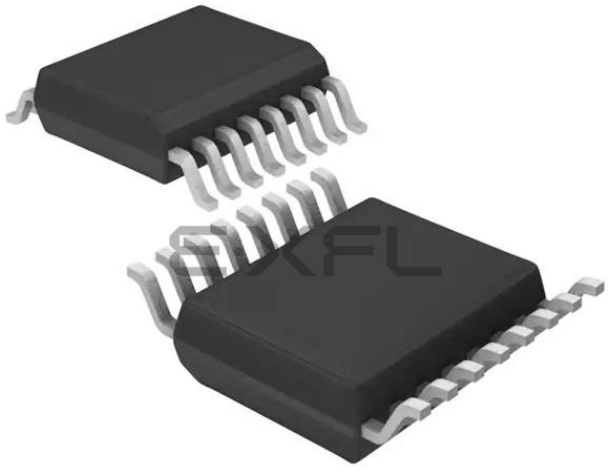

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Details	
Product Status	Active
Core Processor	S08
Core Size	8-Bit
Speed	40MHz
Connectivity	I²C, LINbus, SCI, SPI
Peripherals	LVD, POR, PWM, WDT
Number of I/O	12
Program Memory Size	16KB (16K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	1K x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 5.5V
Data Converters	A/D 8x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°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/product-detail/nxp-semiconductors/s9s08sg16e1ctgr

MC9S08SG32 DataSheet Addendum

by: Microcontroller Solutions Group

This is the MC9S08SG32 DataSheet set consisting of the following files:

- MC9S08SG32 DataSheet Addendum, Rev 1
- MC9S08SG32 DataSheet, Rev 8

Revision History

To provide the most up-to-date information, the revision of our documents on the World Wide Web will be the most current. Your printed copy may be an earlier revision. To verify you have the latest information available, refer to:

http://freescale.com/

The following revision history table summarizes changes contained in this document.

Revision Number	Revision Date	Description of Changes
1	6/2007	Updated the TPM module, incorporated minor revisions for the T_j, PTxSE slew rate, FPROT and Appendix B packaging information. -SAMPLES DRAFT-
2	10/2007	Qualify Draft includes updates to TPM module and the Electricals appendix. Also, revised the order numbering information.
3	5/2008	Updated some electricals and made some minor grammatical/formatting revisions. Corrected the SPI block module version. Removed incorrect ADC temperature sensor value from the Features section. Updated the package information with a special mask set identifier.
4	5/2008	Added the EMC Radiated Emissions data. Removed the Susceptibility Data. Updated the Corporate addresses on the back cover.
5	03/2009	Added the High Temperature Device Specifications and updated the charts.
6	04/2009	Updated ADC characteristics for Temp Sensor Slope to be a range of 25 C–150 Çadded Control Timing table row 2 to separate standard characteristics from the AEC Grade 0 characteristics, and included the text, “AEC Grade 0” to the text of footnote 3 for Table B-1 Device Numbering System. Added notes to the ADC chapter specifying that, for this device, there are only 16 analog input pins and consequently no APCTL3 register. Updated the Literature Request information on the back cover.
7	10/2009	Revised Table A-6 DC Characteristics, Row 24 Bandgap Voltage Reference for AEC Grade 0 from 1.21V to 1.22 V. Removed AEC Grade 0 (red diamond) from the Table A-9 ICS Frequency Specifications, Row 9 Total deviation of trimmed DCO output frequency over voltage and temperature so that it is not listed for AEC Grade 0.

Table 1-2 provides the functional version of the on-chip modules.

Table 1-2. Module Versions

Module		Version
Analog Comparator (5V)	(ACMP)	3
Analog-to-Digital Converter	(ADC10)	1
Central Processor Unit	(CPU)	3
Inter-Integrated Circuit	(IIC)	2
Internal Clock Source	(ICS)	2
Low Power Oscillator	(XOSC)	1
Modulo Timer	(MTIM)	1
On-Chip In-Circuit Emulator	(DBG)	2
Real-Time Counter	(RTC)	1
Serial Peripheral Interface	(SPI)	3
Serial Communications Interface	(SCI)	4
Timer Pulse Width Modulator	(TPM)	3

Whenever any reset is initiated (whether from an external signal or from an internal system), the $\overline{\text{RESET}}$ pin is driven low for about 66 bus cycles. The reset circuitry decodes the cause of reset and records it by setting a corresponding bit in the system reset status register (SRS).

