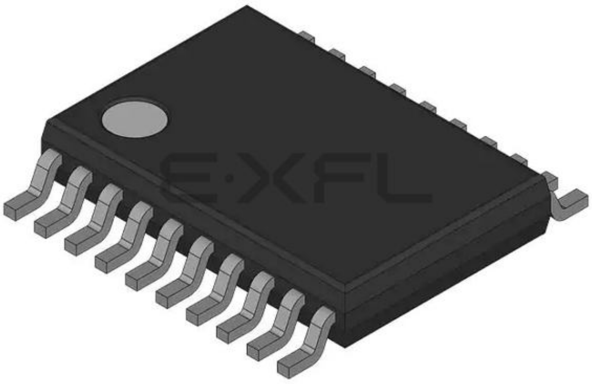

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RAM Size	-
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Mounting Type	-
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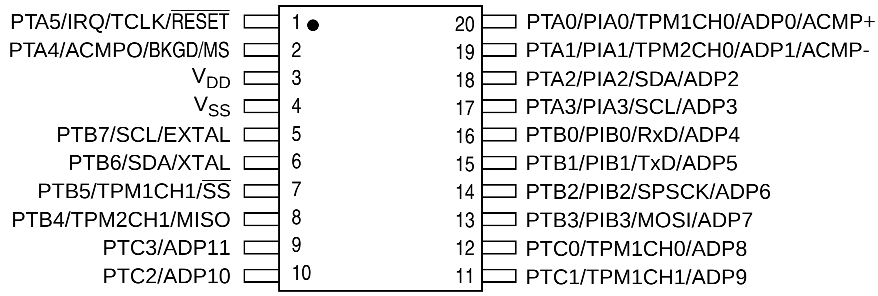


Figure 2-2. 20-Pin PDIP, SOIC, and TSSOP

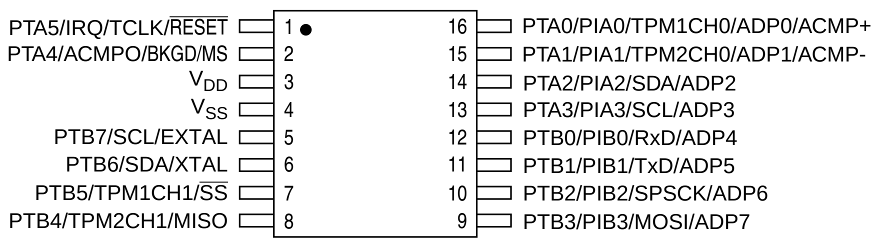


Figure 2-3. 16-Pin TSSOP

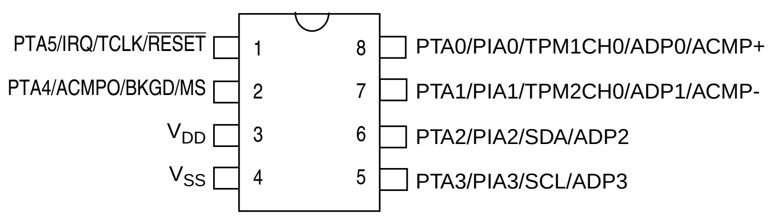
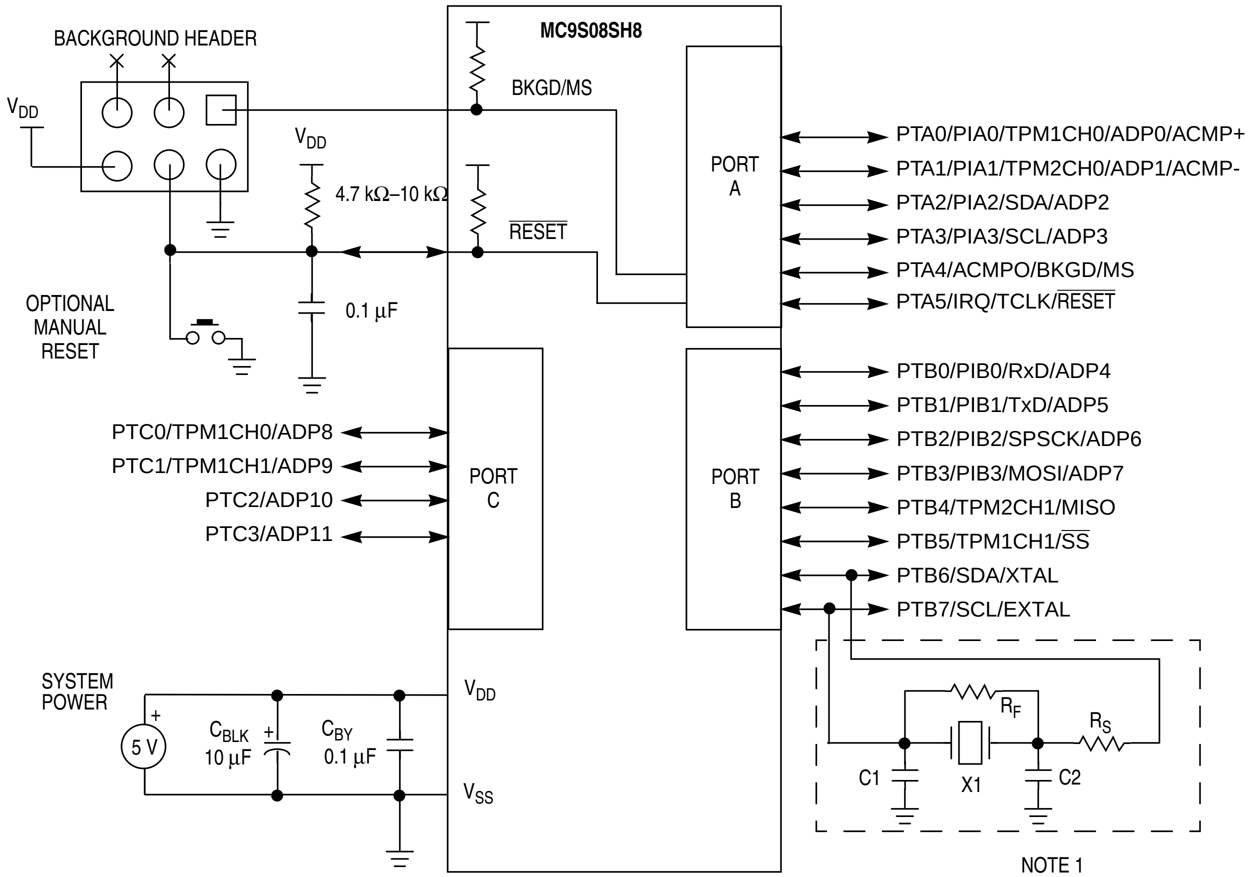


