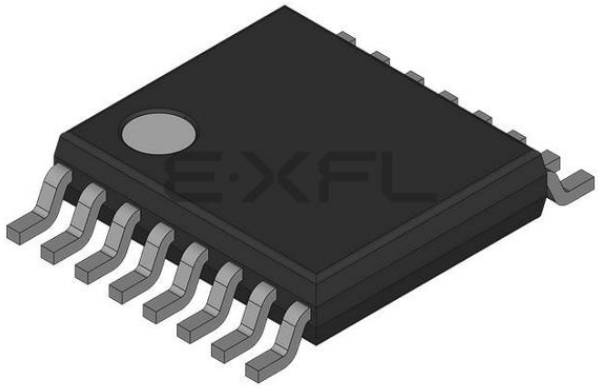

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Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	S08
Core Size	8-Bit
Speed	40MHz
Connectivity	I²C, LINbus, SCI, SPI
Peripherals	LVD, POR, PWM, WDT
Number of I/O	12
Program Memory Size	4KB (4K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	256 x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 5.5V
Data Converters	A/D 8x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 105°C (TA)
Mounting Type	Surface Mount
Package / Case	16-TSSOP (0.173", 4.40mm Width)
Supplier Device Package	16-TSSOP
Purchase URL	https://www.e-xfl.com/pro/item?MUrl=&PartUrl=s9s08sg4e2vtg

Chapter 1
Device Overview

The MC9S08SG8 members of the low-cost, high-performance HCS08 family of 8-bit microcontroller units (MCUs). All MCUs in the family use the enhanced HCS08 core and are available with a variety of modules, memory sizes, memory types, and package types. The high-temperature devices have been qualified to meet or exceed AEC Grade 0 requirements to allow them to operate up to 150 °C TA.

1.1 Devices in the MC9S08SG8 Series

Table 1-1 summarizes the feature set available in the MC9S08SG8 series of MCUs.

Table 1-1. MC9S08SG8 Features by MCU and Package

Feature	9S08SG8			9S08SG4		
FLASH size (bytes)	8192			4096		
RAM size (bytes)	512			256		
Pin quantity	20	16	8	20	16	8
ACMP	yes					
ADC channels	12	8	4	12	8	4
DBG	yes					
ICS	yes	yes	yes[1]	yes	yes	yes [1]
IIC	yes					
MTIM	yes					
Pin Interrupts	8	8	4	8	8	4
Pin I/O	16	12	4	16	12	4
RTC	yes					
SCI	yes	yes	no	yes	yes	no
SPI	yes	yes	no	yes	yes	no
TPM1 channels	2	2	1	2	2	1
TPM2 channels	2	2	1	2	2	1
XOSC	yes	yes	no	yes	yes	no

[1] FBE and FEE modes are not available in 8-pin packages.

Chapter 3
Modes of Operation

3.1 Introduction

The operating modes of the MC9S08SG8 are described in this chapter. Entry into each mode, exit from each mode, and functionality while in each of the modes are described.

3.2 Features

- Active background mode for code development
- Wait mode — CPU shuts down to conserve power; system clocks are running and full regulation is maintained
- Stop modes — System clocks are stopped and voltage regulator is in standby
  - Stop3 — All internal circuits are powered for fast recovery
  - Stop2 — Partial power down of internal circuits, RAM content is retained

3.3 Run Mode

This is the normal operating mode for the MC9S08SG8. This mode is selected upon the MCU exiting reset if the BKGD/MS pin is high. In this mode, the CPU executes code from internal memory with execution beginning at the address fetched from memory at 0xFFFE–0xFFFF after reset.

3.4 Active Background Mode

The active background mode functions are managed through the background debug controller (BDC) in the HCS08 core. The BDC, together with the on-chip debug module (DBG), provide the means for analyzing MCU operation during software development.

Active background mode is entered in any of the following ways:

- When the BKGD/MS pin is low during POR or immediately after issuing a background debug force reset (see Section 5.7.2, “System Background Debug Force Reset Register (SBDFR)”)
- When a BACKGROUND command is received through the BKGD/MS pin
- When a BGND instruction is executed
- When encountering a BDC breakpoint
- When encountering a DBG breakpoint

After entering active background mode, the CPU is held in a suspended state waiting for serial background commands rather than executing instructions from the user application program.

Table 3-2. Stop Mode Behavior

Peripheral	Mode	
	Stop2	Stop3
CPU	Off	Standby
RAM	Standby	Standby
FLASH	Off	Standby
Parallel Port Registers	Off	Standby
ADC	Off	Optionally On[1]
ACMP	Off	Optionally On[2]
BDM	Off[3]	Optionally On
ICS	Off	Optionally On[4]
IIC	Off	Standby
LVD/LVW	Off[5]	Optionally On
MTIM	Off	Standby
RTC	Optionally On	Optionally On
SCI	Off	Standby
SPI	Off	Standby
TPM	Off	Standby
Voltage Regulator	Standby	Optionally On[6]
XOSC	Off	Optionally On[7]
I/O Pins	States Held	States Held

1 Requires the asynchronous ADC clock and LVD to be enabled, else in standby.

2 Requires the LVD to be enabled when compare to internal bandgap reference option is enabled.

3 If ENBDM is set when entering stop2, the MCU will actually enter stop3.

4 IRCLKEN and IREFSTEN set in ICSC1, else in standby.

5 If LVDSE is set when entering stop2, the MCU will actually enter stop3.

6 Voltage regulator will be on if BDM is enabled or if LVD is enabled when entering stop3.

7 ERCLKEN and EREFSTEN set in ICSC2, else in standby. For high frequency range (RANGE in ICSC2 set) requires the LVD to also be enabled in stop3.