NOTE

- This pin does not contain a clamp diode to V_{DD} and should not be driven above V_{DD}.
- The voltage measured on the internally pulled up $\overline{\text{RESET}}$ pin will not be pulled to V_{DD}. The internal gates connected to this pin are pulled to V_{DD}. If the $\overline{\text{RESET}}$ pin is required to drive to a V_{DD} level, an external pullup should be used.
- In EMC-sensitive applications, an external RC filter is recommended on the $\overline{\text{RESET}}$. See Figure 2-4 for an example.

2.2.4 Background / Mode Select (BKGD/MS)

During a power-on-reset (POR) or background debug force reset (see Section 5.7.2, “System Background Debug Force Reset Register (SBDFR),” for more information), the BKGD/MS pin functions as a mode select pin. Immediately after any reset, the pin functions as the background pin and can be used for background debug communication. The BKGD/MS pin contains an internal pullup device.

If nothing is connected to this pin, the MCU enters normal operating mode at the rising edge of the internal reset after a POR or force BDC reset. If a debug system is connected to the 6-pin standard background debug header, it can hold BKGD/MS low during a POR or immediately after issuing a background debug force reset, which will force the MCU to active background mode.

The BKGD pin is used primarily for background debug controller (BDC) communications using a custom protocol that uses 16 clock cycles of the target MCU’s BDC clock per bit time. The target MCU’s BDC clock could be as fast as the maximum bus clock rate, so there must never be any significant capacitance connected to the BKGD/MS pin that could interfere with background serial communications.

Although the BKGD pin is a pseudo open-drain pin, the background debug communication protocol provides brief, actively driven, high speedup pulses to ensure fast rise times. Small capacitances from cables and the absolute value of the internal pullup device play almost no role in determining rise and fall times on the BKGD pin.

2.2.5 General-Purpose I/O and Peripheral Ports

The MC9S08SG32 Series of MCUs support up to 22 general-purpose I/O pins which are shared with on-chip peripheral functions (timers, serial I/O, ADC, etc.).

When a port pin is configured as a general-purpose output or a peripheral uses the port pin as an output, software can select one of two drive strengths and enable or disable slew rate control. When a port pin is configured as a general-purpose input or a peripheral uses the port pin as an input, software can enable a pull-up device. Immediately after reset, all of these pins are configured as high-impedance general-purpose inputs with internal pull-up devices disabled.

4.4 RAM

The MC9S08SG32 Series includes static RAM. The locations in RAM below 0x0100 can be accessed using the more efficient direct addressing mode, and any single bit in this area can be accessed with the bit manipulation instructions (BCLR, BSET, BRCLR, and BRSET). Locating the most frequently accessed program variables in this area of RAM is preferred.

The RAM retains data when the MCU is in low-power wait, stop2, or stop3 mode. At power-on the contents of RAM are uninitialized. RAM data is unaffected by any reset provided that the supply voltage does not drop below the minimum value for RAM retention (V_{RAM}).

For compatibility with M68HC05 MCUs, the HCS08 resets the stack pointer to 0x00FF. In the MC9S08SG32 Series, it is usually best to reinitialize the stack pointer to the top of the RAM so the direct page RAM can be used for frequently accessed RAM variables and bit-addressable program variables. Include the following 2-instruction sequence in your reset initialization routine (where RamLast is equated to the highest address of the RAM in the Freescale Semiconductor-provided equate file).

```
LDHX    #RamLast+1    ;point one past RAM
TXS                   ;SP<-(H:X-1)
```

When security is enabled, the RAM is considered a secure memory resource and is not accessible through BDM or through code executing from non-secure memory. See Section 4.6, “Security”, for a detailed description of the security feature.

4.5 FLASH

The FLASH memory is intended primarily for program storage. In-circuit programming allows the operating program to be loaded into the FLASH memory after final assembly of the application product. It is possible to program the entire array through the single-wire background debug interface. Because no special voltages are needed for FLASH erase and programming operations, in-application programming is also possible through other software-controlled communication paths. For a more detailed discussion of in-circuit and in-application programming, refer to the *HCS08 Family Reference Manual, Volume I,* Freescale Semiconductor document order number HCS08RMv1/D.

5.7.1 System Reset Status Register (SRS)

This high page register includes read-only status flags to indicate the source of the most recent reset. When a debug host forces reset by writing 1 to BDFR in the SBDFR register, none of the status bits in SRS will be set. Writing any value to this register address causes a COP reset when the COP is enabled except the values 0x55 and 0xAA. Writing a 0x55-0xAA sequence to this address clears the COP watchdog timer without affecting the contents of this register. The reset state of these bits depends on what caused the MCU to reset.