Figure 2-4. 8-Pin SOIC

2.2 Recommended System Connections

Figure 2-5 shows pin connections that are common to MC9S08SH8 application systems.



NOTES:
1. External crystal circuit not required if using the internal clock option.
2. RESET pin can only be used to reset into user mode, you can not enter BDM using RESET pin. BDM can be entered by holding MS low during POR or writing a 1 to BDFR in SBDFR with MS low after issuing BDM command.
3. RC filter on RESET pin recommended for noisy environments.

Figure 2-5. Basic System Connections

2.2.1 Power

V_{DD} and V_{SS} are the primary power supply pins for the MCU. This voltage source supplies power to all I/O buffer circuitry, ACMP and ADC modules, and to an internal voltage regulator. The internal voltage regulator provides regulated lower-voltage source to the CPU and other internal circuitry of the MCU.

Typically, application systems have two separate capacitors across the power pins. In this case, there should be a bulk electrolytic capacitor, such as a 10-µF tantalum capacitor, to provide bulk charge storage for the overall system and a 0.1-µF ceramic bypass capacitor located as near to the MCU power pins as practical to suppress high-frequency noise. Each pin must have a bypass capacitor for best noise suppression.

4.5.1 Features

Features of the FLASH memory include:

- FLASH size
  - MC9S08SH8: 8,192 bytes (16 pages of 512 bytes each)
  - MC9S08SH4: 4,096 bytes (8 pages of 512 bytes each)
- Single power supply program and erase
- Command interface for fast program and erase operation
- Up to 100,000 program/erase cycles at typical voltage and temperature
- Flexible block protection
- Security feature for FLASH and RAM
- Auto power-down for low-frequency read accesses

4.5.2 Program and Erase Times

Before any program or erase command can be accepted, the FLASH clock divider register (FCDIV) must be written to set the internal clock for the FLASH module to a frequency (f_{FCLK}) between 150 kHz and 200 kHz (see Section 4.7.1, "FLASH Clock Divider Register (FCDIV)"). This register can be written only once, so normally this write is done during reset initialization. FCDIV cannot be written if the access error flag, FACCERR in FSTAT, is set. The user must ensure that FACCERR is not set before writing to the FCDIV register. One period of the resulting clock ($1/f_{FCLK}$) is used by the command processor to time program and erase pulses. An integer number of these timing pulses are used by the command processor to complete a program or erase command.

Table 4-5 shows program and erase times. The bus clock frequency and FCDIV determine the frequency of FCLK (f_{FCLK}). The time for one cycle of FCLK is $t_{FCLK} = 1/f_{FCLK}$. The times are shown as a number of cycles of FCLK and as an absolute time for the case where $t_{FCLK} = 5\ \mu s$. Program and erase times shown include overhead for the command state machine and enabling and disabling of program and erase voltages.

Table 4-5. Program and Erase Times

Parameter	Cycles of FCLK	Time if FCLK = 200 kHz
Byte program	9	45 μs
Byte program (burst)	4	20 μs[1]
Page erase	4000	20 ms
Mass erase	20,000	100 ms

1 Excluding start/end overhead

5.7.4 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	BKGDPE	RSTPE
W								
Reset:	1	1	0	0	0	0	1	u[2]
POR:	1	1	0	0	0	0	1	0
LVR:	1	1	0	0	0	0	1	u

= Unimplemented or Reserved

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

[1] Bit 4 is reserved, writes change the value, but will have no effect on this MCU.

