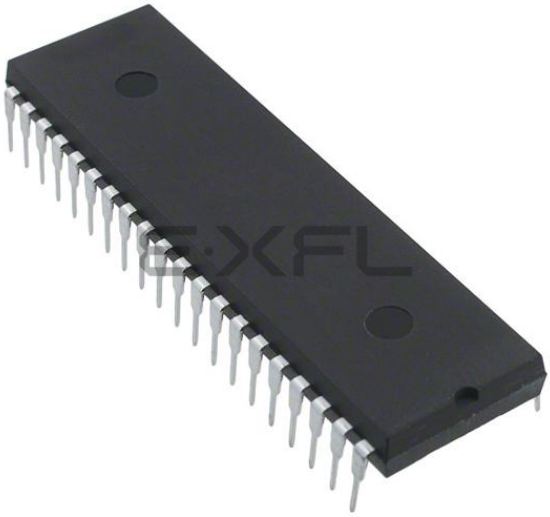

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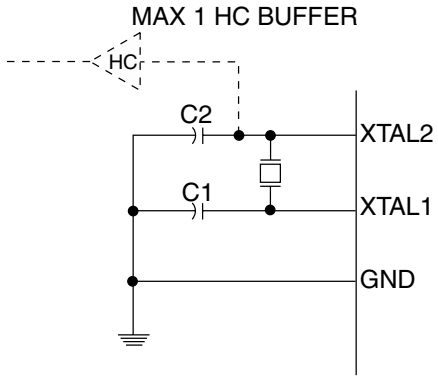
Applications of "Embedded - Microcontrollers"

Details	
Product Status	Obsolete
Core Processor	AVR
Core Size	8-Bit
Speed	4MHz
Connectivity	SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	32
Program Memory Size	8KB (4K x 16)
Program Memory Type	FLASH
EEPROM Size	512 x 8
RAM Size	512 x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 6V
Data Converters	-
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C
Mounting Type	Through Hole
Package / Case	40-DIP (0.600", 15.24mm)
Supplier Device Package	40-PDIP
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/at90s8515-4pi

Crystal Oscillator

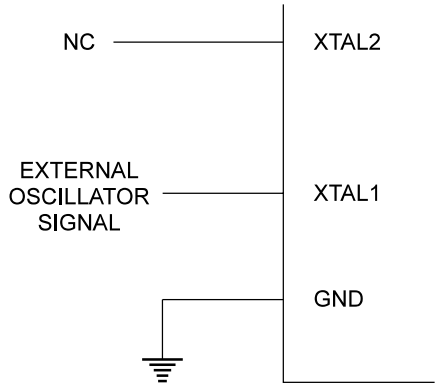
XTAL1 and XTAL2 are input and output, respectively, of an inverting amplifier that can be configured for use as an on-chip oscillator, as shown in Figure 2. Either a quartz crystal or a ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 3.

Figure 2. Oscillator Connections



Note: When using the MCU oscillator as a clock for an external device, an HC buffer should be connected as indicated in the figure.

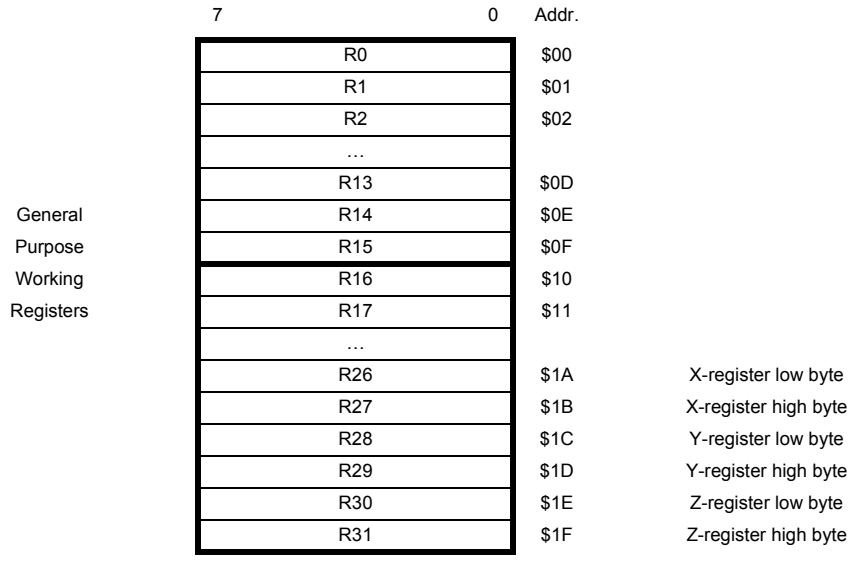
Figure 3. External Clock Drive Configuration



General-purpose Register File

Figure 6 shows the structure of the 32 general-purpose working registers in the CPU.

Figure 6. AVR CPU General-purpose Working Registers



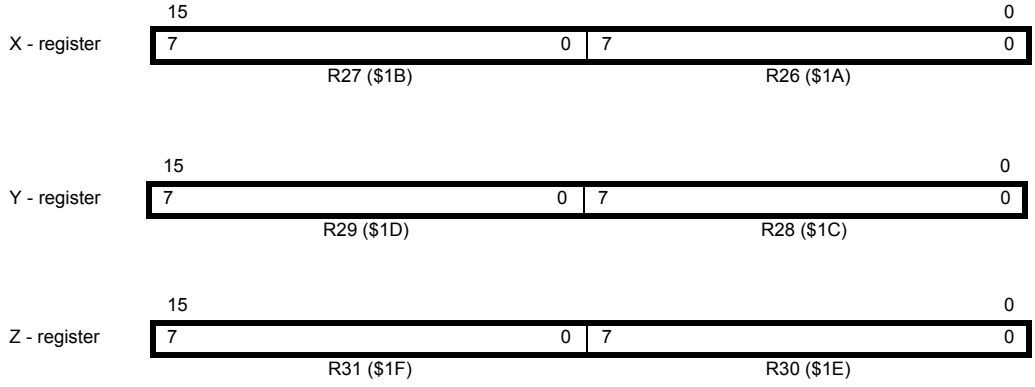
All the register operating instructions in the instruction set have direct and single-cycle access to all registers. The only exception are the five constant arithmetic and logic instructions SBCI, SUBI, CPI, ANDI and ORI between a constant and a register and the LDI instruction for load immediate constant data. These instructions apply to the second half of the registers in the register file (R16..R31). The general SBC, SUB, CP, AND and OR and all other operations between two registers or on a single register apply to the entire register file.

