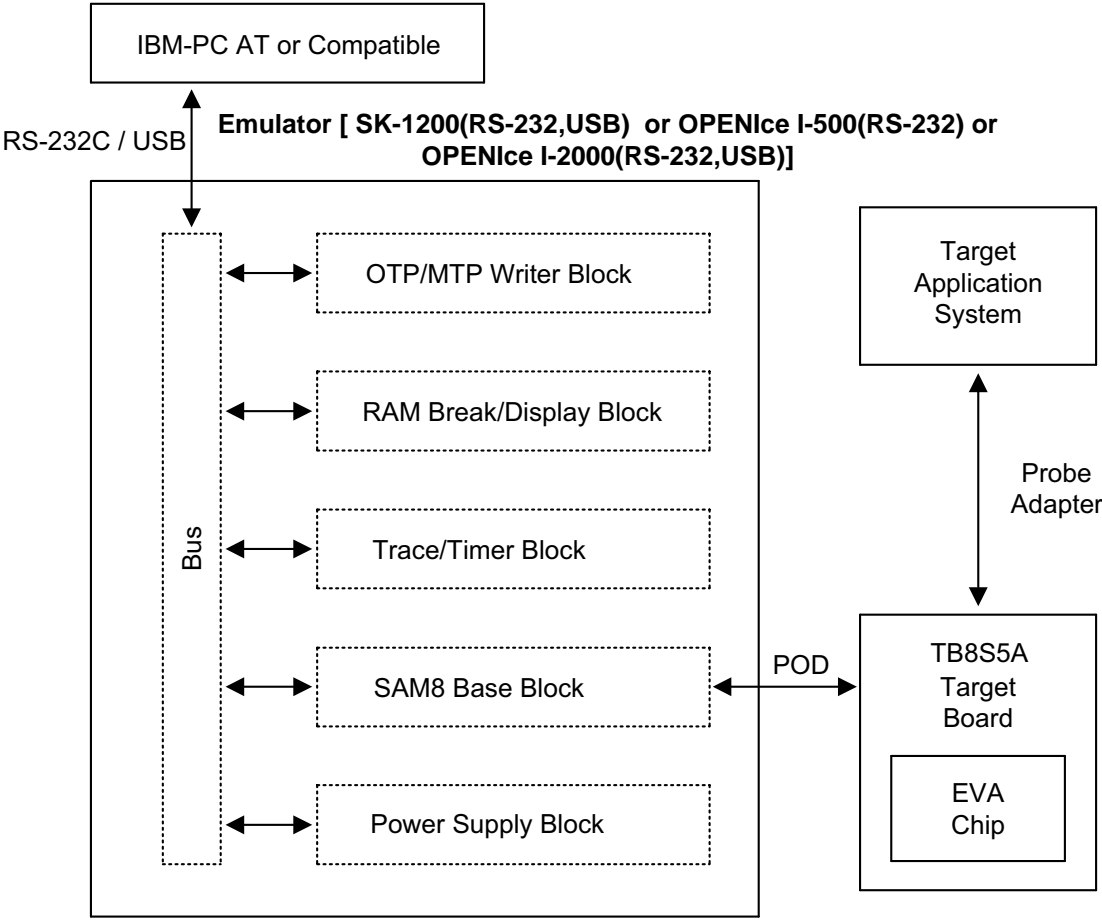



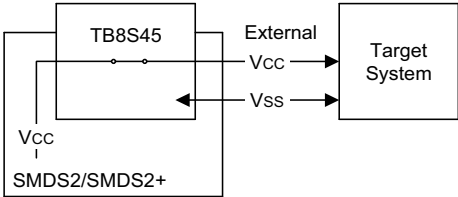

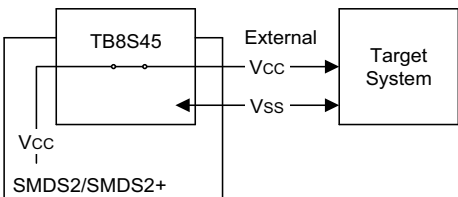
Figure 138. Development System Configuration

Target Board

The TB8S5A Target Board is specific to the S3F8S5A MCU, and ships complete with all target system cables and adapters. This target board is operated as a target CPU with an emulator (OPENIce I-500/2000, SK-1200).

Table 117 shows the TB8S5A Target Board’s power selection settings.

Table 117. Power Selection Settings for the TB8S5A Target Board

To User_V _{CC} Settings	Operating Mode	Comments
To user_V _{DD} off  on		The SMDS2/SMDS2+ main board supplies V _{DD} to the target board (evaluation chip) and the target system.
To user_V _{DD} off  on		The SMDS2/SMDS2+ main board supplies V _{DD} only to the target board (evaluation chip). The target system must have its own power supply.