[2] u = unaffected

Table 5-6. 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.
1 BKGDPE	**Background Debug Mode Pin Enable** — This write-once bit when set enables the PTA4/ACMPO/BKGD/MS pin to function as BKGD/MS. When clear, the pin functions as one of its output-only alternative functions. This pin defaults to the BKGD/MS function following any MCU reset. 0 PTA4/ACMPO/BKGD/MS pin functions as PTA4 or ACMPO. 1 PTA4/ACMPO/BKGD/MS pin functions as BKGD/MS.
0 RSTPE	**$\overline{\text{RESET}}$ Pin Enable** — This write-once bit when set enables the PTA5/IRQ/TCLK/$\overline{\text{RESET}}$ pin to function as $\overline{\text{RESET}}$. When clear, the pin functions as one of its alternative functions. This pin defaults to a general-purpose input port function following a POR reset. When configured as $\overline{\text{RESET}}$, the pin will be unaffected by LVR or other internal resets. When RSTPE is set, an internal pullup device is enabled on $\overline{\text{RESET}}$. 0 PTA5/IRQ/TCLK/$\overline{\text{RESET}}$ pin functions as PTA5, IRQ or TCLK. 1 PTA5/IRQ/TCLK/$\overline{\text{RESET}}$ pin functions as $\overline{\text{RESET}}$.

5.7.7 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 5-9. System Power Management Status and Control 1 Register (SPMSC1)

Table 5-10. 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.

In cases where separate power supplies are used for analog and digital power, the ground connection between these supplies must be at the V_{SSAD} pin. This should be the only ground connection between these supplies if possible. The V_{SSAD} pin makes a good single point ground location.

9.6.1.2 Analog Reference Pins

In addition to the analog supplies, the ADC module has connections for two reference voltage inputs. The high reference is V_{REFH}, which may be shared on the same pin as V_{DDAD} on some devices. The low reference is V_{REFL}, which may be shared on the same pin as V_{SSAD} on some devices.

When available on a separate pin, V_{REFH} may be connected to the same potential as V_{DDAD}, or may be driven by an external source that is between the minimum V_{DDAD} spec and the V_{DDAD} potential (V_{REFH} must never exceed V_{DDAD}). When available on a separate pin, V_{REFL} must be connected to the same voltage potential as V_{SSAD}. Both V_{REFH} and V_{REFL} must be routed carefully for maximum noise immunity and bypass capacitors placed as near as possible to the package.

AC current in the form of current spikes required to supply charge to the capacitor array at each successive approximation step is drawn through the V_{REFH} and V_{REFL} loop. The best external component to meet this current demand is a 0.1 μF capacitor with good high frequency characteristics. This capacitor is connected between V_{REFH} and V_{REFL} and must be placed as near as possible to the package pins. Resistance in the path is not recommended because the current will cause a voltage drop which could result in conversion errors. Inductance in this path must be minimum (parasitic only).

9.6.1.3 Analog Input Pins

The external analog inputs are typically shared with digital I/O pins on MCU devices. The pin I/O control is disabled by setting the appropriate control bit in one of the pin control registers. Conversions can be performed on inputs without the associated pin control register bit set. It is recommended that the pin control register bit always be set when using a pin as an analog input. This avoids problems with contention because the output buffer will be in its high impedance state and the pullup is disabled. Also, the input buffer draws dc current when its input is not at either V_{DD} or V_{SS}. Setting the pin control register bits for all pins used as analog inputs should be done to achieve lowest operating current.

Empirical data shows that capacitors on the analog inputs improve performance in the presence of noise or when the source impedance is high. Use of 0.01 μF capacitors with good high-frequency characteristics is sufficient. These capacitors are not necessary in all cases, but when used they must be placed as near as possible to the package pins and be referenced to V_{SSA}.

For proper conversion, the input voltage must fall between V_{REFH} and V_{REFL}. If the input is equal to or exceeds V_{REFH}, the converter circuit converts the signal to $3FF (full scale 10-bit representation) or $FF (full scale 8-bit representation). If the input is equal to or less than V_{REFL}, the converter circuit converts it to $000. Input voltages between V_{REFH} and V_{REFL} are straight-line linear conversions. There will be a brief current associated with V_{REFL} when the sampling capacitor is charging. The input is sampled for 3.5 cycles of the ADCK source when ADLSMP is low, or 23.5 cycles when ADLSMP is high.

For minimal loss of accuracy due to current injection, pins adjacent to the analog input pins should not be transitioning during conversions.

Table 11-3. IICF Field Descriptions

Field	Description
7–6 MULT	**IIC Multiplier Factor**. The MULT bits define the multiplier factor, mul. This factor, along with the SCL divider, generates the IIC baud rate. The multiplier factor mul as defined by the MULT bits is provided below. 00 mul = 01 01 mul = 02 10 mul = 04 11 Reserved
5–0 ICR	**IIC Clock Rate**. The ICR bits are used to prescale the bus clock for bit rate selection. These bits and the MULT bits determine the IIC baud rate, the SDA hold time, the SCL Start hold time, and the SCL Stop hold time. Table 11-5 provides the SCL divider and hold values for corresponding values of the ICR. The SCL divider multiplied by multiplier factor mul generates IIC baud rate. $$\text{IIC baud rate} = \frac{\text{bus speed (Hz)}}{\text{mul} \times \text{SCLdivider}} \quad \textit{Eqn. 11-1}$$ SDA hold time is the delay from the falling edge of SCL (IIC clock) to the changing of SDA (IIC data). $$\text{SDA hold time} = \text{bus period (s)} \times \text{mul} \times \text{SDA hold value} \quad \textit{Eqn. 11-2}$$ SCL start hold time is the delay from the falling edge of SDA (IIC data) while SCL is high (Start condition) to the falling edge of SCL (IIC clock). $$\text{SCL Start hold time} = \text{bus period (s)} \times \text{mul} \times \text{SCL Start hold value} \quad \textit{Eqn. 11-3}$$ SCL stop hold time is the delay from the rising edge of SCL (IIC clock) to the rising edge of SDA SDA (IIC data) while SCL is high (Stop condition). $$\text{SCL Stop hold time} = \text{bus period (s)} \times \text{mul} \times \text{SCL Stop hold value} \quad \textit{Eqn. 11-4}$$