As shown in Figure 6, each register is also assigned a data memory address, mapping them directly into the first 32 locations of the user Data Space. Although not being physically implemented as SRAM locations, this memory organization provides great flexibility in access of the registers, as the X-, Y- and Z-registers can be set to index any register in the file.

X-register, Y-register and Z-register

The registers R26..R31 have some added functions to their general-purpose usage. These registers are address pointers for indirect addressing of the Data Space. The three indirect address registers X, Y, and Z are defined as:

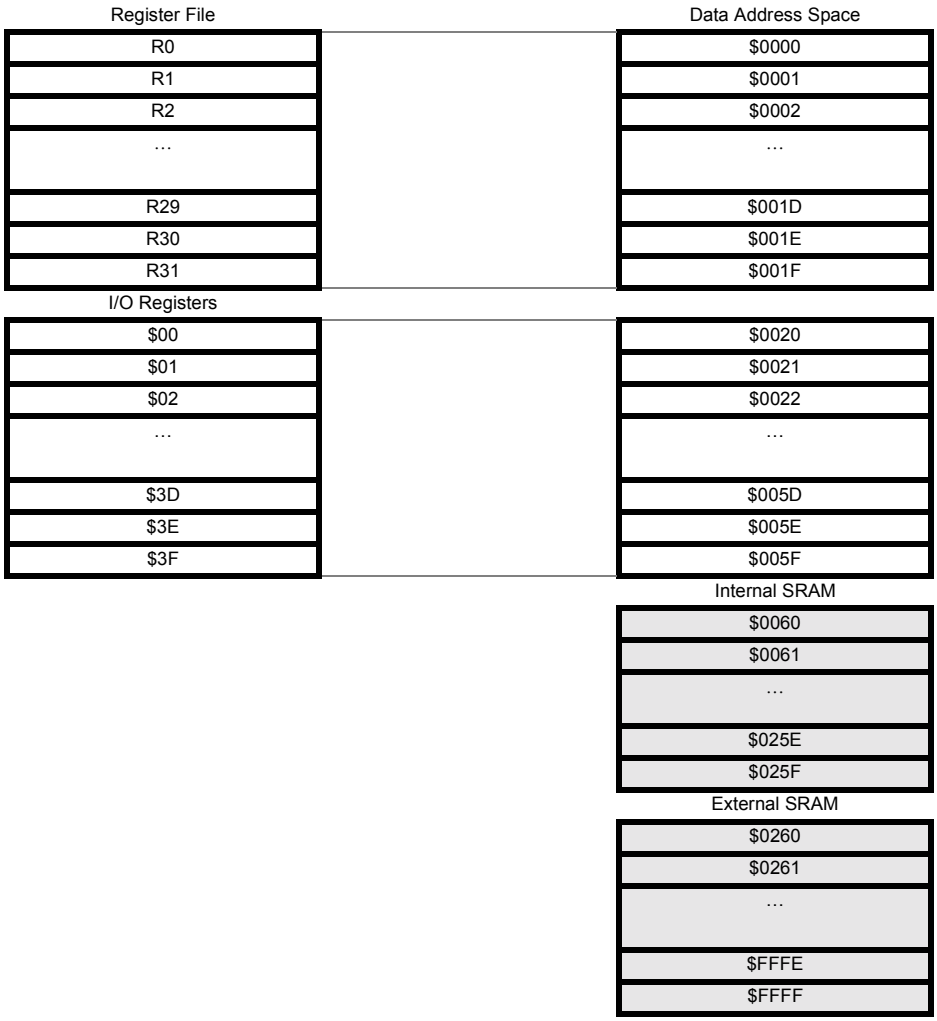
Figure 7. X-, Y-, and Z-registers



SRAM Data Memory – Internal and External

Figure 8 shows how the AT90S8515 SRAM memory is organized.

Figure 8. SRAM Organization



The lower 608 data memory locations address the Register file, the I/O memory and the internal data SRAM. The first 96 locations address the Register file + I/O memory, and the next 512 locations address the internal data SRAM. An optional external data SRAM can be placed in the same SRAM memory space. This SRAM will occupy the location following the internal SRAM and up to as much as 64K - 1, depending on SRAM size.

When the addresses accessing the data memory space exceed the internal data SRAM locations, the external data SRAM is accessed using the same instructions as for the internal data SRAM access. When the internal data space is accessed, the read and write strobe pins ($\overline{RD}$ and $\overline{WR}$) are inactive during the whole access cycle. External SRAM operation is enabled by setting the SRE bit in the MCUCR register. See page 29 for details.

Accessing external SRAM takes one additional clock cycle per byte compared to access of the internal SRAM. This means that the commands LD, ST, LDS, STS, PUSH and POP take one additional clock cycle. If the stack is placed in external SRAM, interrupts, subroutine calls and returns take two clock cycles extra because the 2-byte program counter is pushed and popped. When external SRAM interface is used with wait state,

Reset and Interrupt Handling

The AT90S8515 provides 12 different interrupt sources. These interrupts and the separate reset vector each have a separate program vector in the program memory space. All interrupts are assigned individual enable bits that must be set (one) together with the I-bit in the Status Register in order to enable the interrupt.

The lowest addresses in the program memory space are automatically defined as the Reset and Interrupt vectors. The complete list of vectors is shown in Table 2. The list also determines the priority levels of the different interrupts. The lower the address, the higher the priority level. RESET has the highest priority, and next is INT0 (the External Interrupt Request 0), etc.

Table 2. Reset and Interrupt Vectors

Vector No.	Program Address	Source	Interrupt Definition
1	$000	RESET	External Reset, Power-on Reset and Watchdog Reset
2	$001	INT0	External Interrupt Request 0
3	$002	INT1	External Interrupt Request 1
4	$003	TIMER1 CAPT	Timer/Counter1 Capture Event
5	$004	TIMER1 COMPA	Timer/Counter1 Compare Match A
6	$005	TIMER1 COMPB	Timer/Counter1 Compare Match B
7	$006	TIMER1 OVF	Timer/Counter1 Overflow
8	$007	TIMER0, OVF	Timer/Counter0 Overflow
9	$008	SPI, STC	Serial Transfer Complete
10	$009	UART, RX	UART, Rx Complete
11	$00A	UART, UDRE	UART Data Register Empty
12	$00B	UART, TX	UART, Tx Complete
13	$00C	ANA_COMP	Analog Comparator