Nonvolatile FLASH registers, shown in Table 4-4, are located in the FLASH memory. These registers include an 8-byte backdoor key, NVBACKKEY, which can be used to gain access to secure memory resources. During reset events, the contents of NVPROT and NVOPT in the nonvolatile register area of the FLASH memory are transferred into corresponding FPROT and FOPT working registers in the high-page registers to control security and block protection options.

Table 4-4. Nonvolatile Register Summary

Address	Register Name	Bit 7	6	5	4	3	2	1	Bit 0
0xFFAE	Reserved for storage of FTRIM	—	—	—	—	—	—	—	FTRIM
0xFFAF	Reserved for storage of ICSTRM	TRIM							
0xFFB0 – 0xFFB7	NVBACKKEY	8-Byte Comparison Key							
0xFFB8 – 0xFFBC	Reserved	— —	— —	— —	— —	— —	— —	— —	— —
0xFFBD	NVPROT	FPS							FPDIS
0xFFBE	Reserved	—	—	—	—	—	—	—	—
0xFFBF	NVOPT	KEYEN	FNORED	—	—	—	—	SEC	

Provided the key enable (KEYEN) bit is 1, the 8-byte comparison key can be used to temporarily disengage memory security. This key mechanism can be accessed only through user code running in secure memory. (A security key cannot be entered directly through background debug commands.) This security key can be disabled completely by programming the KEYEN bit to 0. If the security key is disabled, the only way to disengage security is by mass erasing the FLASH if needed (normally through the background debug interface) and verifying that FLASH is blank. To avoid returning to secure mode after the next reset, program the security bits (SEC) to the unsecured state (1:0).

5.7.3 System Options Register 1 (SOPT1)

This high page register is a write-once register so only the first write after reset is honored. It can be read at any time. Any subsequent attempt to write to SOPT1 (intentionally or unintentionally) is ignored to avoid accidental changes to these sensitive settings. SOPT1 should be written during the user's reset initialization program to set the desired controls even if the desired settings are the same as the reset settings.

	7	6	5	4[1]	3	2	1	0
R	COPT		STOPE		0	IICPS	0	0
W								
Reset:	1	1	0	0	0	0	0	0

= Unimplemented or Reserved

Figure 5-4. System Options Register 1 (SOPT1)

1 NOTE: Bit 4 is reserved. Writes change the value, but have no effect on this MCU.

Table 5-5. SOPT1 Register Field Descriptions

Field	Description
7:6 COPT[1:0]	**COP Watchdog Timeout** — These write-once bits select the timeout period of the COP. COPT along with COPCLKS in SOPT2 defines the COP timeout period. See Table 5-1.
5 STOPE	**Stop Mode Enable** — This write-once bit is used to enable stop mode. If stop mode is disabled and a user program attempts to execute a STOP instruction, an illegal opcode reset is forced. 0 Stop mode disabled. 1 Stop mode enabled.
2 IICPS	**IIC Pin Select** — This bit selects the location of the SDA and SCL pins of the IIC module. 0 SDA on PTA2, SCL on PTA3. 1 SDA on PTB6, SCL on PTB7.

5.7.6 System Power Management Status and Control 1 Register (SPMSC1)

This high page register contains status and control bits to support the low voltage detect function, and to enable the bandgap voltage reference for use by the ADC module.

	7	6	5	4	3	2	1	0
R	LVWF[1]	0	LVWIE	LVDRE	LVDSE	LVDE	0	BGBE
W		LVWACK						
Reset:	0	0	0	1	1	1	0	0

= Unimplemented or Reserved

[1] LVWF will be set in the case when V_{Supply} transitions below the trip point or after reset and V_{Supply} is already below V_{LVW}

Figure 5-8. System Power Management Status and Control 1 Register (SPMSC1)