SMDS2+ Selection

To write data into the available program memory in the SMDS2+ C Compiler, select the target board for SMDS2+ through a switch. Otherwise, the program memory writing function is not available. Table 118 depicts the SMDS2+ tool selection setting.

Table 118. SMDS2+ Tool Selection Setting


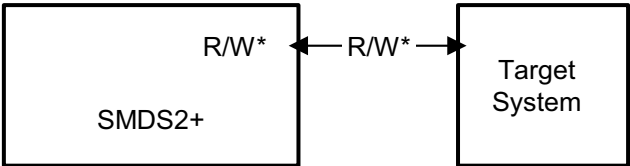
JP4 Setting	Operating Mode
SMDS2  SMDS2+	

Table 119 depicts the use of single header pins to select clock source, PWM, or operation mode.

Table 119. Single Header Pins to Select Clock Source/PWM/Operation Mode

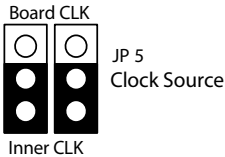
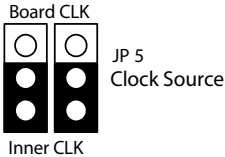
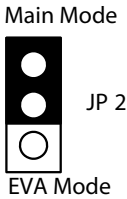
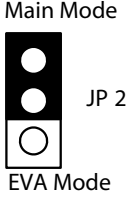
Target Board Part	Description
 <p>Board CLK JP 5 Clock Source Inner CLK</p>	<p>Uses the SMDS2/SMDS2+ internal clock source as the system clock; default setting.</p>
 <p>Board CLK JP 5 Clock Source Inner CLK</p>	<p>Uses an external crystal or a ceramic oscillator as the system clock.</p>
 <p>Main Mode JP 2 EVA Mode</p>	<p>The S3E8S50 evaluation chip runs in Main Mode; a debug interface is not available.</p>
 <p>Main Mode JP 2 EVA Mode</p>	<p>The S3E8S50 evaluation chip runs in EVA Mode. When running a debug program, set the jumper to this mode; default setting.</p>

Table 120 depicts the use of single header pins as the input path for external trigger sources.

Table 120. Single Header Pins as Input Path for External Trigger Sources

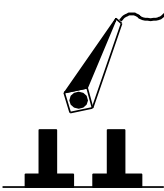
Target Board Part	Description
External Triggers	 <p>Connector from External Trigger Sources of the Application System</p>
○ Ch1(TP3)	
○ Ch2(TP4)	
<p>You can connect an external trigger source to one of the two external trigger channels (CH1 or CH2) for the SK-1000/SMDS2+ breakpoint and trace functions.</p>	

Figure 139 depicts the DIP switch for the Smart Option.

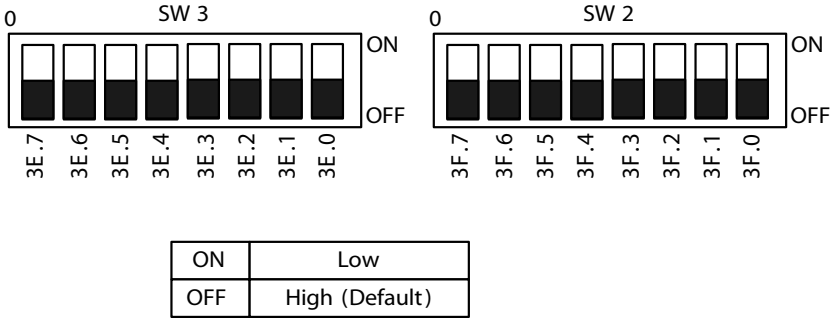


Figure 139. DIP Switch for the Smart Option

► **Note:** In Figure 139, particularly for the EVA chip, the Smart Option is determined by the DIP switch, not the software. The reserved bits should remain at their default values; i.e., High.

Target Board LEDs

IDLE LED. This LED is ON when the S3E8S50 evaluation chip is in Idle Mode.

STOP LED. This LED is ON when the S3E8S50 evaluation chip is in Stop Mode.

Figure 140 shows the pin assignments for the TB8S5A Target Board's 48-pin connector.