The most typical and general program setup for the Reset and Interrupt vector addresses are:

```
Address   Labels       Code              Comments
$000                   rjmp   RESET        ; Reset Handler
$001                   rjmp   EXT_INT0     ; IRQ0 Handler
$002                   rjmp   EXT_INT1     ; IRQ1 Handler
$003                   rjmp   TIM1_CAPT    ; Timer1 Capture Handler
$004                   rjmp   TIM1_COMPA   ; Timer1 CompareA Handler
$005                   rjmp   TIM1_COMPB   ; Timer1 CompareB Handler
$006                   rjmp   TIM1_OVF       ; Timer1 Overflow Handler
$007                   rjmp   TIM0_OVF     ; Timer0 Overflow Handler
$008                   rjmp   SPI_STC      ; SPI Transfer Complete Handler
$009                   rjmp   UART_RXC     ; UART RX Complete Handler
$00a                   rjmp   UART_DRE     ; UDR Empty Handler
$00b                   rjmp   UART_TXC     ; UART TX Complete Handler
$00c                   rjmp   ANA_COMP     ; Analog Comparator Handler
;
$00d      MAIN:        ldi r16,high(RAMEND); Main program start
$00e                   out SPH,r16
```

The user can select the start-up time according to typical oscillator start-up. The number of WDT oscillator cycles used for each time-out is shown in Table 4. The frequency of the Watchdog Oscillator is voltage-dependent as shown in "Typical Characteristics" on page 95.

Table 4. Number of Watchdog Oscillator Cycles

FSTRT	Time-out at V_{CC} = 5V	Number of WDT Cycles
Programmed	0.28 ms	256
Unprogrammed	16.0 ms	16K

Power-on Reset

A Power-on Reset (POR) circuit ensures that the device is reset from power-on. As shown in Figure 23, an internal timer clocked from the Watchdog Timer oscillator prevents the MCU from starting until after a certain period after V_{CC} has reached the Power-on Threshold Voltage (V_{POT}), regardless of the V_{CC} rise time (see Figure 24). The FSTRT Fuse bit in the Flash can be programmed to give a shorter start-up time if a ceramic resonator or any other fast-start oscillator is used to clock the MCU.

If the built-in start-up delay is sufficient, $\overline{\text{RESET}}$ can be connected to V_{CC} directly or via an external pull-up resistor. By holding the pin low for a period after V_{CC} has been applied, the Power-on Reset period can be extended. Refer to Figure 25 for a timing example of this.

Figure 24. MCU Start-up, $\overline{\text{RESET}}$ Tied to V_{CC}.

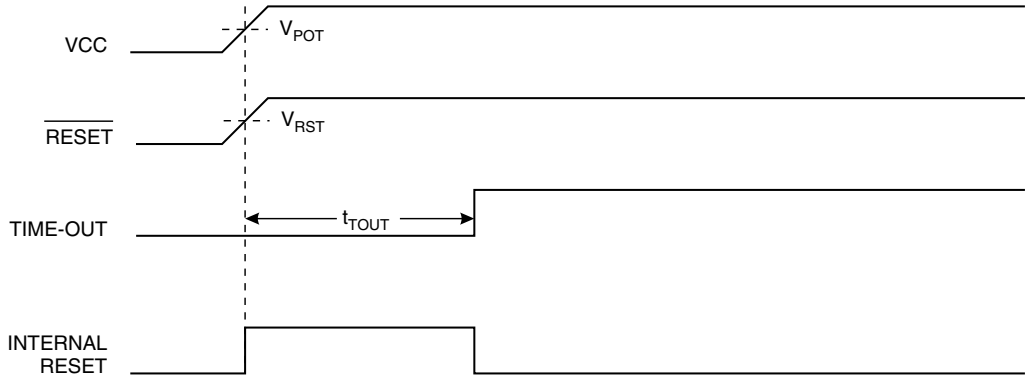
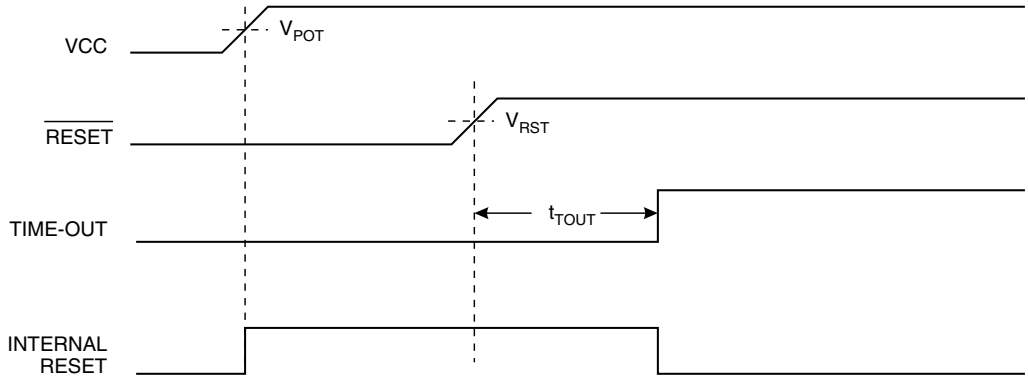


Figure 25. MCU Start-up, $\overline{\text{RESET}}$ Controlled Externally



- **Bit 5 – SE: Sleep Enable**

The SE bit must be set (one) to make the MCU enter the Sleep Mode when the SLEEP instruction is executed. To avoid the MCU entering the Sleep Mode, unless it is the programmer's purpose, it is recommended to set the Sleep Enable (SE) bit just before the execution of the SLEEP instruction.

- **Bit 4 – SM: Sleep Mode**

This bit selects between the two available sleep modes. When SM is cleared (zero), Idle Mode is selected as Sleep Mode. When SM is set (one), Power-down mode is selected as Sleep Mode. For details, refer to the section "Sleep Modes".

- **Bits 3, 2 – ISC11, ISC10: Interrupt Sense Control 1, Bit 1 and Bit 0**

The External Interrupt 1 is activated by the external pin INT1 if the SREG I-flag and the corresponding interrupt mask in the GIMSK are set. The level and edges on the external INT1 pin that activate the interrupt are defined in Table 5.

Table 5. Interrupt 1 Sense Control

ISC11	ISC10	Description
0	0	The low level of INT1 generates an interrupt request.
0	1	Reserved
1	0	The falling edge of INT1 generates an interrupt request.
1	1	The rising edge of INT1 generates an interrupt request.