For example, if the bus speed is 8 MHz, the table below shows the possible hold time values with different ICR and MULT selections to achieve an IIC baud rate of 100kbps.

Table 11-4. Hold Time Values for 8 MHz Bus Speed

MULT	ICR	Hold Times (µs)		
		SDA	SCL Start	SCL Stop
0x2	0x00	3.500	3.000	5.500
0x1	0x07	2.500	4.000	5.250
0x1	0x0B	2.250	4.000	5.250
0x0	0x14	2.125	4.250	5.125
0x0	0x18	1.125	4.750	5.125

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
6. Write: IICC1
   — to enable MST (master mode)
7. Write: IICD
   — with the address of the target slave. (The lsb of this byte determines whether the communication is master receive or transmit.)

Module Use

The routine shown in Figure 11-12 can handle both master and slave IIC operations. For slave operation, an incoming IIC message that contains the proper address begins IIC communication. For master operation, communication must be initiated by writing to the IICD register.

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

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.

13.1.1 Features

Features of the RTC module include:

- 8-bit up-counter
  - 8-bit modulo match limit
  - Software controllable periodic interrupt on match
- Three software selectable clock sources for input to prescaler with selectable binary-based and decimal-based divider values
  - 1-kHz internal low-power oscillator (LPO)
  - External clock (ERCLK)
  - 32-kHz internal clock (IRCLK)

13.1.2 Modes of Operation

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

13.1.2.1 Wait Mode

The RTC continues to run in wait mode if enabled before executing the appropriate instruction. Therefore, the RTC can bring the MCU out of wait mode if the real-time interrupt is enabled. For lowest possible current consumption, the RTC should be stopped by software if not needed as an interrupt source during wait mode.

13.1.2.2 Stop Modes

The RTC continues to run in stop2 or stop3 mode if the RTC is enabled before executing the STOP instruction. Therefore, the RTC can bring the MCU out of stop modes with no external components, if the real-time interrupt is enabled.

The LPO clock can be used in stop2 and stop3 modes. ERCLK and IRCLK clocks are only available in stop3 mode.

Power consumption is lower when all clock sources are disabled, but in that case, the real-time interrupt cannot wake up the MCU from stop modes.

13.1.2.3 Active Background Mode

The RTC suspends all counting during active background mode until the microcontroller returns to normal user operating mode. Counting resumes from the suspended value as long as the RTCMOD register is not written and the RTCPS and RTCLKS bits are not altered.

13.3.2 RTC Counter Register (RTCCNT)

RTCCNT is the read-only value of the current RTC count of the 8-bit counter.

	7	6	5	4	3	2	1	0
R	RTCCNT							
W								
Reset:	0	0	0	0	0	0	0	0

Figure 13-4. RTC Counter Register (RTCCNT)

Table 13-4. RTCCNT Field Descriptions

Field	Description
7:0 RTCCNT	RTC Count. These eight read-only bits contain the current value of the 8-bit counter. Writes have no effect to this register. Reset, writing to RTCMOD, or writing different values to RTCLKS and RTCPS clear the count to 0x00.

13.3.3 RTC Modulo Register (RTCMOD)

	7	6	5	4	3	2	1	0
R W	RTCMOD							
Reset:	0	0	0	0	0	0	0	0

Figure 13-5. RTC Modulo Register (RTCMOD)

Table 13-5. RTCMOD Field Descriptions

Field	Description
7:0 RTCMOD	RTC Modulo. These eight read/write bits contain the modulo value used to reset the count to 0x00 upon a compare match and set the RTIF status bit. A value of 0x00 sets the RTIF bit on each rising edge of the prescaler output. Writing to RTCMOD resets the prescaler and the RTCCNT counters to 0x00. Reset sets the modulo to 0x00.

13.4 Functional Description

The RTC is composed of a main 8-bit up-counter with an 8-bit modulo register, a clock source selector, and a prescaler block with binary-based and decimal-based selectable values. The module also contains software selectable interrupt logic.

After any MCU reset, the counter is stopped and reset to 0x00, the modulus register is set to 0x00, and the prescaler is off. The 1-kHz internal oscillator clock is selected as the default clock source. To start the prescaler, write any value other than zero to the prescaler select bits (RTCPS).

Three clock sources are software selectable: the low power oscillator clock (LPO), the external clock (ERCLK), and the internal clock (IRCLK). The RTC clock select bits (RTCLKS) select the desired clock source. If a different value is written to RTCLKS, the prescaler and RTCCNT counters are reset to 0x00.

Figure 14-3 shows the receiver portion of the SCI.