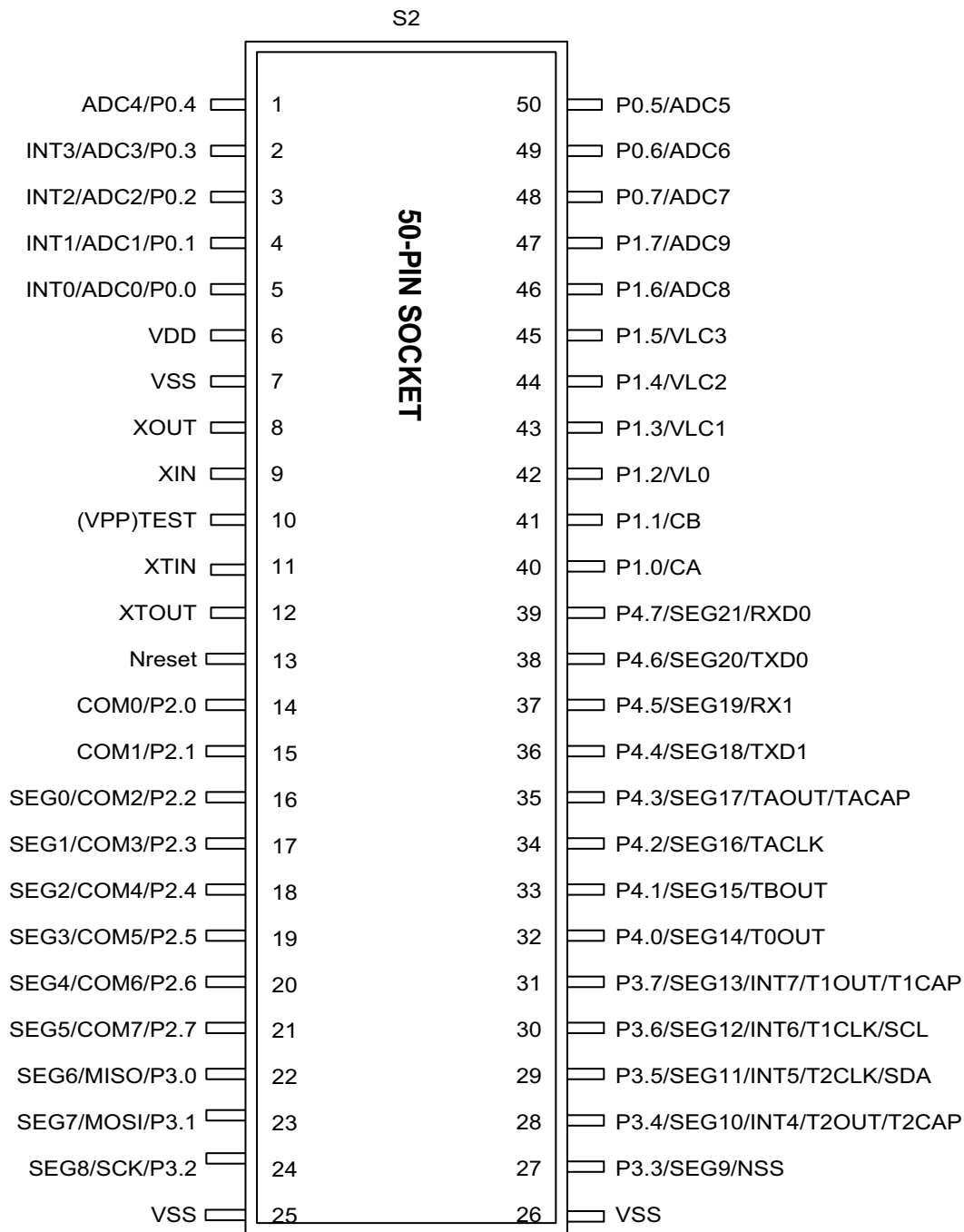


Figure 140. TB8S5A 48-Pin Connector

Figure 141 shows the S3F8S5A MCU's probe adapter for the 48-pin package.

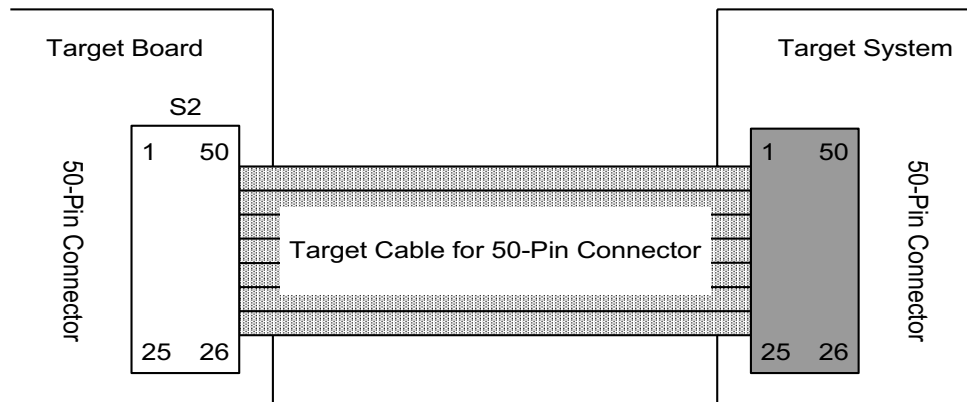


Figure 141. S3F8S5A Probe Adapter for the 44-Pin Package

Third Parties for Development Tools

Zilog provides a complete line of development tools that support the S3 Family of Microcontrollers. With long experience in developing MCU systems, these third party firms are bonafide leaders in MCU development tool technology.