- **Bits 1, 0 – ISC01, ISC00: Interrupt Sense Control 0, Bit 1 and Bit 0**

The External Interrupt 0 is activated by the external pin INT0 if the SREG I-flag and the corresponding interrupt mask are set. The level and edges on the external INT0 pin that activate the interrupt are defined in Table 6.

Table 6. Interrupt 0 Sense Control

ISC01	ISC00	Description
0	0	The low level of INT0 generates an interrupt request.
0	1	Reserved
1	0	The falling edge of INT0 generates an interrupt request.
1	1	The rising edge of INT0 generates an interrupt request.

The value on the INTn pin is sampled before detecting edges. If edge interrupt is selected, pulses with a duration longer than one CPU clock period will generate an interrupt. Shorter pulses are not guaranteed to generate an interrupt. If low-level interrupt is selected, the low level must be held until the completion of the currently executing instruction to generate an interrupt. If enabled, a level-triggered interrupt will generate an interrupt request as long as the pin is held low.

The Stop condition provides a Timer Enable/Disable function. The CK down divided modes are scaled directly from the CK oscillator clock. If the external pin modes are used for Timer/Counter1, transitions on PB1/(T1) will clock the counter even if the pin is configured as an output. This feature can give the user software control of the counting.

Timer/Counter1 – TCNT1H AND TCNT1L

Bit	15	14	13	12	11	10	9	8	
$2D ($4D)	MSB								TCNT1H
$2C ($4C)								LSB	TCNT1L
	7	6	5	4	3	2	1	0	
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	

This 16-bit register contains the prescaled value of the 16-bit Timer/Counter1. To ensure that both the high and low bytes are read and written simultaneously when the CPU accesses these registers, the access is performed using an 8-bit temporary register (TEMP). This temporary register is also used when accessing OCR1A, OCR1B and ICR1. If the main program and interrupt routines perform access to registers using TEMP, interrupts must be disabled during access from the main program (and from interrupt routines if interrupts are allowed from within interrupt routines).

- TCNT1 Timer/Counter1 Write:
  When the CPU writes to the high byte TCNT1H, the written data is placed in the TEMP register. Next, when the CPU writes the low byte TCNT1L, this byte of data is combined with the byte data in the TEMP register, and all 16 bits are written to the TCNT1 Timer/Counter1 register simultaneously. Consequently, the high byte TCNT1H must be accessed first for a full 16-bit register write operation.
- TCNT1 Timer/Counter1 Read:
  When the CPU reads the low byte TCNT1L, the data of the low byte TCNT1L is sent to the CPU and the data of the high byte TCNT1H is placed in the TEMP register. When the CPU reads the data in the high byte TCNT1H, the CPU receives the data in the TEMP register. Consequently, the low byte TCNT1L must be accessed first for a full 16-bit register read operation.

The Timer/Counter1 is realized as an up or up/down (in PWM mode) counter with read and write access. If Timer/Counter1 is written to and a clock source is selected, the Timer/Counter1 continues counting in the timer clock cycle after it is preset with the written value.

Timer/Counter1 Output Compare Register – OCR1AH AND OCR1AL

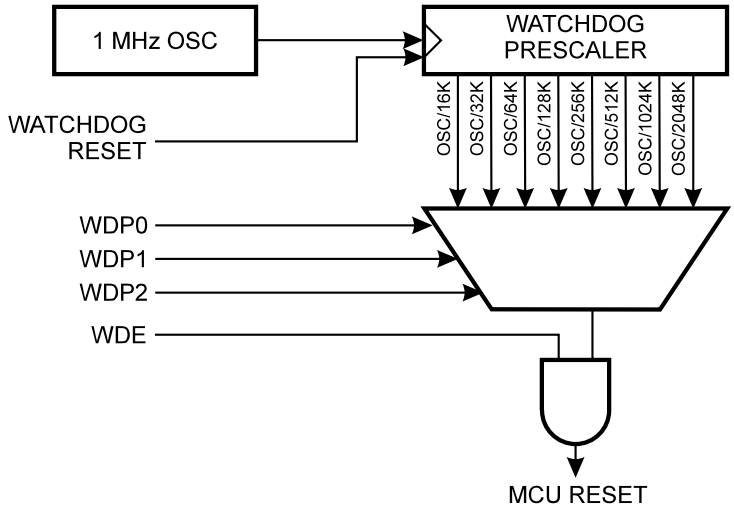
Bit	15	14	13	12	11	10	9	8	
$2B ($4B)	MSB								OCR1AH
$2A ($4A)								LSB	OCR1AL
	7	6	5	4	3	2	1	0	
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	

Watchdog Timer

The Watchdog Timer is clocked from a separate On-chip oscillator that runs at 1 MHz. This is the typical value at V_{CC} = 5V. See characterization data for typical values at other V_{CC} levels. By controlling the Watchdog Timer prescaler, the Watchdog reset interval can be adjusted (see Table 14 for a detailed description). The WDR (Watchdog Reset) instruction resets the Watchdog Timer. Eight different clock cycle periods can be selected to determine the reset period. If the reset period expires without another Watchdog reset, the AT90S8515 resets and executes from the reset vector. For timing details on the Watchdog reset, refer to page 25.

To prevent unintentional disabling of the Watchdog, a special turn-off sequence must be followed when the Watchdog is disabled. Refer to the description of the Watchdog Timer Control Register for details.

Figure 33. Watchdog Timer



Watchdog Timer Control Register – WDTCR

Bit	7	6	5	4	3	2	1	0	
$21 ($41)	–	–	–	WDTOE	WDE	WDP2	WDP1	WDP0	WDTCR
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

- **Bits 7..5 – Res: Reserved Bits**

These bits are reserved bits in the AT90S8515 and will always read as zero.

- **Bit 4 – WDTOE: Watchdog Turn-off Enable**

This bit must be set (one) when the WDE bit is cleared. Otherwise, the Watchdog will not be disabled. Once set, hardware will clear this bit to zero after four clock cycles. Refer to the description of the WDE bit for a Watchdog disable procedure.

- **Bit 3 – WDE: Watchdog Enable**

When the WDE is set (one) the Watchdog Timer is enabled, and if the WDE is cleared (zero) the Watchdog Timer function is disabled. WDE can only be cleared if the WDTOE bit is set (one). To disable an enabled Watchdog Timer, the following procedure must be followed:

If the 10(11)-bit Transmitter shift register is empty, data is transferred from UDR to the shift register. At this time the UDRE (UART Data Register Empty) bit in the UART Status Register, USR, is set. When this bit is set (one), the UART is ready to receive the next character. At the same time as the data is transferred from UDR to the 10(11)-bit shift register, bit 0 of the shift register is cleared (start bit) and bit 9 or 10 is set (stop bit). If 9-bit data word is selected (the CHR9 bit in the UART Control Register, UCR is set), the TXB8 bit in UCR is transferred to bit 9 in the Transmit shift register.