Table 5-9. SPMSC1 Register Field Descriptions

Field	Description
7 LVWF	**Low-Voltage Warning Flag** — The LVWF bit indicates the low voltage warning status. 0 Low voltage warning is not present. 1 Low voltage warning is present or was present.
6 LVWACK	**Low-Voltage Warning Acknowledge** — The LVWF bit indicates the low voltage warning status.Writing a 1 to LVWACK clears LVWF to a 0 if a low voltage warning is not present.
5 LVWIE	**Low-Voltage Warning Interrupt Enable** — This bit enables hardware interrupt requests for LVWF. 0 Hardware interrupt disabled (use polling). 1 Request a hardware interrupt when LVWF = 1.
4 LVDRE	**Low-Voltage Detect Reset Enable** — This write-once bit enables LVD events to generate a hardware reset (provided LVDE = 1). 0 LVD events do not generate hardware resets. 1 Force an MCU reset when an enabled low-voltage detect event occurs.
3 LVDSE	**Low-Voltage Detect Stop Enable** — Provided LVDE = 1, this control bit determines whether the low-voltage detect function operates when the MCU is in stop mode. 0 Low-voltage detect disabled during stop mode. 1 Low-voltage detect enabled during stop mode.
2 LVDE	**Low-Voltage Detect Enable** — This write-once bit enables low-voltage detect logic and qualifies the operation of other bits in this register. 0 LVD logic disabled. 1 LVD logic enabled.
0 BGBE	**Bandgap Buffer Enable** — This bit enables an internal buffer for the bandgap voltage reference for use by the ADC module on one of its internal channels or ACMP on its ACMP+ input. 0 Bandgap buffer disabled. 1 Bandgap buffer enabled.

Chapter 7
Central Processor Unit (S08CPUV2)

7.1 Introduction

This section provides summary information about the registers, addressing modes, and instruction set of the CPU of the HCS08 Family. For a more detailed discussion, refer to the *HCS08 Family Reference Manual, volume 1,* Freescale Semiconductor document order number HCS08RMV1/D.

The HCS08 CPU is fully source- and object-code-compatible with the M68HC08 CPU. Several instructions and enhanced addressing modes were added to improve C compiler efficiency and to support a new background debug system which replaces the monitor mode of earlier M68HC08 microcontrollers (MCU).

7.1.1 Features

Features of the HCS08 CPU include:

- Object code fully upward-compatible with M68HC05 and M68HC08 Families
- All registers and memory are mapped to a single 64-Kbyte address space
- 16-bit stack pointer (any size stack anywhere in 64-Kbyte address space)
- 16-bit index register (H:X) with powerful indexed addressing modes
- 8-bit accumulator (A)
- Many instructions treat X as a second general-purpose 8-bit register
- Seven addressing modes:
  - Inherent — Operands in internal registers
  - Relative — 8-bit signed offset to branch destination
  - Immediate — Operand in next object code byte(s)
  - Direct — Operand in memory at 0x0000–0x00FF
  - Extended — Operand anywhere in 64-Kbyte address space
  - Indexed relative to H:X — Five submodes including auto increment
  - Indexed relative to SP — Improves C efficiency dramatically
- Memory-to-memory data move instructions with four address mode combinations
- Overflow, half-carry, negative, zero, and carry condition codes support conditional branching on the results of signed, unsigned, and binary-coded decimal (BCD) operations
- Efficient bit manipulation instructions
- Fast 8-bit by 8-bit multiply and 16-bit by 8-bit divide instructions
- STOP and WAIT instructions to invoke low-power operating modes

Chapter 9
Analog-to-Digital Converter (S08ADCV1)

9.1 Introduction

The 10-bit analog-to-digital converter (ADC) is a successive approximation ADC designed for operation within an integrated microcontroller system-on-chip.

NOTE

The MC9S08SG8 Family of devices do not include stop1 mode.

The ADC channel assignments, alternate clock function, and hardware trigger function are configured as described below for the MC9S08SG8 family of devices.

9.1.1 Channel Assignments

The ADC channel assignments for the MC9S08SG8 devices are shown in Table 9-1. Reserved channels convert to an unknown value.

Table 9-1. ADC Channel Assignment

ADCH	Channel	Input
00000	AD0	PTA0/ADP0
00001	AD1	PTA1/ADP1
00010	AD2	PTA2/ADP2
00011	AD3	PTA3/ADP3
00100	AD4	PTB0/ADP4
00101	AD5	PTB1/ADP5
00110	AD6	PTB2/ADP6
00111	AD7	PTB3/ADP7
01000	AD8	PTC0/ADP8
01001	AD9	PTC1/ADP9
01010	AD10	PTC2/ADP10
01011	AD11	PTC3/ADP11
01100	AD12	V_{SS}
01101	AD13	V_{SS}
01110	AD14	V_{SS}
01111	AD15	V_{SS}

ADCH	Channel	Input
10000	AD16	V_{SS}
10001	AD17	V_{SS}
10010	AD18	V_{SS}
10011	AD19	V_{SS}
10100	AD20	V_{SS}
10101	AD21	Reserved
10110	AD22	Reserved
10111	AD23	Reserved
11000	AD24	Reserved
11001	AD25	Reserved
11010	AD26	Temperature Sensor[1]
11011	AD27	Internal Bandgap[2]
11100	-	Reserved
11101	V_{REFH}	V_{DD}
11110	V_{REFL}	V_{SS}
11111	Module Disabled	None

1 For information, see Section 9.1.4, “Temperature Sensor”.

2 Requires BGBE =1 in SPMSC1 see Section 5.7.7, “System Power Management Status and Control 2 Register (SPMSC2)”. For value of bandgap voltage reference see A.6, “DC Characteristics”.