In-circuit emulators:

- OPENice-i500/2000
- SK-1200 SmartKit

OTP/MTP Programmers:

- SPW-uni
- GW-uni (8-gang programmer)
- AS-pro

To obtain the S3 Family development tools that will satisfy your S3F8S5A development objectives, contact your local [Zilog Sales Office](#), or visit Zilog's [Third Party Tools page](#) to review our list of third party tool suppliers.

Ordering Information

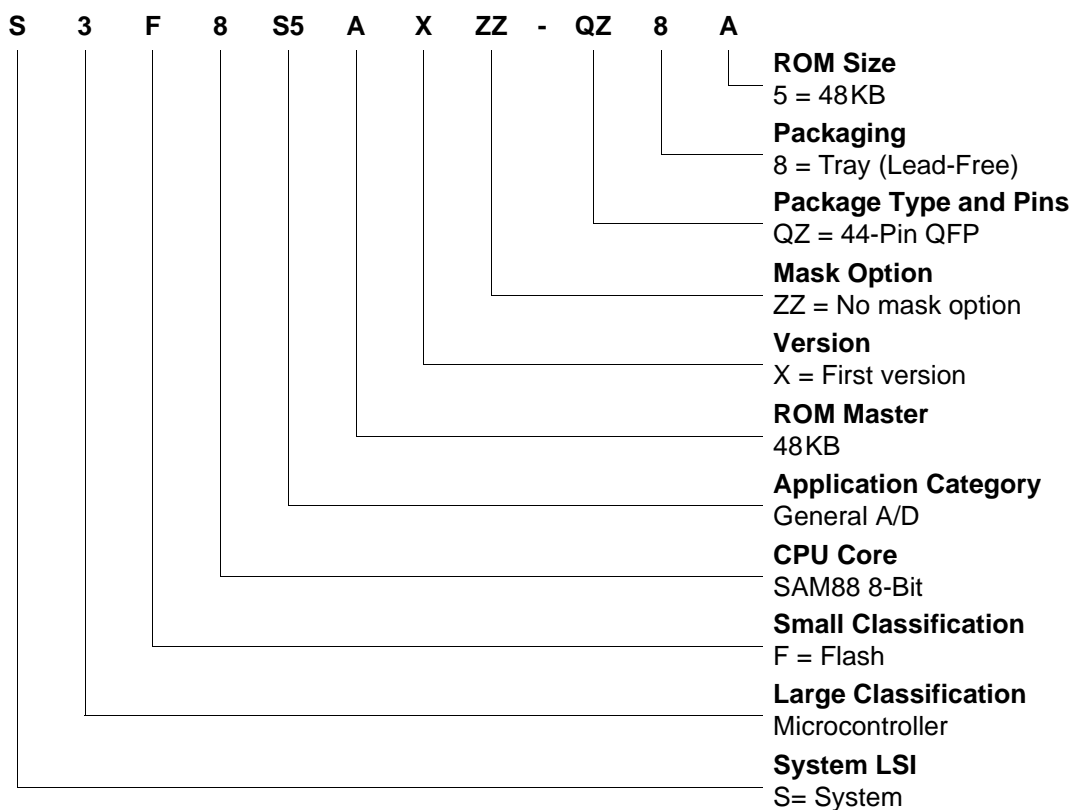
Table 121 identifies the basic features and package styles available for the S3F8S5A MCU.

Table 121. Ordering Information for the S3F8S5A MCU

Device	Flash Size	RAM Size	LCD	GPIO	ADC	Package
S3F8S5AXZZ-QZ8A	48KB	1040B	18 x 8	34	8	44-Pin QFP
S3F8S5AXZZ-AQ9A	48KB	1040B	18 x 8	32	6	42-Pin SDIP

Part Number Suffix Designations

Zilog part numbers consist of a number of components. For example, part number S3F8S5AXZZ-QZ8A is an unmasked 8-bit MCU with 48KB of Flash memory in a 44-pin QFP package and built using lead-free solder.



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