	7	6	5	4	3	2	1	0
R	POR	PIN	COP	ILOP	ILAD	0	LVD	0
W	Writing 0x55, 0xAA to SRS address clears COP watchdog timer.							
POR:	1	0	0	0	0	0	1	0
LVR:	u[1]	0	0	0	0	0	1	0
Any other reset:	0	Note[2]	Note[2]	Note[2]	Note[2]	0	0	0

1 u = unaffected

2 Any of these reset sources that are active at the time of reset entry will cause the corresponding bit(s) to be set; bits corresponding to sources that are not active at the time of reset entry will be cleared.

Figure 5-2. System Reset Status (SRS)

Table 5-3. SRS Register Field Descriptions

Field	Description
7 POR	**Power-On Reset** — Reset was caused by the power-on detection logic. Because the internal supply voltage was ramping up at the time, the low-voltage reset (LVR) status bit is also set to indicate that the reset occurred while the internal supply was below the LVR threshold. 0 Reset not caused by POR. 1 POR caused reset.
6 PIN	**External Reset Pin** — Reset was caused by an active-low level on the external reset pin. 0 Reset not caused by external reset pin. 1 Reset came from external reset pin.
5 COP	**Computer Operating Properly (COP) Watchdog** — Reset was caused by the COP watchdog timer timing out. This reset source can be blocked by COPE = 0. 0 Reset not caused by COP timeout. 1 Reset caused by COP timeout.
4 ILOP	**Illegal Opcode** — Reset was caused by an attempt to execute an unimplemented or illegal opcode. The STOP instruction is considered illegal if stop is disabled by STOPE = 0 in the SOPT register. The BGND instruction is considered illegal if active background mode is disabled by ENBDM = 0 in the BDCSC register. 0 Reset not caused by an illegal opcode. 1 Reset caused by an illegal opcode.

Table 5-3. SRS Register Field Descriptions

Field	Description
3 ILAD	**Illegal Address** — Reset was caused by an attempt to access either data or an instruction at an unimplemented memory address. 0 Reset not caused by an illegal address 1 Reset caused by an illegal address
1 LVD	**Low Voltage Detect** — If the LVDRE bit is set and the supply drops below the LVD trip voltage, an LVD reset will occur. This bit is also set by POR. 0 Reset not caused by LVD trip or POR. 1 Reset caused by LVD trip or POR.

5.7.2 System Background Debug Force Reset Register (SBDFR)

This high page register contains a single write-only control bit. A serial background command such as WRITE_BYTE must be used to write to SBDFR. Attempts to write this register from a user program are ignored. Reads always return 0x00.

	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0
W								BDFR[1]
Reset:	0	0	0	0	0	0	0	0

= Unimplemented or Reserved

1 BDFR is writable only through serial background debug commands, not from user programs.

Figure 5-3. System Background Debug Force Reset Register (SBDFR)

Table 5-4. SBDFR Register Field Descriptions

Field	Description
0 BDFR	**Background Debug Force Reset** — A serial background command such as WRITE_BYTE can be used to allow an external debug host to force a target system reset. Writing 1 to this bit forces an MCU reset. This bit cannot be written from a user program.

5.7.7 System Power Management Status and Control 2 Register (SPMSC2)

This register is used to report the status of the low voltage warning function, and to configure the stop mode behavior of the MCU. This register 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	3	2	1	0
R	0	0	LVDV[1]	LVWV	PPDF	0	0	PPDC[2]
W						PPDACK		
Power-on Reset:	0	0	0	0	0	0	0	0
LVD Reset:	0	0	u	u	0	0	0	0
Any other Reset:	0	0	u	u	0	0	0	0

= Unimplemented or Reserved u = Unaffected by reset

1 This bit can be written only one time after power-on reset. Additional writes are ignored.

2 This bit can be written only one time after reset. Additional writes are ignored.

Figure 5-9. System Power Management Status and Control 2 Register (SPMSC2)

Table 5-10. SPMSC2 Register Field Descriptions

Field	Description
5 LVDV	**Low-Voltage Detect Voltage Select** — This write-once bit selects the low voltage detect (LVD) trip point setting. It also selects the warning voltage range. See Table 5-11.
4 LVWV	**Low-Voltage Warning Voltage Select** — This bit selects the low voltage warning (LVW) trip point voltage. See Table 5-11.
3 PPDF	**Partial Power Down Flag** — This read-only status bit indicates that the MCU has recovered from stop2 mode. 0 MCU has not recovered from stop2 mode. 1 MCU recovered from stop2 mode.
2 PPDACK	**Partial Power Down Acknowledge** — Writing a 1 to PPDACK clears the PPDF bit
0 PPDC	**Partial Power Down Control** — This write-once bit controls whether stop2 or stop3 mode is selected. 0 Stop3 mode enabled. 1 Stop2, partial power down, mode enabled.