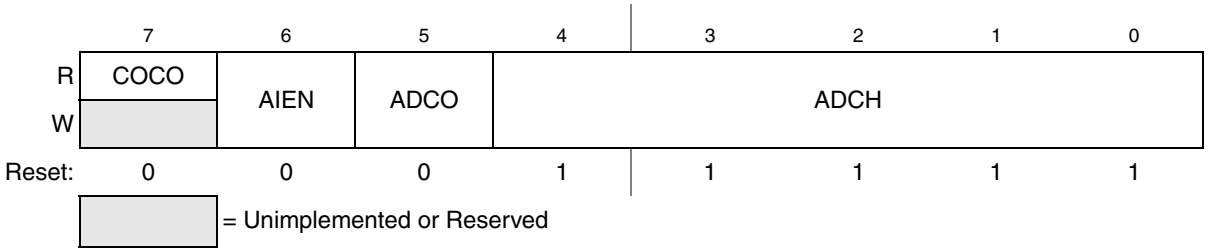

Figure 9-3. Status and Control Register (ADCSC1)

Table 9-3. ADCSC1 Register Field Descriptions

Field	Description
7 COCO	**Conversion Complete Flag** — The COCO flag is a read-only bit which is set each time a conversion is completed when the compare function is disabled (ACFE = 0). When the compare function is enabled (ACFE = 1) the COCO flag is set upon completion of a conversion only if the compare result is true. This bit is cleared whenever ADCSC1 is written or whenever ADCRL is read. 0 Conversion not completed 1 Conversion completed
6 AIEN	**Interrupt Enable** — AIEN is used to enable conversion complete interrupts. When COCO becomes set while AIEN is high, an interrupt is asserted. 0 Conversion complete interrupt disabled 1 Conversion complete interrupt enabled
5 ADCO	**Continuous Conversion Enable** — ADCO is used to enable continuous conversions. 0 One conversion following a write to the ADCSC1 when software triggered operation is selected, or one conversion following assertion of ADHWT when hardware triggered operation is selected. 1 Continuous conversions initiated following a write to ADCSC1 when software triggered operation is selected. Continuous conversions are initiated by an ADHWT event when hardware triggered operation is selected.
4:0 ADCH	**Input Channel Select** — The ADCH bits form a 5-bit field which is used to select one of the input channels. The input channels are detailed in Figure 9-4. The successive approximation converter subsystem is turned off when the channel select bits are all set to 1. This feature allows for explicit disabling of the ADC and isolation of the input channel from all sources. Terminating continuous conversions this way will prevent an additional, single conversion from being performed. It is not necessary to set the channel select bits to all 1s to place the ADC in a low-power state when continuous conversions are not enabled because the module automatically enters a low-power state when a conversion completes.

Figure 9-4. Input Channel Select

ADCH	Input Select
00000	AD0
00001	AD1
00010	AD2
00011	AD3
00100	AD4
00101	AD5
00110	AD6
00111	AD7

ADCH	Input Select
10000	AD16
10001	AD17
10010	AD18
10011	AD19
10100	AD20
10101	AD21
10110	AD22
10111	AD23

- CLKS bits are written to 00
- IREFS bit is written to 1
- RDIV bits are written to divide trimmed reference clock to be within the range of 31.25 kHz to 39.0625 kHz.

In FLL engaged internal mode, the ICSOUT clock is derived from the FLL clock, which is controlled by the internal reference clock. The FLL loop will lock the frequency to 1024 times the reference frequency, as selected by the RDIV bits. The ICSLCLK is available for BDC communications, and the internal reference clock is enabled.

10.4.1.2 FLL Engaged External (FEE)

The FLL engaged external (FEE) mode is entered when all the following conditions occur:

- CLKS bits are written to 00
- IREFS bit is written to 0
- RDIV bits are written to divide reference clock to be within the range of 31.25 kHz to 39.0625 kHz

In FLL engaged external mode, the ICSOUT clock is derived from the FLL clock which is controlled by the external reference clock.The FLL loop will lock the frequency to 1024 times the reference frequency, as selected by the RDIV bits. The ICSLCLK is available for BDC communications, and the external reference clock is enabled.

10.4.1.3 FLL Bypassed Internal (FBI)

The FLL bypassed internal (FBI) mode is entered when all the following conditions occur:

- CLKS bits are written to 01
- IREFS bit is written to 1.
- BDM mode is active or LP bit is written to 0

In FLL bypassed internal mode, the ICSOUT clock is derived from the internal reference clock. The FLL clock is controlled by the internal reference clock, and the FLL loop will lock the FLL frequency to 1024 times the reference frequency, as selected by the RDIV bits. The ICSLCLK will be available for BDC communications, and the internal reference clock is enabled.

10.4.1.4 FLL Bypassed Internal Low Power (FBILP)

The FLL bypassed internal low power (FBILP) mode is entered when all the following conditions occur:

- CLKS bits are written to 01
- IREFS bit is written to 1.
- BDM mode is not active and LP bit is written to 1

In FLL bypassed internal low power mode, the ICSOUT clock is derived from the internal reference clock and the FLL is disabled. The ICSLCLK will be not be available for BDC communications, and the internal reference clock is enabled.

Freescale-provided equate or header file is used to translate these names into the appropriate absolute addresses.