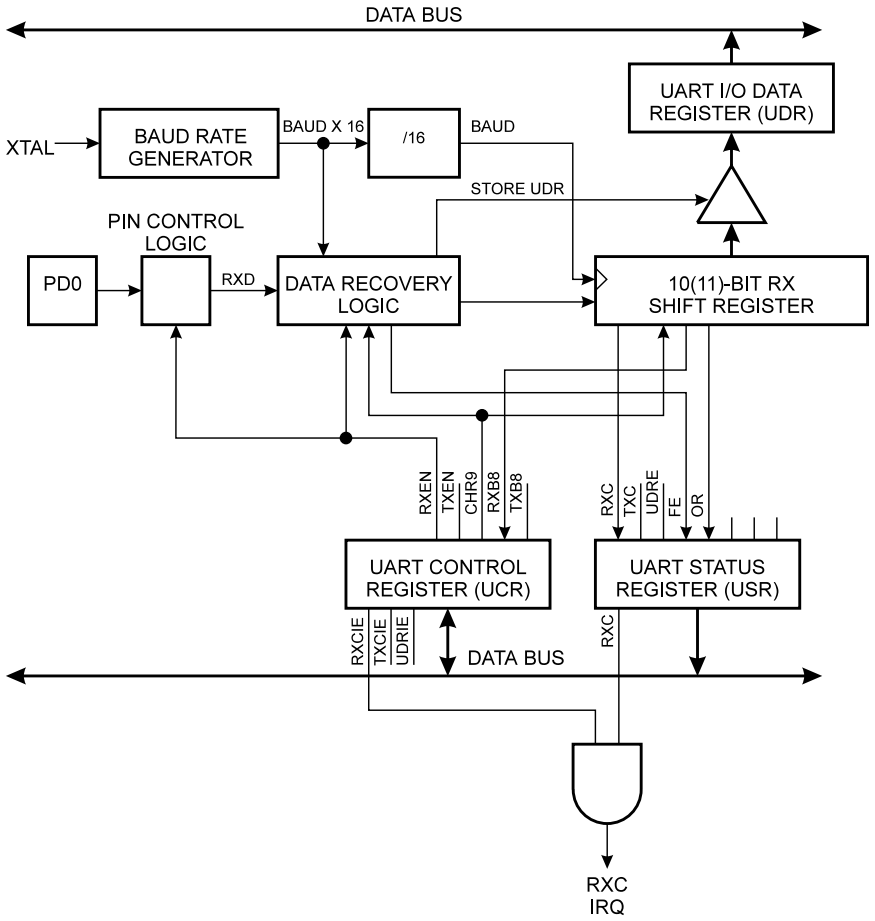
On the baud rate clock following the transfer operation to the shift register, the start bit is shifted out on the TXD pin. Then follows the data, LSB first. When the stop bit has been shifted out, the shift register is loaded if any new data has been written to the UDR during the transmission. During loading, UDRE is set. If there is no new data in the UDR register to send when the stop bit is shifted out, the UDRE flag will remain set until UDR is written again. When no new data has been written and the stop bit has been present on TXD for one bit length, the TX Complete flag (TXC) in USR is set.

The TXEN bit in UCR enables the UART Transmitter when set (one). When this bit is cleared (zero), the PD1 pin can be used for general I/O. When TXEN is set, the UART Transmitter will be connected to PD1, which is forced to be an output pin regardless of the setting of the DDD1 bit in DDRD.

Data Reception

Figure 39 shows a block diagram of the UART Receiver.

Figure 39. UART Receiver



I/O Ports

All AVR ports have true read-modify-write functionality when used as general digital I/O ports. This means that the direction of one port pin can be changed without unintentionally changing the direction of any other pin with the SBI and CBI instructions. The same applies for changing drive value (if configured as output) or the enabling/disabling of pull-up resistors (if configured as input).

Port A

Port A is an 8-bit bi-directional I/O port.

Three I/O memory address locations are allocated for the Port A, one each for the Data Register – PORTA, $1B($3B), Data Direction Register – DDRA, $1A($3A) and the Port A Input Pins – PINA, $19($39). The Port A Input Pins address is read-only, while the Data Register and the Data Direction Register are read/write.

All port pins have individually selectable pull-up resistors. The Port A output buffers can sink 20 mA and thus drive LED displays directly. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated.

The Port A pins have alternate functions related to the optional external data SRAM. Port A can be configured to be the multiplexed low-order address/data bus during accesses to the external data memory. In this mode, Port A has internal pull-up resistors.

When Port A is set to the alternate function by the SRE (external SRAM enable) bit in the MCUCR (MCU Control Register), the alternate settings override the Data Direction Register.

Port A Data Register – PORTA

Bit	7	6	5	4	3	2	1	0	
$1B ($3B)	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	PORTA
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Port A Data Direction Register – DDRA

Bit	7	6	5	4	3	2	1	0	
$1A ($3A)	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	DDRA
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Port A Input Pins Address – PINA

Bit	7	6	5	4	3	2	1	0	
$19 ($39)	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	PINA
Read/Write	R	R	R	R	R	R	R	R	
Initial Value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

The Port A Input Pins address (PINA) is not a register; this address enables access to the physical value on each Port A pin. When reading PORTA, the Port A Data Latch is read and when reading PINA, the logical values present on the pins are read.

Port A as General Digital I/O

All eight pins in Port A have equal functionality when used as digital I/O pins.

PAn, general I/O pin: The DDAn bit in the DDRA register selects the direction of this pin. If DDAn is set (one), PAn is configured as an output pin. If DDAn is cleared (zero), PAn is configured as an input pin. If PORTAn is set (one) when the pin is configured as an input pin, the MOS pull-up resistor is activated. To switch the pull-up resistor off, the

PORTAn has to be cleared (zero) or the pin has to be configured as an output pin. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not active..