6.6.2.7 Port B Interrupt Pin Select Register (PTBPS)

	7	6	5	4	3	2	1	0
R	0	0	0	0	PTBPS3	PTBPS2	PTBPS1	PTBPS0
W								
Reset:	0	0	0	0	0	0	0	0

Figure 6-17. Port B Interrupt Pin Select Register (PTBPS)

Table 6-16. PTBPS Register Field Descriptions

Field	Description
3:0 PTBPS[3:0]	**Port B Interrupt Pin Selects** — Each of the PTBPSn bits enable the corresponding port B interrupt pin. 0 Pin not enabled as interrupt. 1 Pin enabled as interrupt.

6.6.2.8 Port B Interrupt Edge Select Register (PTBES)

	7	6	5	4	3	2	1	0
R	0	0	0	0	PTBES3	PTBES2	PTBES1	PTBES0
W								
Reset:	0	0	0	0	0	0	0	0

Figure 6-18. Port B Edge Select Register (PTBES)

Table 6-17. PTBES Register Field Descriptions

Field	Description
3:0 PTBES[3:0]	**Port B Edge Selects** — Each of the PTBESn bits serves a dual purpose by selecting the polarity of the active interrupt edge as well as selecting a pull-up or pull-down device if enabled. 0 A pull-up device is connected to the associated pin and detects falling edge/low level for interrupt generation. 1 A pull-down device is connected to the associated pin and detects rising edge/high level for interrupt generation.

7.2 Programmer's Model and CPU Registers

Figure 7-1 shows the five CPU registers. CPU registers are not part of the memory map.

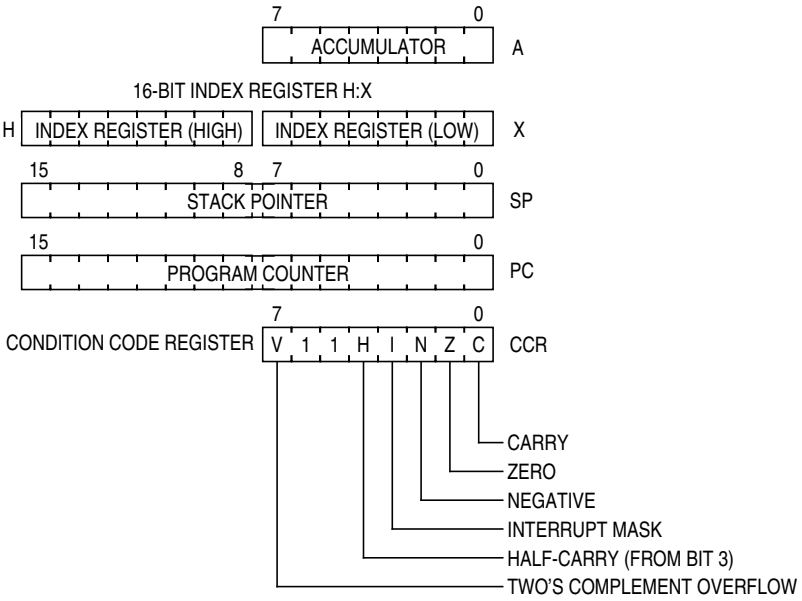


Figure 7-1. CPU Registers

7.2.1 Accumulator (A)

The A accumulator is a general-purpose 8-bit register. One operand input to the arithmetic logic unit (ALU) is connected to the accumulator and the ALU results are often stored into the A accumulator after arithmetic and logical operations. The accumulator can be loaded from memory using various addressing modes to specify the address where the loaded data comes from, or the contents of A can be stored to memory using various addressing modes to specify the address where data from A will be stored.

Reset has no effect on the contents of the A accumulator.

7.2.2 Index Register (H:X)

This 16-bit register is actually two separate 8-bit registers (H and X), which often work together as a 16-bit address pointer where H holds the upper byte of an address and X holds the lower byte of the address. All indexed addressing mode instructions use the full 16-bit value in H:X as an index reference pointer; however, for compatibility with the earlier M68HC05 Family, some instructions operate only on the low-order 8-bit half (X).

Many instructions treat X as a second general-purpose 8-bit register that can be used to hold 8-bit data values. X can be cleared, incremented, decremented, complemented, negated, shifted, or rotated. Transfer instructions allow data to be transferred from A or transferred to A where arithmetic and logical operations can then be performed.

For compatibility with the earlier M68HC05 Family, H is forced to 0x00 during reset. Reset has no effect on the contents of X.

8.2 Features

The ACMP has the following features:

- Full rail to rail supply operation.
- Selectable interrupt on rising edge, falling edge, or either rising or falling edges of comparator output.
- Option to compare to fixed internal bandgap reference voltage.
- Option to allow comparator output to be visible on a pin, ACMPO.
- Can operate in stop3 mode

8.3 Modes of Operation

This section defines the ACMP operation in wait, stop and background debug modes.