11.3.1 IIC Address Register (IICA)

	7	6	5	4	3	2	1	0
R	AD7	AD6	AD5	AD4	AD3	AD2	AD1	0
W								
Reset	0	0	0	0	0	0	0	0

= Unimplemented or Reserved

Figure 11-3. IIC Address Register (IICA)

Table 11-2. IICA Field Descriptions

Field	Description
7–1 AD[7:1]	**Slave Address.** The AD[7:1] field contains the slave address to be used by the IIC module. This field is used on the 7-bit address scheme and the lower seven bits of the 10-bit address scheme.

11.3.2 IIC Frequency Divider Register (IICF)

	7	6	5	4	3	2	1	0
R	MULT		ICR					
W								
Reset	0	0	0	0	0	0	0	0

Figure 11-4. IIC Frequency Divider Register (IICF)

11.4 Functional Description

This section provides a complete functional description of the IIC module.

11.4.1 IIC Protocol

The IIC bus system uses a serial data line (SDA) and a serial clock line (SCL) for data transfer. All devices connected to it must have open drain or open collector outputs. A logic AND function is exercised on both lines with external pullup resistors. The value of these resistors is system dependent.

Normally, a standard communication is composed of four parts:

- Start signal
- Slave address transmission
- Data transfer
- Stop signal

The stop signal should not be confused with the CPU stop instruction. The IIC bus system communication is described briefly in the following sections and illustrated in Figure 11-9.

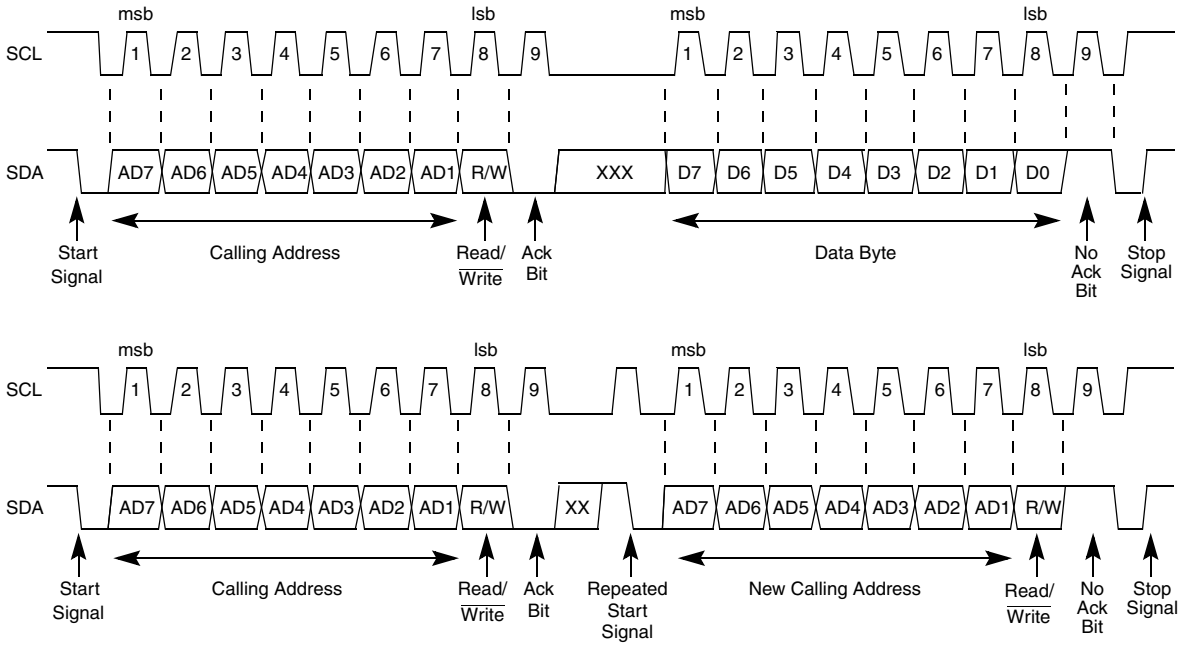

Figure 11-9. IIC Bus Transmission Signals

11.4.1.1 Start Signal

When the bus is free, no master device is engaging the bus (SCL and SDA lines are at logical high), a master may initiate communication by sending a start signal. As shown in Figure 11-9, a start signal is defined as a high-to-low transition of SDA while SCL is high. This signal denotes the beginning of a new data transfer (each data transfer may contain several bytes of data) and brings all slaves out of their idle states.