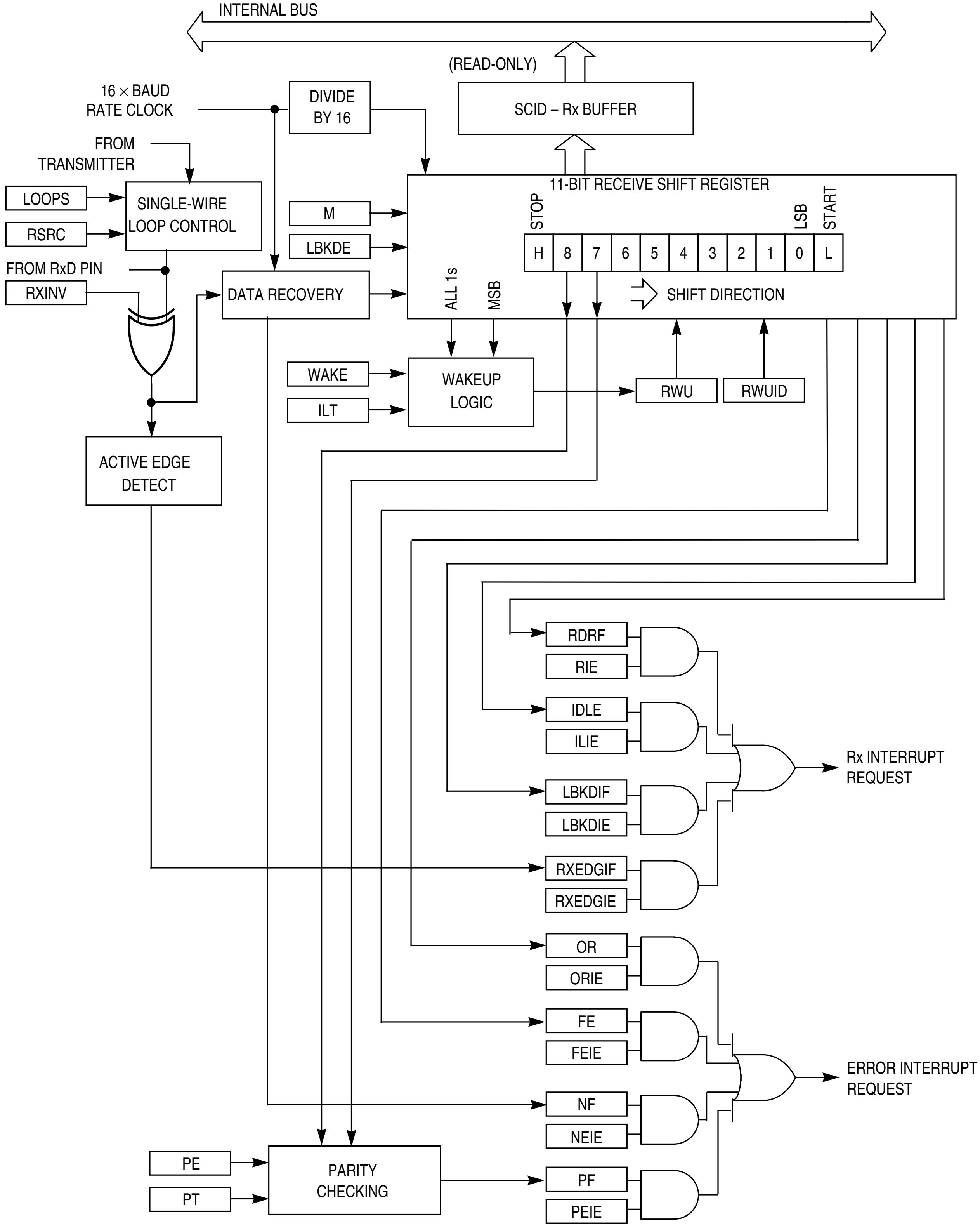


Figure 14-3. SCI Receiver Block Diagram

Table 14-5. SCIxS1 Field Descriptions (continued)

Field	Description
1 FE	**Framing Error Flag** — FE is set at the same time as RDRF when the receiver detects a logic 0 where the stop bit was expected. This suggests the receiver was not properly aligned to a character frame. To clear FE, read SCIxS1 with FE = 1 and then read the SCI data register (SCIxD). 0 No framing error detected. This does not guarantee the framing is correct. 1 Framing error.
0 PF	**Parity Error Flag** — PF is set at the same time as RDRF when parity is enabled (PE = 1) and the parity bit in the received character does not agree with the expected parity value. To clear PF, read SCIxS1 and then read the SCI data register (SCIxD). 0 No parity error. 1 Parity error.

14.2.5 SCI Status Register 2 (SCIxS2)

This register has one read-only status flag.