8.3.0.1 ACMP in Wait Mode

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

8.3.0.2 ACMP in Stop Modes

8.3.0.2.1 Stop3 Mode Operation

The ACMP continues to operate in Stop3 mode if enabled and compare operation remains active. If ACOPE is enabled, comparator output operates as in the normal operating mode and comparator output is placed onto the external pin. The MCU is brought out of stop when a compare event occurs and ACIE is enabled; ACF flag sets accordingly.

If stop is exited with a reset, the ACMP will be put into its reset state.

8.3.0.2.2 Stop2 Mode Operation

During Stop2 mode, the ACMP module will be fully powered down. Upon wake-up from Stop2 mode, the ACMP module will be in the reset state.

8.3.0.3 ACMP in Active Background Mode

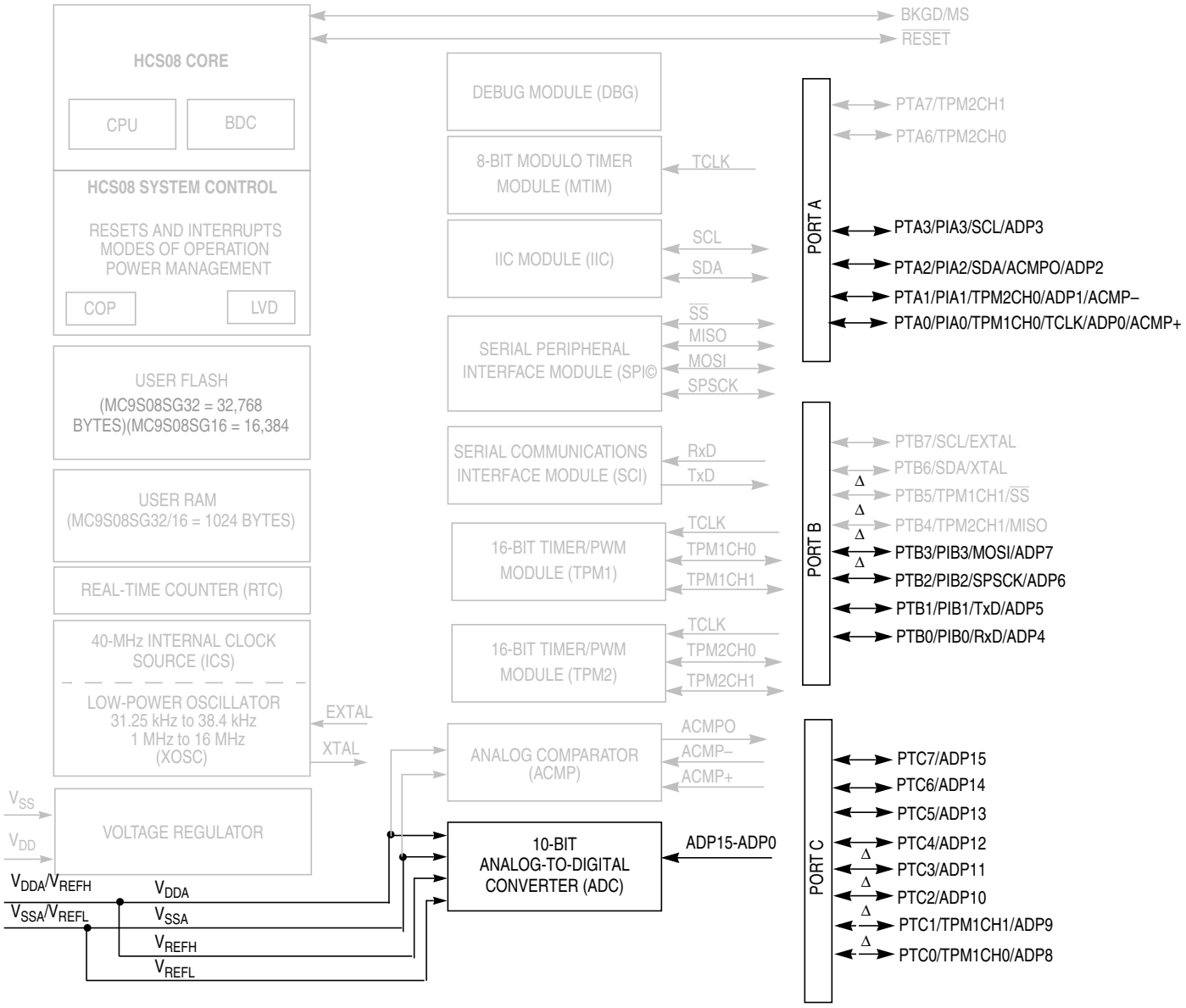
When the microcontroller is in active background mode, the ACMP will continue to operate normally.