11.7 Initialization/Application Information

Module Initialization (Slave)

1. Write: IICC2
   — to enable or disable general call
   — to select 10-bit or 7-bit addressing mode
2. Write: IICA
   — to set the slave address
3. Write: IICC1
   — to enable IIC and interrupts
4. Initialize RAM variables (IICEN = 1 and IICIE = 1) for transmit data
5. Initialize RAM variables used to achieve the routine shown in Figure 11-12

Module Initialization (Master)

1. Write: IICF
   — to set the IIC baud rate (example provided in this chapter)
2. Write: IICC1
   — to enable IIC and interrupts
3. Initialize RAM variables (IICEN = 1 and IICIE = 1) for transmit data
4. Initialize RAM variables used to achieve the routine shown in Figure 11-12
5. Write: IICC1
   — to enable TX

Register Model

IICA	AD[7:1]							0
	When addressed as a slave (in slave mode), the module responds to this address							
IICF	MULT		ICR					
	Baud rate = BUSCLK / (2 x MULT x (SCL DIVIDER))							
IICC1	IICEN	IICIE	MST	TX	TXAK	RSTA	0	0
	Module configuration							
IICS	TCF	IAAS	BUSY	ARBL	0	SRW	IICIF	RXAK
	Module status flags							
IICD	DATA							
	Data register; Write to transmit IIC data read to read IIC data							
IICC2	GCAEN	ADEXT	0	0	0	AD10	AD9	AD8
	Address configuration							

Figure 11-11. IIC Module Quick Start

12.1.2 Features

Timer system features include:

- 8-bit up-counter
  - — Free-running or 8-bit modulo limit
  - — Software controllable interrupt on overflow
  - — Counter reset bit (TRST)
  - — Counter stop bit (TSTP)
- Four software selectable clock sources for input to prescaler:
  - — System bus clock — rising edge
  - — Fixed frequency clock (XCLK) — rising edge
  - — External clock source on the TCLK pin — rising edge
  - — External clock source on the TCLK pin — falling edge
- Nine selectable clock prescale values:
  - — Clock source divide by 1, 2, 4, 8, 16, 32, 64, 128, or 256

12.1.3 Modes of Operation

This section defines the MTIM's operation in stop, wait and background debug modes.

12.1.3.1 MTIM in Wait Mode

The MTIM continues to run in wait mode if enabled before executing the WAIT instruction. Therefore, the MTIM can be used to bring the MCU out of wait mode if the timer overflow interrupt is enabled. For lowest possible current consumption, the MTIM should be stopped by software if not needed as an interrupt source during wait mode.

12.1.3.2 MTIM in Stop Modes

The MTIM is disabled in all stop modes, regardless of the settings before executing the STOP instruction. Therefore, the MTIM cannot be used as a wake up source from stop modes.

Waking from stop1 and stop2 modes, the MTIM will be put into its reset state. If stop3 is exited with a reset, the MTIM will be put into its reset state. If stop3 is exited with an interrupt, the MTIM continues from the state it was in when stop3 was entered. If the counter was active upon entering stop3, the count will resume from the current value.

12.1.3.3 MTIM in Active Background Mode

The MTIM suspends all counting until the microcontroller returns to normal user operating mode. Counting resumes from the suspended value as long as an MTIM reset did not occur (TRST written to a 1 or MTIMMOD written).

Chapter 13
Real-Time Counter (S08RTCV1)

13.1 Introduction

The RTC module consists of one 8-bit counter, one 8-bit comparator, several binary-based and decimal-based prescaler dividers, two clock sources, and one programmable periodic interrupt. This module can be used for time-of-day, calendar or any task scheduling functions. It can also serve as a cyclic wake up from low power modes without the need of external components.

Instead of hardware interrupts, software polling may be used to monitor the TDRE and TC status flags if the corresponding TIE or TCIE local interrupt masks are 0s.

When a program detects that the receive data register is full (RDRF = 1), it gets the data from the receive data register by reading SCID. The RDRF flag is cleared by reading SCIS1 while RDRF = 1 and then reading SCID.

When polling is used, this sequence is naturally satisfied in the normal course of the user program. If hardware interrupts are used, SCIS1 must be read in the interrupt service routine (ISR). Normally, this is done in the ISR anyway to check for receive errors, so the sequence is automatically satisfied.

The IDLE status flag includes logic that prevents it from getting set repeatedly when the RxD line remains idle for an extended period of time. IDLE is cleared by reading SCIS1 while IDLE = 1 and then reading SCID. After IDLE has been cleared, it cannot become set again until the receiver has received at least one new character and has set RDRF.

If the associated error was detected in the received character that caused RDRF to be set, the error flags — noise flag (NF), framing error (FE), and parity error flag (PF) — get set at the same time as RDRF. These flags are not set in overrun cases.

If RDRF was already set when a new character is ready to be transferred from the receive shifter to the receive data buffer, the overrun (OR) flag gets set instead the data along with any associated NF, FE, or PF condition is lost.

At any time, an active edge on the RxD serial data input pin causes the RXEDGIF flag to set. The RXEDGIF flag is cleared by writing a “1” to it. This function does depend on the receiver being enabled (RE = 1).

14.3.5 Additional SCI Functions

The following sections describe additional SCI functions.

14.3.5.1 8- and 9-Bit Data Modes

The SCI system (transmitter and receiver) can be configured to operate in 9-bit data mode by setting the M control bit in SCIC1. In 9-bit mode, there is a ninth data bit to the left of the MSB of the SCI data register. For the transmit data buffer, this bit is stored in T8 in SCIC3. For the receiver, the ninth bit is held in R8 in SCIC3.

For coherent writes to the transmit data buffer, write to the T8 bit before writing to SCID.

If the bit value to be transmitted as the ninth bit of a new character is the same as for the previous character, it is not necessary to write to T8 again. When data is transferred from the transmit data buffer to the transmit shifter, the value in T8 is copied at the same time data is transferred from SCID to the shifter.