Table 19. DDAn Effects on Port A Pins

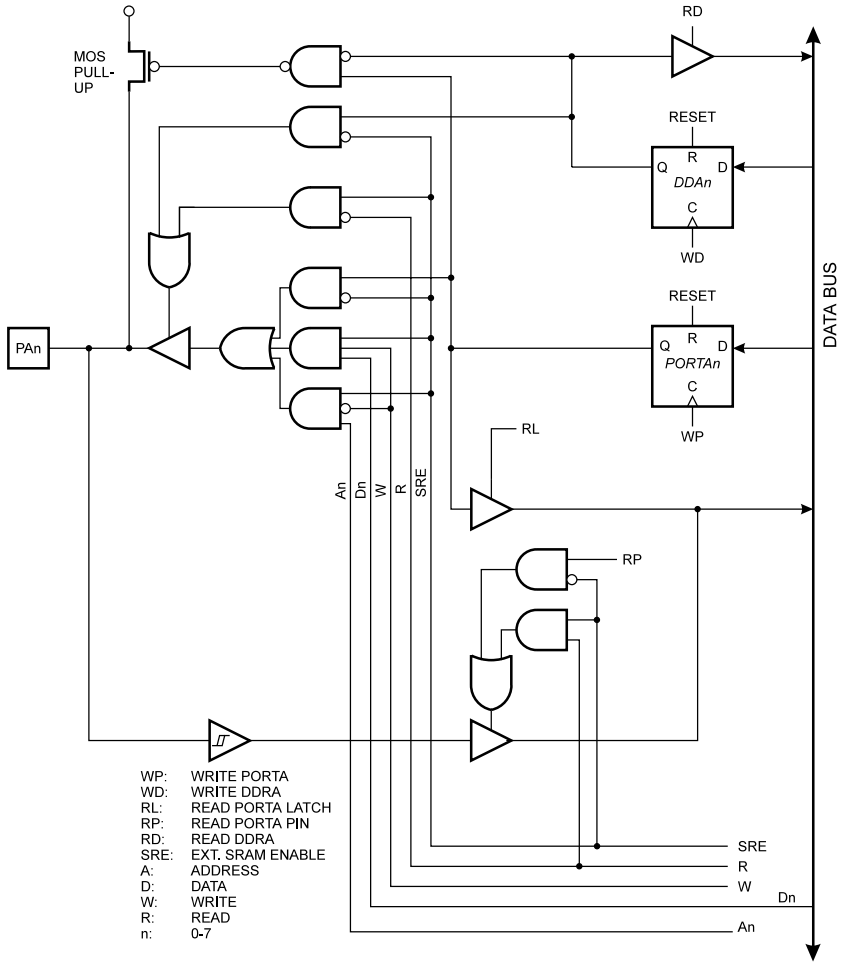
DDAn	PORTAn	I/O	Pull-up	Comment
0	0	Input	No	Tri-state (high-Z)
0	1	Input	Yes	PAn will source current if ext. pulled low.
1	0	Output	No	Push-pull Zero Output
1	1	Output	No	Push-pull One Output

Note: n: 7,6…0, pin number.

Port A Schematics

Note that all port pins are synchronized. The synchronization latch is, however, not shown in the figure.

Figure 45. Port A Schematic Diagrams (Pins PA0 - PA7)



Port B as General Digital I/O

All eight pins in Port B have equal functionality when used as digital I/O pins.

PBn, general I/O pin: The DDBn bit in the DDRB register selects the direction of this pin. If DDBn is set (one), PBn is configured as an output pin. If DDBn is cleared (zero), PBn is configured as an input pin. If PORTBn is set (one) when the pin is configured as an input pin, the MOS pull-up resistor is activated. To switch the pull-up resistor off, the PORTBn has to be cleared (zero) or the pin has to be configured as an output pin. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not active.

Table 21. DDBn Effects on Port B Pins

DDBn	PORTBn	I/O	Pull up	Comment
0	0	Input	No	Tri-state (high-Z)
0	1	Input	Yes	PBn will source current if ext. pulled low.
1	0	Output	No	Push-pull Zero Output
1	1	Output	No	Push-pull One Output

Note: n: 7,6…0, pin number.

Alternate Functions of Port B

The alternate pin configuration is as follows:

- **SCK – Port B, Bit 7**

SCK: Master clock output, slave clock input pin for SPI channel. When the SPI is enabled as a slave, this pin is configured as an input regardless of the setting of DDB7. When the SPI is enabled as a master, the data direction of this pin is controlled by DDB7. When the pin is forced to be an input, the pull-up can still be controlled by the PORTB7 bit. See the description of the SPI port for further details.

- **MISO – Port B, Bit 6**

MISO: Master data input, slave data output pin for SPI channel. When the SPI is enabled as a master, this pin is configured as an input regardless of the setting of DDB6. When the SPI is enabled as a slave, the data direction of this pin is controlled by DDB6. When the pin is forced to be an input, the pull-up can still be controlled by the PORTB6 bit. See the description of the SPI port for further details.

- **MOSI – Port B, Bit 5**

MOSI: SPI Master data output, slave data input for SPI channel. When the SPI is enabled as a slave, this pin is configured as an input regardless of the setting of DDB5. When the SPI is enabled as a master, the data direction of this pin is controlled by DDB5. When the pin is forced to be an input, the pull-up can still be controlled by the PORTB5 bit. See the description of the SPI port for further details.

- **SS – Port B, Bit 4**

$\overline{SS}$: Slave port select input. When the SPI is enabled as a slave, this pin is configured as an input regardless of the setting of DDB4. As a slave, the SPI is activated when this pin is driven low. When the SPI is enabled as a master, the data direction of this pin is controlled by DDB4. When the pin is forced to be an input, the pull-up can still be controlled by the PORTB4 bit. See the description of the SPI port for further details.

- **AIN1 – Port B, Bit 3**

AIN1: Analog Comparator Negative Input. When configured as an input (DDB3 is cleared [zero]) and with the internal MOS pull-up resistor switched off (PB3 is cleared [zero]), this pin also serves as the negative input of the On-chip Analog Comparator.

Port C Data Direction Register – DDRC

Bit	7	6	5	4	3	2	1	0	
$14 ($34)	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	DDRC
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Port C Input Pins Address – PINC

Bit	7	6	5	4	3	2	1	0	
$13 ($33)	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	PINC
Read/Write	R	R	R	R	R	R	R	R	
Initial Value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

The Port C Input Pins address (PINC) is not a register; this address enables access to the physical value on each Port C pin. When reading PORTC, the Port C Data Latch is read and when reading PINC, the logical values present on the pins are read.

Port C as General Digital I/O

All eight pins in Port C have equal functionality when used as digital I/O pins.