8.4 Block Diagram

The block diagram for the Analog Comparator module is shown Figure 8-2.

8.7 Functional Description

The analog comparator can be used to compare two analog input voltages applied to ACMP+ and ACMP-; or it can be used to compare an analog input voltage applied to ACMP- with an internal bandgap reference voltage. ACBGS is used to select between the bandgap reference voltage or the ACMP+ pin as the input to the non-inverting input of the analog comparator. The comparator output is high when the non-inverting input is greater than the inverting input, and is low when the non-inverting input is less than the inverting input. ACMOD is used to select the condition which will cause ACF to be set. ACF can be set on a rising edge of the comparator output, a falling edge of the comparator output, or either a rising or a falling edge (toggle). The comparator output can be read directly through ACO. The comparator output can be driven onto the ACMPO pin using ACOPE.



NOTE

- PTC7-PTC0 and PTA7-PTA6 are not available on 16-pin packages.
- PTC7-PTC4 and PTA7-PTA6 are not available on 20-pin packages.
- For the 16-pin and 20-pin packages: V_{DDA}/V_{REFH} and V_{SSA}/V_{REFL} are double bonded to V_{DD} and V_{SS} respectively.

Δ = Pin can be enabled as part of the ganged output drive feature.

Figure 9-1. MC9S08SG32 Series Block Diagram Highlighting ADC Block and Pins

approximation algorithm is performed to determine the digital value of the analog signal. The result of the conversion is transferred to ADCRH and ADCRL upon completion of the conversion algorithm.

If the bus frequency is less than the f_{ADCK} frequency, precise sample time for continuous conversions cannot be guaranteed when short sample is enabled (ADLSMP=0). If the bus frequency is less than 1/11th of the f_{ADCK} frequency, precise sample time for continuous conversions cannot be guaranteed when long sample is enabled (ADLSMP=1).

The maximum total conversion time for different conditions is summarized in Table 9-13.

Table 9-13. Total Conversion Time vs. Control Conditions

Conversion Type	ADICLK	ADLSMP	Max Total Conversion Time
Single or first continuous 8-bit	0x, 10	0	20 ADCK cycles + 5 bus clock cycles
Single or first continuous 10-bit	0x, 10	0	23 ADCK cycles + 5 bus clock cycles
Single or first continuous 8-bit	0x, 10	1	40 ADCK cycles + 5 bus clock cycles
Single or first continuous 10-bit	0x, 10	1	43 ADCK cycles + 5 bus clock cycles
Single or first continuous 8-bit	11	0	5 µs + 20 ADCK + 5 bus clock cycles
Single or first continuous 10-bit	11	0	5 µs + 23 ADCK + 5 bus clock cycles
Single or first continuous 8-bit	11	1	5 µs + 40 ADCK + 5 bus clock cycles
Single or first continuous 10-bit	11	1	5 µs + 43 ADCK + 5 bus clock cycles
Subsequent continuous 8-bit; $f_{BUS} \geq f_{ADCK}$	xx	0	17 ADCK cycles
Subsequent continuous 10-bit; $f_{BUS} \geq f_{ADCK}$	xx	0	20 ADCK cycles
Subsequent continuous 8-bit; $f_{BUS} \geq f_{ADCK}/11$	xx	1	37 ADCK cycles
Subsequent continuous 10-bit; $f_{BUS} \geq f_{ADCK}/11$	xx	1	40 ADCK cycles

The maximum total conversion time is determined by the clock source chosen and the divide ratio selected. The clock source is selectable by the ADICLK bits, and the divide ratio is specified by the ADIV bits. For example, in 10-bit mode, with the bus clock selected as the input clock source, the input clock divide-by-1 ratio selected, and a bus frequency of 8 MHz, then the conversion time for a single conversion is:

$$\text{Conversion time} = \frac{23 \text{ ADCK cyc}}{8 \text{ MHz}/1} + \frac{5 \text{ bus cyc}}{8 \text{ MHz}} = 3.5 \text{ µs}$$

$$\text{Number of bus cycles} = 3.5 \text{ µs} \times 8 \text{ MHz} = 28 \text{ cycles}$$

NOTE

The ADCK frequency must be between f_{ADCK} minimum and f_{ADCK} maximum to meet ADC specifications.

- 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.

11.4.1.2 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.

11.4.1.3 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.

11.4.1.4 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.

13.1.3 Block Diagram

The block diagram for the RTC module is shown in Figure 13-2.