9-bit data mode typically is used in conjunction with parity to allow eight bits of data plus the parity in the ninth bit. Or it is used with address-mark wakeup so the ninth data bit can serve as the wakeup bit. In custom protocols, the ninth bit can also serve as a software-controlled marker.

15.5 Functional Description

An SPI transfer is initiated by checking for the SPI transmit buffer empty flag (SPTEF = 1) and then writing a byte of data to the SPI data register (SPID) in the master SPI device. When the SPI shift register is available, this byte of data is moved from the transmit data buffer to the shifter, SPTEF is set to indicate there is room in the buffer to queue another transmit character if desired, and the SPI serial transfer starts.

During the SPI transfer, data is sampled (read) on the MISO pin at one SPSCK edge and shifted, changing the bit value on the MOSI pin, one-half SPSCK cycle later. After eight SPSCK cycles, the data that was in the shift register of the master has been shifted out the MOSI pin to the slave while eight bits of data were shifted in the MISO pin into the master's shift register. At the end of this transfer, the received data byte is moved from the shifter into the receive data buffer and SPRF is set to indicate the data can be read by reading SPID. If another byte of data is waiting in the transmit buffer at the end of a transfer, it is moved into the shifter, SPTEF is set, and a new transfer is started.

Normally, SPI data is transferred most significant bit (MSB) first. If the least significant bit first enable (LSBFE) bit is set, SPI data is shifted LSB first.

When the SPI is configured as a slave, its $\overline{SS}$ pin must be driven low before a transfer starts and $\overline{SS}$ must stay low throughout the transfer. If a clock format where CPHA = 0 is selected, $\overline{SS}$ must be driven to a logic 1 between successive transfers. If CPHA = 1, $\overline{SS}$ may remain low between successive transfers. See Section 15.5.1, "SPI Clock Formats" for more details.

Because the transmitter and receiver are double buffered, a second byte, in addition to the byte currently being shifted out, can be queued into the transmit data buffer, and a previously received character can be in the receive data buffer while a new character is being shifted in. The SPTEF flag indicates when the transmit buffer has room for a new character. The SPRF flag indicates when a received character is available in the receive data buffer. The received character must be read out of the receive buffer (read SPID) before the next transfer is finished or a receive overrun error results.

In the case of a receive overrun, the new data is lost because the receive buffer still held the previous character and was not ready to accept the new data. There is no indication for such an overrun condition so the application system designer must ensure that previous data has been read from the receive buffer before a new transfer is initiated.

15.5.1 SPI Clock Formats

To accommodate a wide variety of synchronous serial peripherals from different manufacturers, the SPI system has a clock polarity (CPOL) bit and a clock phase (CPHA) control bit to select one of four clock formats for data transfers. CPOL selectively inserts an inverter in series with the clock. CPHA chooses between two different clock phase relationships between the clock and data.

Figure 15-10 shows the clock formats when CPHA = 1. At the top of the figure, the eight bit times are shown for reference with bit 1 starting at the first SPSCK edge and bit 8 ending one-half SPSCK cycle after the sixteenth SPSCK edge. The MSB first and LSB first lines show the order of SPI data bits depending on the setting in LSBFE. Both variations of SPSCK polarity are shown, but only one of these waveforms applies for a specific transfer, depending on the value in CPOL. The SAMPLE IN waveform applies to the MOSI input of a slave or the MISO input of a master. The MOSI waveform applies to the

16.4.1.3 Counting Modes

The main timer counter has two counting modes. When center-aligned PWM is selected (CPWMS=1), the counter operates in up/down counting mode. Otherwise, the counter operates as a simple up counter. As an up counter, the timer counter counts from 0x0000 through its terminal count and then continues with 0x0000. The terminal count is 0xFFFF or a modulus value in TPMxMODH:TPMxMODL.

When center-aligned PWM operation is specified, the counter counts up from 0x0000 through its terminal count and then down to 0x0000 where it changes back to up counting. Both 0x0000 and the terminal count value are normal length counts (one timer clock period long). In this mode, the timer overflow flag (TOF) becomes set at the end of the terminal-count period (as the count changes to the next lower count value).

16.4.1.4 Manual Counter Reset

The main timer counter can be manually reset at any time by writing any value to either half of TPMxCNTH or TPMxCNTL. Resetting the counter in this manner also resets the coherency mechanism in case only half of the counter was read before resetting the count.

16.4.2 Channel Mode Selection

Provided CPWMS=0, the MSnB and MSnA control bits in the channel n status and control registers determine the basic mode of operation for the corresponding channel. Choices include input capture, output compare, and edge-aligned PWM.

16.4.2.1 Input Capture Mode

With the input-capture function, the TPM can capture the time at which an external event occurs. When an active edge occurs on the pin of an input-capture channel, the TPM latches the contents of the TPM counter into the channel-value registers (TPMxCnVH:TPMxCnVL). Rising edges, falling edges, or any edge may be chosen as the active edge that triggers an input capture.

In input capture mode, the TPMxCnVH and TPMxCnVL registers are read only.