	7	6	5	4	3	2	1	0
R	LBKDIF	RXEDGIF	0	RXINV	RWUID	BRK13	LBKDE	RAF
W			(unimplemented)					(unimplemented)
Reset	0	0	0	0	0	0	0	0

= Unimplemented or Reserved

Figure 14-9. SCI Status Register 2 (SCIxS2)

Table 14-6. SCIxS2 Field Descriptions

Field	Description
7 LBKDIF	**LIN Break Detect Interrupt Flag** — LBKDIF is set when the LIN break detect circuitry is enabled and a LIN break character is detected. LBKDIF is cleared by writing a “1” to it. 0 No LIN break character has been detected. 1 LIN break character has been detected.
6 RXEDGIF	**RxD Pin Active Edge Interrupt Flag** — RXEDGIF is set when an active edge (falling if RXINV = 0, rising if RXINV=1) on the RxD pin occurs. RXEDGIF is cleared by writing a “1” to it. 0 No active edge on the receive pin has occurred. 1 An active edge on the receive pin has occurred.
4 RXINV[1]	**Receive Data Inversion** — Setting this bit reverses the polarity of the received data input. 0 Receive data not inverted 1 Receive data inverted
3 RWUID	**Receive Wake Up Idle Detect**— RWUID controls whether the idle character that wakes up the receiver sets the IDLE bit. 0 During receive standby state (RWU = 1), the IDLE bit does not get set upon detection of an idle character. 1 During receive standby state (RWU = 1), the IDLE bit gets set upon detection of an idle character.
2 BRK13	**Break Character Generation Length** — BRK13 is used to select a longer transmitted break character length. Detection of a framing error is not affected by the state of this bit. 0 Break character is transmitted with length of 10 bit times (11 if M = 1) 1 Break character is transmitted with length of 13 bit times (14 if M = 1)

flag is set. If RDRF was already set indicating the receive data register (buffer) was already full, the overrun (OR) status flag is set and the new data is lost. Because the SCI receiver is double-buffered, the program has one full character time after RDRF is set before the data in the receive data buffer must be read to avoid a receiver overrun.

When a program detects that the receive data register is full (RDRF = 1), it gets the data from the receive data register by reading SCIxD. The RDRF flag is cleared automatically by a 2-step sequence which is normally satisfied in the course of the user's program that handles receive data. Refer to Section 14.3.4, "Interrupts and Status Flags" for more details about flag clearing.

14.3.3.1 Data Sampling Technique

The SCI receiver uses a 16× baud rate clock for sampling. The receiver starts by taking logic level samples at 16 times the baud rate to search for a falling edge on the RxD serial data input pin. A falling edge is defined as a logic 0 sample after three consecutive logic 1 samples. The 16× baud rate clock is used to divide the bit time into 16 segments labeled RT1 through RT16. When a falling edge is located, three more samples are taken at RT3, RT5, and RT7 to make sure this was a real start bit and not merely noise. If at least two of these three samples are 0, the receiver assumes it is synchronized to a receive character.

The receiver then samples each bit time, including the start and stop bits, at RT8, RT9, and RT10 to determine the logic level for that bit. The logic level is interpreted to be that of the majority of the samples taken during the bit time. In the case of the start bit, the bit is assumed to be 0 if at least two of the samples at RT3, RT5, and RT7 are 0 even if one or all of the samples taken at RT8, RT9, and RT10 are 1s. If any sample in any bit time (including the start and stop bits) in a character frame fails to agree with the logic level for that bit, the noise flag (NF) will be set when the received character is transferred to the receive data buffer.

The falling edge detection logic continuously looks for falling edges, and if an edge is detected, the sample clock is resynchronized to bit times. This improves the reliability of the receiver in the presence of noise or mismatched baud rates. It does not improve worst case analysis because some characters do not have any extra falling edges anywhere in the character frame.

In the case of a framing error, provided the received character was not a break character, the sampling logic that searches for a falling edge is filled with three logic 1 samples so that a new start bit can be detected almost immediately.

In the case of a framing error, the receiver is inhibited from receiving any new characters until the framing error flag is cleared. The receive shift register continues to function, but a complete character cannot transfer to the receive data buffer if FE is still set.

14.3.3.2 Receiver Wakeup Operation

Receiver wakeup is a hardware mechanism that allows an SCI receiver to ignore the characters in a message that is intended for a different SCI receiver. In such a system, all receivers evaluate the first character(s) of each message, and as soon as they determine the message is intended for a different receiver, they write logic 1 to the receiver wake up (RWU) control bit in SCIxC2. When RWU bit is set, the status flags associated with the receiver (with the exception of the idle bit, IDLE, when RWUID bit is set) are inhibited from setting, thus eliminating the software overhead for handling the unimportant

When BDM is active, the coherency mechanism is frozen (unless reset by writing to TPMxSC register) such that the buffer latches remain in the state they were in when the BDM became active, even if one or both halves of the modulo register are written while BDM is active. Any write to the modulo registers bypasses the buffer latches and directly writes to the modulo register while BDM is active.

	7	6	5	4	3	2	1	0
R/W	Bit 15	14	13	12	11	10	9	Bit 8
Reset	0	0	0	0	0	0	0	0

Figure 16-10. TPM Counter Modulo Register High (TPMxMODH)

	7	6	5	4	3	2	1	0
R/W	Bit 7	6	5	4	3	2	1	Bit 0
Reset	0	0	0	0	0	0	0	0

Figure 16-11. TPM Counter Modulo Register Low (TPMxMODL)

Reset the TPM counter before writing to the TPM modulo registers to avoid confusion about when the first counter overflow will occur.

16.3.4 TPM Channel n Status and Control Register (TPMxCnSC)

TPMxCnSC contains the channel-interrupt-status flag and control bits used to configure the interrupt enable, channel configuration, and pin function.