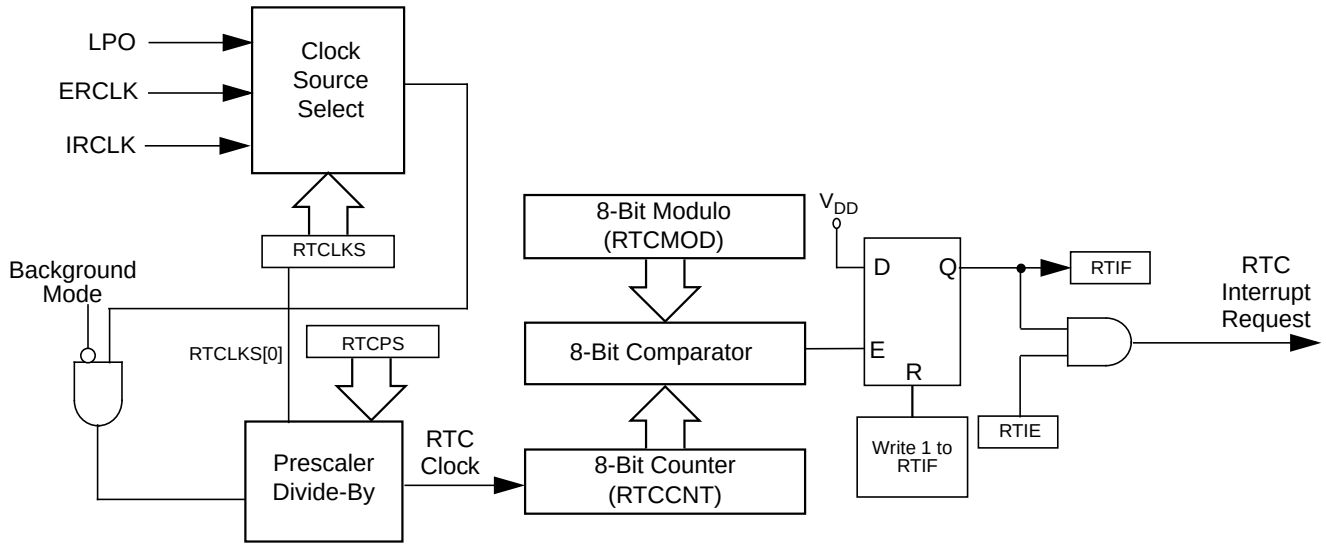


Figure 13-2. Real-Time Counter (RTC) Block Diagram

13.2 External Signal Description

The RTC does not include any off-chip signals.

13.3 Register Definition

The RTC includes a status and control register, an 8-bit counter register, and an 8-bit modulo register.

Refer to the direct-page register summary in the memory section of this document for the absolute address assignments for all RTC registers.This section refers to registers and control bits only by their names and relative address offsets.

Table 13-1 is a summary of RTC registers.

Table 13-1. RTC Register Summary

Name		7	6	5	4	3	2	1	0
RTCSC	R	RTIF	RTCLKS		RTIE	RTCPS			
	W								
RTCCNT	R	RTCCNT							
	W								
RTCMOD	R	RTCMOD							
	W								

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 MOSI output

16.2.1.1 EXTCLK — External Clock Source

Control bits in the timer status and control register allow the user to select nothing (timer disable), the bus-rate clock (the normal default source), a crystal-related clock, or an external clock as the clock which drives the TPM prescaler and subsequently the 16-bit TPM counter. The external clock source is synchronized in the TPM. The bus clock clocks the synchronizer; the frequency of the external source must be no more than one-fourth the frequency of the bus-rate clock, to meet Nyquist criteria and allowing for jitter.

The external clock signal shares the same pin as a channel I/O pin, so the channel pin will not be usable for channel I/O function when selected as the external clock source. It is the user's responsibility to avoid such settings. If this pin is used as an external clock source (CLKSB:CLKSA = 1:1), the channel can still be used in output compare mode as a software timer (ELSnB:ELSnA = 0:0).

16.2.1.2 TPMxCHn — TPM Channel n I/O Pin(s)

Each TPM channel is associated with an I/O pin on the MCU. The function of this pin depends on the channel configuration. The TPM pins share with general purpose I/O pins, where each pin has a port data register bit, and a data direction control bit, and the port has optional passive pullups which may be enabled whenever a port pin is acting as an input.

The TPM channel does not control the I/O pin when (ELSnB:ELSnA = 0:0) or when (CLKSB:CLKSA = 0:0) so it normally reverts to general purpose I/O control. When CPWMS = 1 (and ELSnB:ELSnA not = 0:0), all channels within the TPM are configured for center-aligned PWM and the TPMxCHn pins are all controlled by the TPM system. When CPWMS=0, the MSnB:MSnA control bits determine whether the channel is configured for input capture, output compare, or edge-aligned PWM.