When either half of the 16-bit capture register is read, the other half is latched into a buffer to support coherent 16-bit accesses in big-endian or little-endian order. The coherency sequence can be manually reset by writing to the channel status/control register (TPMxCnSC).

An input capture event sets a flag bit (CHnF) which may optionally generate a CPU interrupt request.

While in BDM, the input capture function works as configured by the user. When an external event occurs, the TPM latches the contents of the TPM counter (which is frozen because of the BDM mode) into the channel value registers and sets the flag bit.

16.4.2.2 Output Compare Mode

With the output-compare function, the TPM can generate timed pulses with programmable position, polarity, duration, and frequency. When the counter reaches the value in the channel-value registers of an output-compare channel, the TPM can set, clear, or toggle the channel pin.

17.3.6 Hardware Breakpoints

The BRKEN control bit in the DBGC register may be set to 1 to allow any of the trigger conditions described in Section 17.3.5, “Trigger Modes,” to be used to generate a hardware breakpoint request to the CPU. TAG in DBGC controls whether the breakpoint request will be treated as a tag-type breakpoint or a force-type breakpoint. A tag breakpoint causes the current opcode to be marked as it enters the instruction queue. If a tagged opcode reaches the end of the pipe, the CPU executes a BGND instruction to go to active background mode rather than executing the tagged opcode. A force-type breakpoint causes the CPU to finish the current instruction and then go to active background mode.

If the background mode has not been enabled (ENBDM = 1) by a serial WRITE_CONTROL command through the BKGD pin, the CPU will execute an SWI instruction instead of going to active background mode.

17.4 Register Definition

This section contains the descriptions of the BDC and DBG registers and control bits.

Refer to the high-page register summary in the device overview chapter of this data sheet for the absolute address assignments for all DBG registers. This section refers to registers and control bits only by their names. A Freescale-provided equate or header file is used to translate these names into the appropriate absolute addresses.

17.4.1 BDC Registers and Control Bits

The BDC has two registers:

- The BDC status and control register (BDCSCR) is an 8-bit register containing control and status bits for the background debug controller.
- The BDC breakpoint match register (BDCBKPT) holds a 16-bit breakpoint match address.

These registers are accessed with dedicated serial BDC commands and are not located in the memory space of the target MCU (so they do not have addresses and cannot be accessed by user programs).

Some of the bits in the BDCSCR have write limitations; otherwise, these registers may be read or written at any time. For example, the ENBDM control bit may not be written while the MCU is in active background mode. (This prevents the ambiguous condition of the control bit forbidding active background mode while the MCU is already in active background mode.) Also, the four status bits (BDMACT, WS, WSF, and DVF) are read-only status indicators and can never be written by the WRITE_CONTROL serial BDC command. The clock switch (CLKSW) control bit may be read or written at any time.

A.7 Supply Current Characteristics

This section includes information about power supply current in various operating modes.

Table A-7. Supply Current Characteristics

Num	C	Parameter	Symbol	V_{DD} (V)	Typ[1]	Max[2]	Unit	Temp Rated[3]	
								Standard	AEC Grade 0
1	C	Run supply current[4] measured at (CPU clock = 4 MHz, f_{Bus} = 2 MHz)	RI_{DD}	5	1.1	1.5	mA	x	x
	C			3	1	1.5		x	x
2	P	Run supply current[3] measured at (CPU clock = 16 MHz, f_{Bus} = 8 MHz)	RI_{DD}	5	3.9	5	mA	x	x
	C			3	3.9	5		x	x
3	C	Run supply current[5] measured at (CPU clock = 32 MHz, f_{Bus} = 16 MHz)	RI_{DD}	5	7.25	7.7	mA	x	x
	C			3	7.15	7.6		x	x
4		Stop3 mode supply current	$S3I_{DD}$						
	C	–40 °C (C & M suffix)		5	1.1	—	µA	x	
	P	25 °C (All parts)			1.5	—		x	
	P[6]	85 °C (C suffix only)			9.0	26		x	
	P[6]	105 °C (V suffix only)			20.6	60		x	
	P[6]	125 °C (M suffix only)			45.2	130		x	
	C	–40 °C (C & M suffix)		3	1.0	—	µA	x	
	C	25 °C (All parts)			1.4	—		x	
	C	85 °C (C suffix only)			7.8	19		x	
	C	105 °C (V suffix only)			18.2	45		x	
	C	125 °C (M suffix only)			40.1	95		x	
5		Stop2 mode supply current	$S2I_{DD}$						
	C	–40 °C (C & M suffix)		5	1.1	—	µA	x	
	P	25 °C (All parts)			1.4	—		x	
	P[6]	85 °C (C suffix only)			6.8	22		x	
	P[6]	105 °C (V suffix only)			15.2	50		x	
	P[6]	125 °C (M suffix only)			32.7	99		x	
	C	–40 °C (C & M suffix)		3	1.0	—	µA	x	
	C	25 °C (All parts)			1.3	—		x	
	C	85 °C (C suffix only)			5.8	16		x	
	C	105 °C (V suffix only)			13.1	36		x	
	C	125 °C (M suffix only)			28.3	76		x	