	7	6	5	4	3	2	1	0
R	CHnF	CHnIE	MSnB	MSnA	ELSnB	ELSnA	0	0
W	0							
Reset	0	0	0	0	0	0	0	0

= Unimplemented or Reserved

Figure 16-12. TPM Channel n Status and Control Register (TPMxCnSC)

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.

In output compare mode, values are transferred to the corresponding timer channel registers only after both 8-bit halves of a 16-bit register have been written and according to the value of CLKSB:CLKSA bits, so:

- If (CLKSB:CLKSA = 0:0), the registers are updated when the second byte is written
- If (CLKSB:CLKSA not = 0:0), the registers are updated at the next change of the TPM counter (end of the prescaler counting) after the second byte is written.

The coherency sequence can be manually reset by writing to the channel status/control register (TPMxCnSC).

An output compare event sets a flag bit (CHnF) which may optionally generate a CPU-interrupt request.

16.4.2.3 Edge-Aligned PWM Mode

This type of PWM output uses the normal up-counting mode of the timer counter (CPWMS=0) and can be used when other channels in the same TPM are configured for input capture or output compare functions. The period of this PWM signal is determined by the value of the modulus register (TPMxMODH:TPMxMODL) plus 1. The duty cycle is determined by the setting in the timer channel register (TPMxCnVH:TPMxCnVL). The polarity of this PWM signal is determined by the setting in the ELSnA control bit. 0% and 100% duty cycle cases are possible.

The output compare value in the TPM channel registers determines the pulse width (duty cycle) of the PWM signal (Figure 16-15). The time between the modulus overflow and the output compare is the pulse width. If ELSnA=0, the counter overflow forces the PWM signal high, and the output compare forces the PWM signal low. If ELSnA=1, the counter overflow forces the PWM signal low, and the output compare forces the PWM signal high.

17.1.2 Features

Features of the BDC module include:

- Single pin for mode selection and background communications
- BDC registers are not located in the memory map
- SYNC command to determine target communications rate
- Non-intrusive commands for memory access
- Active background mode commands for CPU register access
- GO and TRACE1 commands
- BACKGROUND command can wake CPU from stop or wait modes
- One hardware address breakpoint built into BDC
- Oscillator runs in stop mode, if BDC enabled
- COP watchdog disabled while in active background mode

Features of the ICE system include:

- Two trigger comparators: Two address + read/write (R/W) or one full address + data + R/W
- Flexible 8-word by 16-bit FIFO (first-in, first-out) buffer for capture information:
  - Change-of-flow addresses or
  - Event-only data
- Two types of breakpoints:
  - Tag breakpoints for instruction opcodes
  - Force breakpoints for any address access
- Nine trigger modes:
  - Basic: A-only, A OR B
  - Sequence: A then B
  - Full: A AND B data, A AND NOT B data
  - Event (store data): Event-only B, A then event-only B
  - Range: Inside range (A ≤ address ≤ B), outside range (address < A or address > B)

17.2 Background Debug Controller (BDC)

All MCUs in the HCS08 Family contain a single-wire background debug interface that supports in-circuit programming of on-chip nonvolatile memory and sophisticated non-intrusive debug capabilities. Unlike debug interfaces on earlier 8-bit MCUs, this system does not interfere with normal application resources. It does not use any user memory or locations in the memory map and does not share any on-chip peripherals.

BDC commands are divided into two groups:

- Active background mode commands require that the target MCU is in active background mode (the user program is not running). Active background mode commands allow the CPU registers to be read or written, and allow the user to trace one user instruction at a time, or GO to the user program from active background mode.

the host must perform ((8 – CNT) – 1) dummy reads of the FIFO to advance it to the first significant entry in the FIFO.

In most trigger modes, the information stored in the FIFO consists of 16-bit change-of-flow addresses. In these cases, read DBGFH then DBGFL to get one coherent word of information out of the FIFO. Reading DBGFL (the low-order byte of the FIFO data port) causes the FIFO to shift so the next word of information is available at the FIFO data port. In the event-only trigger modes (see Section 17.3.5, "Trigger Modes"), 8-bit data information is stored into the FIFO. In these cases, the high-order half of the FIFO (DBGFH) is not used and data is read out of the FIFO by simply reading DBGFL. Each time DBGFL is read, the FIFO is shifted so the next data value is available through the FIFO data port at DBGFL.

In trigger modes where the FIFO is storing change-of-flow addresses, there is a delay between CPU addresses and the input side of the FIFO. Because of this delay, if the trigger event itself is a change-of-flow address or a change-of-flow address appears during the next two bus cycles after a trigger event starts the FIFO, it will not be saved into the FIFO. In the case of an end-trace, if the trigger event is a change-of-flow, it will be saved as the last change-of-flow entry for that debug run.

The FIFO can also be used to generate a profile of executed instruction addresses when the debugger is not armed. When ARM = 0, reading DBGFL causes the address of the most-recently fetched opcode to be saved in the FIFO. To use the profiling feature, a host debugger would read addresses out of the FIFO by reading DBGFH then DBGFL at regular periodic intervals. The first eight values would be discarded because they correspond to the eight DBGFL reads needed to initially fill the FIFO. Additional periodic reads of DBGFH and DBGFL return delayed information about executed instructions so the host debugger can develop a profile of executed instruction addresses.