PCn, general I/O pin: The DDCn bit in the DDRC register selects the direction of this pin. If DDCn is set (one), PCn is configured as an output pin. If DDCn is cleared (zero), PCn is configured as an input pin. If PORTCn is set (one) when the pin is configured as an input pin, the MOS pull-up resistor is activated. To switch the pull-up resistor off, PORTCn has to be cleared (zero) or the pin has to be configured as an output pin. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not active.

Table 22. DDCn Effects on Port C Pins

DDCn	PORTCn	I/O	Pull-up	Comment
0	0	Input	No	Tri-state (high-Z)
0	1	Input	Yes	PCn will source current if ext. pulled low.
1	0	Output	No	Push-pull Zero Output
1	1	Output	No	Push-pull One Output

Note: n: 7…0, pin number

Figure 56. Port D Schematic Diagram (Pin PD4)

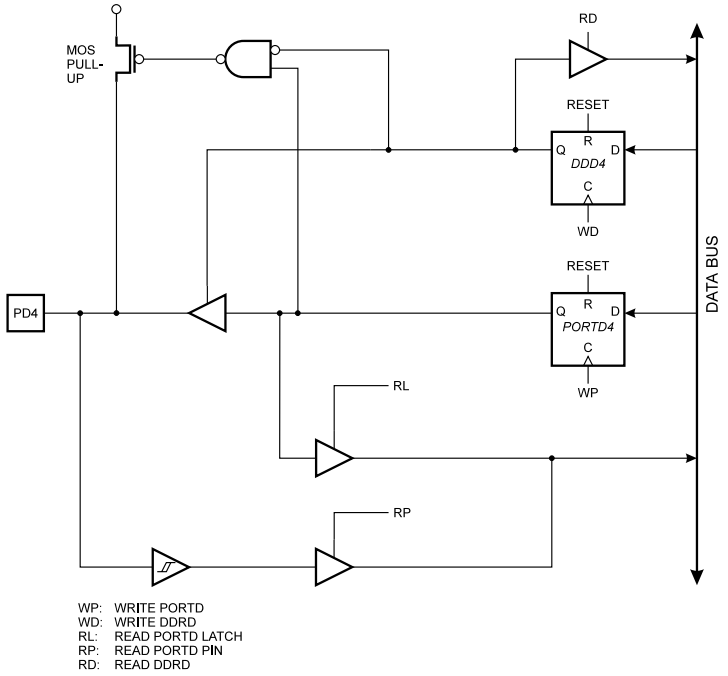
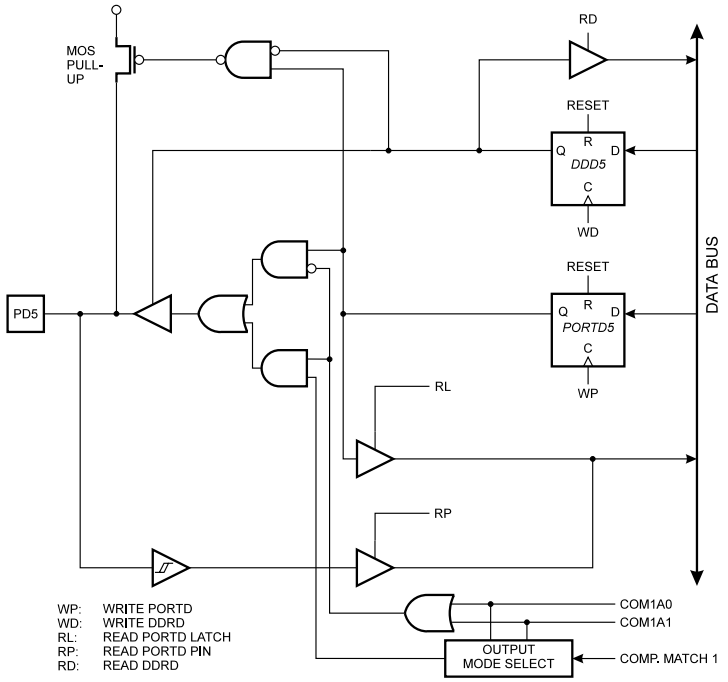


Figure 57. Port D Schematic Diagram (Pin PD5)



Chip Erase

The Chip Erase command will erase the Flash and EEPROM memories and the Lock bits. The Lock bits are not reset until the Flash and EEPROM have been completely erased. The Fuse bits are not changed. Chip Erase must be performed before the Flash or EEPROM is reprogrammed.

Load Command “Chip Erase”

1. Set XA1, XA0 to “10”. This enables command loading.
2. Set BS to “0”.
3. Set DATA to “1000 0000”. This is the command for Chip Erase.
4. Give XTAL1 a positive pulse. This loads the command.
5. Give $\overline{WR}$ a t_{WLWH_CE}-wide negative pulse to execute Chip Erase. See Table 30 on page 85 for t_{WLWH_CE} value. Chip Erase does not generate any activity on the RDY/$\overline{BSY}$ pin.

Programming the Flash

A: Load Command “Write Flash”

1. Set XA1, XA0 to “10”. This enables command loading.
2. Set BS to “0”.
3. Set DATA to “0001 0000”. This is the command for Write Flash.
4. Give XTAL1 a positive pulse. This loads the command.

B: Load Address High Byte

1. Set XA1, XA0 to “00”. This enables address loading.
2. Set BS to “1”. This selects high byte.
3. Set DATA = Address high byte ($00 - $0F).
4. Give XTAL1 a positive pulse. This loads the address high byte.

C: Load Address Low Byte

1. Set XA1, XA0 to “00”. This enables address loading.
2. Set BS to “0”. This selects low byte.
3. Set DATA = Address low byte ($00 - $FF).
4. Give XTAL1 a positive pulse. This loads the address low byte.

D: Load Data Low Byte

1. Set XA1, XA0 to “01”. This enables data loading.
2. Set DATA = Data low byte ($00 - $FF).
3. Give XTAL1 a positive pulse. This loads the data low byte.

E: Write Data Low Byte

1. Set BS to “0”. This selects low data.
2. Give $\overline{WR}$ a negative pulse. This starts programming of the data byte. RDY/$\overline{BSY}$ goes low.
3. Wait until RDY/$\overline{BSY}$ goes high to program the next byte.

(See Figure 61 for signal waveforms.)

F: Load Data High Byte

1. Set XA1, XA0 to “01”. This enables data loading.
2. Set DATA = Data high byte ($00 - $FF).
3. Give XTAL1 a positive pulse. This loads the data high byte.