When a channel is configured for input capture (CPWMS=0, MSnB:MSnA = 0:0 and ELSnB:ELSnA not = 0:0), the TPMxCHn pin is forced to act as an edge-sensitive input to the TPM. ELSnB:ELSnA control bits determine what polarity edge or edges will trigger input-capture events. A synchronizer based on the bus clock is used to synchronize input edges to the bus clock. This implies the minimum pulse width—that can be reliably detected—on an input capture pin is four bus clock periods (with ideal clock pulses as near as two bus clocks can be detected). TPM uses this pin as an input capture input to override the port data and data direction controls for the same pin.

When a channel is configured for output compare (CPWMS=0, MSnB:MSnA = 0:1 and ELSnB:ELSnA not = 0:0), the associated data direction control is overridden, the TPMxCHn pin is considered an output controlled by the TPM, and the ELSnB:ELSnA control bits determine how the pin is controlled. The remaining three combinations of ELSnB:ELSnA determine whether the TPMxCHn pin is toggled, cleared, or set each time the 16-bit channel value register matches the timer counter.

When the output compare toggle mode is initially selected, the previous value on the pin is driven out until the next output compare event—then the pin is toggled.

Figure 17-3 shows the host receiving a logic 1 from the target HCS08 MCU. Because the host is asynchronous to the target MCU, there is a 0-to-1 cycle delay from the host-generated falling edge on BKGD to the perceived start of the bit time in the target MCU. The host holds the BKGD pin low long enough for the target to recognize it (at least two target BDC cycles). The host must release the low drive before the target MCU drives a brief active-high speedup pulse seven cycles after the perceived start of the bit time. The host should sample the bit level about 10 cycles after it started the bit time.

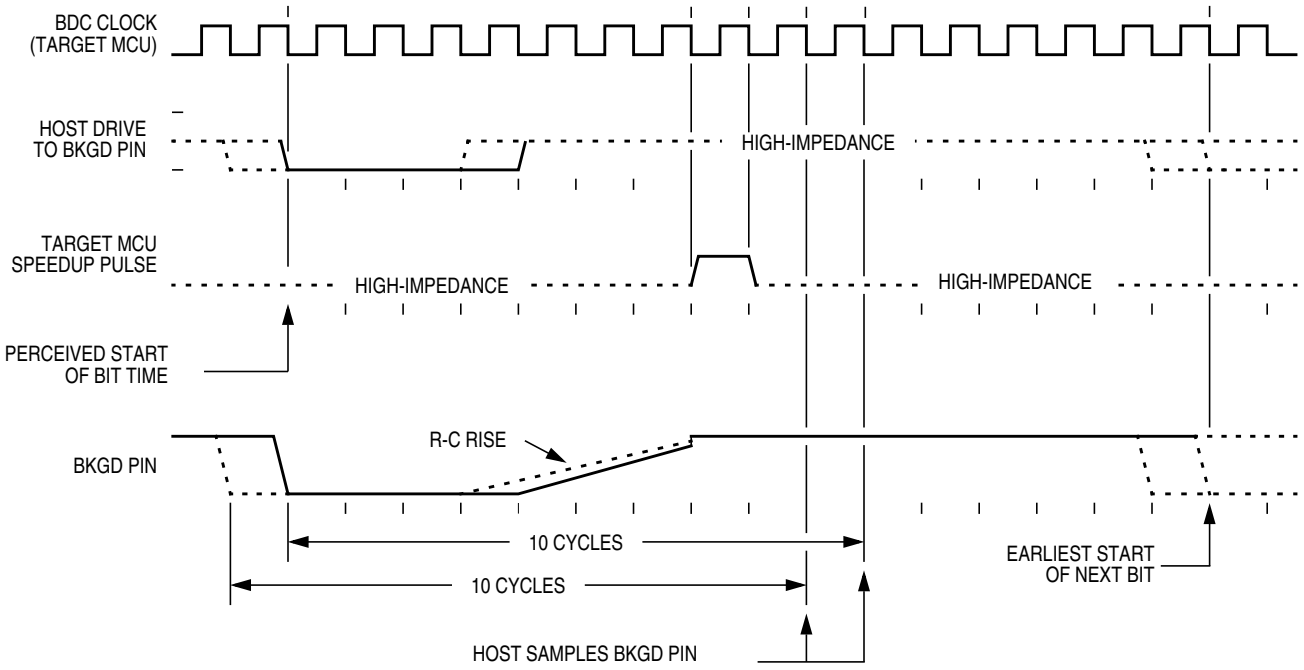


Figure 17-3. BDC Target-to-Host Serial Bit Timing (Logic 1)