17.3.3 Change-of-Flow Information

To minimize the amount of information stored in the FIFO, only information related to instructions that cause a change to the normal sequential execution of instructions is stored. With knowledge of the source and object code program stored in the target system, an external debugger system can reconstruct the path of execution through many instructions from the change-of-flow information stored in the FIFO.

For conditional branch instructions where the branch is taken (branch condition was true), the source address is stored (the address of the conditional branch opcode). Because BRA and BRN instructions are not conditional, these events do not cause change-of-flow information to be stored in the FIFO.

Indirect JMP and JSR instructions use the current contents of the H:X index register pair to determine the destination address, so the debug system stores the run-time destination address for any indirect JMP or JSR. For interrupts, RTI, or RTS, the destination address is stored in the FIFO as change-of-flow information.

17.3.4 Tag vs. Force Breakpoints and Triggers

Tagging is a term that refers to identifying an instruction opcode as it is fetched into the instruction queue, but not taking any other action until and unless that instruction is actually executed by the CPU. This distinction is important because any change-of-flow from a jump, branch, subroutine call, or interrupt causes some instructions that have been fetched into the instruction queue to be thrown away without being executed.

A.13 FLASH Specification

This section provides details about program/erase times and program-erase endurance for the FLASH memory.

Program and erase operations do not require any special power sources other than the normal V_{DD} supply. For more detailed information about program/erase operations, see the Memory section.

Table A-16. FLASH Characteristics

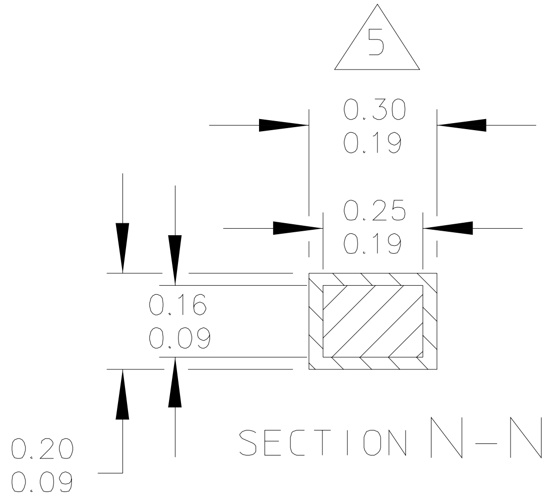
Num	C	Characteristic	Symbol	Min	Typical	Max	Unit
1	—	Supply voltage for program/erase	$V_{prog/erase}$	2.7		5.5	V
2	—	Supply voltage for read operation	V_{Read}	2.7		5.5	V
3	—	Internal FCLK frequency[1]	f_{FCLK}	150		200	kHz
4	—	Internal FCLK period ($1/f_{FCLK}$)	t_{Fcyc}	5		6.67	µs
5	—	Byte program time (random location)[2]	t_{prog}		9		t_{Fcyc}
6	—	Byte program time (burst mode)[2]	t_{Burst}		4		t_{Fcyc}
7	—	Page erase time[2]	t_{Page}		4000		t_{Fcyc}
8	—	Mass erase time[2]	t_{Mass}		20,000		t_{Fcyc}
9	C	Program/erase endurance[3] T_L to T_H = –40°C to +125°C T = 25°C	n_{FLPE}	 10,000 —	 — 100,000	 — —	cycles
10	C	Data retention[4]	t_{D_ret}	15	100	—	years

1 The frequency of this clock is controlled by a software setting.

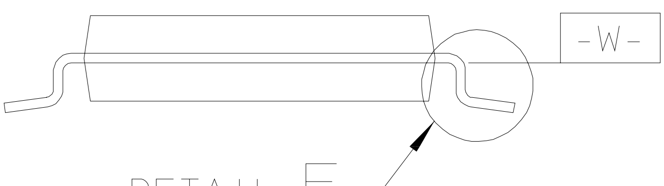
2 These values are hardware state machine controlled. User code does not need to count cycles. This information supplied for calculating approximate time to program and erase.

3 Typical endurance for FLASH is based on the intrinsic bit cell performance. For additional information on how Freescale defines typical endurance, please refer to Engineering Bulletin EB619/D, Typical Endurance for Nonvolatile Memory.

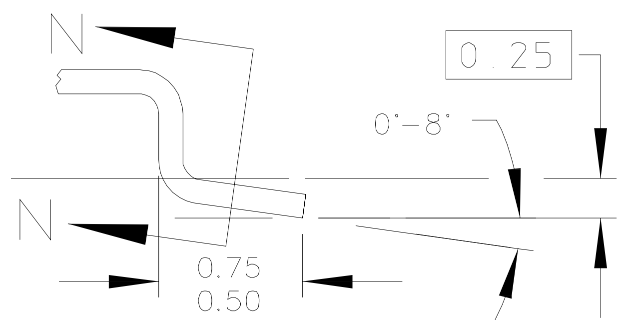
4 Typical data retention values are based on intrinsic capability of the technology measured at high temperature and de-rated to 25°C using the Arrhenius equation. For additional information on how Freescale defines typical data retention, please refer to Engineering Bulletin EB618/D, Typical Data Retention for Nonvolatile Memory.



SECTION N–N



DETAIL E



DETAIL E

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