G: Write Data High Byte

1. Set BS to “1”. This selects high data.
2. Give $\overline{WR}$ a negative pulse. This starts programming of the data byte. RDY/$\overline{BSY}$ goes low.
3. Wait until RDY/$\overline{BSY}$ goes high to program the next byte.

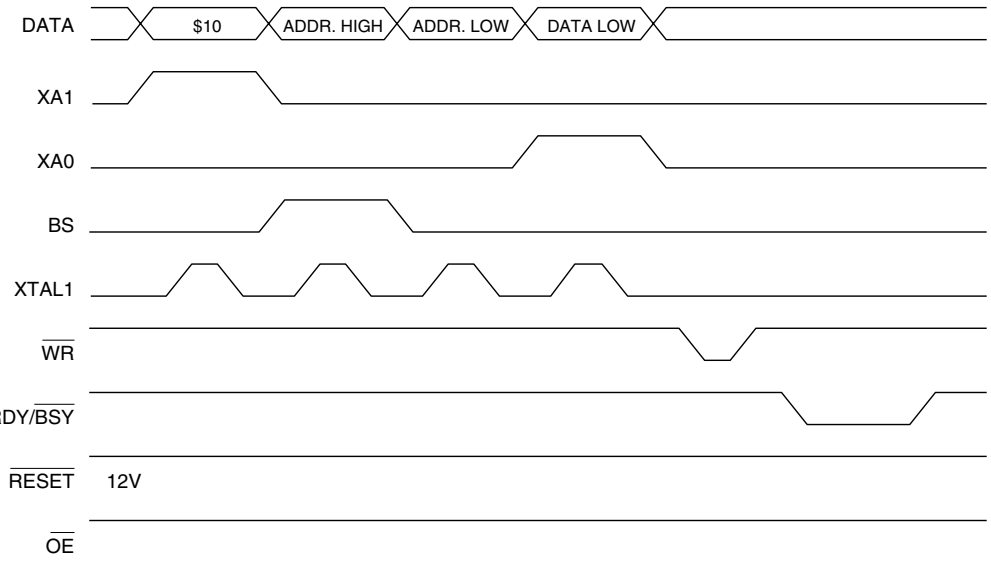
(See Figure 62 for signal waveforms.)

The loaded command and address are retained in the device during programming. For efficient programming, the following should be considered:

- The command needs only be loaded once when writing or reading multiple memory locations.
- Address high byte needs only be loaded before programming a new 256-word page in the Flash.
- Skip writing the data value $FF, that is, the contents of the entire Flash and EEPROM after a Chip Erase.

These considerations also apply to EEPROM programming and Flash, EEPROM and signature byte reading.

Figure 61. Programming the Flash Waveforms



Parallel Programming Characteristics

Figure 63. Parallel Programming Timing

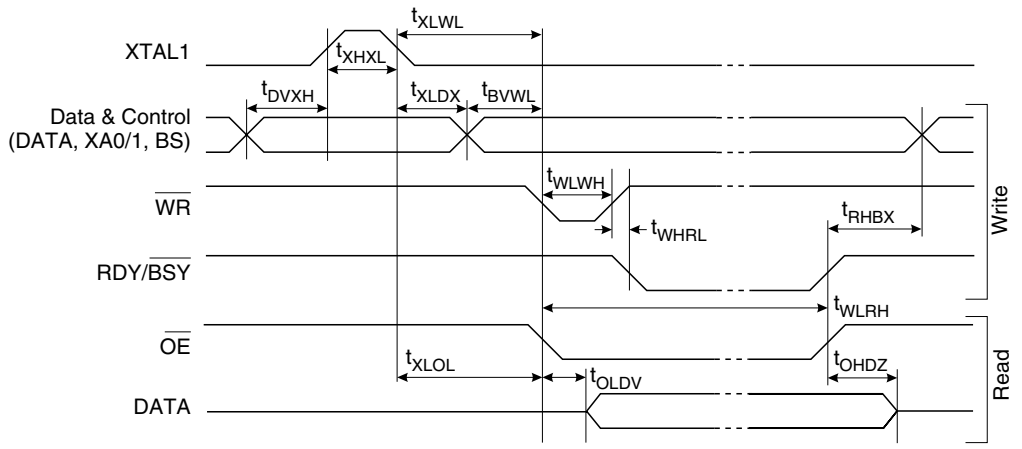


Table 30. Parallel Programming Characteristics, T_A = 25°C ± 10%, V_{CC} = 5V ± 10%

Symbol	Parameter	Min	Typ	Max	Units
V_{PP}	Programming Enable Voltage	11.5		12.5	V
I_{PP}	Programming Enable Current			250.0	µA
t_{DVXH}	Data and Control Setup before XTAL1 High	67.0			ns
t_{XHXL}	XTAL1 Pulse Width High	67.0			ns
t_{XLDX}	Data and Control Hold after XTAL1 Low	67.0			ns
t_{XLWL}	XTAL1 Low to $\overline{WR}$ Low	67.0			ns
t_{BVWL}	BS Valid to $\overline{WR}$ Low	67.0			ns
t_{RHBX}	BS Hold after RDY/$\overline{BSY}$ High	67.0			ns
t_{WLWH}	$\overline{WR}$ Pulse Width Low(1)	67.0			ns
t_{WHRL}	$\overline{WR}$ High to RDY/$\overline{BSY}$ Low(2)		20.0		ns
t_{WLRH}	$\overline{WR}$ Low to RDY/$\overline{BSY}$ High(2)	0.5	0.7	0.9	ms
t_{XLOL}	XTAL1 Low to $\overline{OE}$ Low	67.0			ns
t_{OLDV}	$\overline{OE}$ Low to DATA Valid		20.0		ns
t_{OHDZ}	$\overline{OE}$ High to DATA Tri-stated			20.0	ns
t_{WLWH_CE}	$\overline{WR}$ Pulse Width Low for Chip Erase	5.0	10.0	15.0	ms
t_{WLWH_PFB}	$\overline{WR}$ Pulse Width Low for Programming the Fuse Bits	1.0	1.5	1.8	ms

Notes: 1. Use t_{WLWH_CE} for Chip Erase and t_{WLWH_PFB} for programming the Fuse bits.
2. If t_{WLWH} is held longer than t_{WLRH}, no RDY/$\overline{BSY}$ pulse will be seen.

External Clock Drive Waveforms

Figure 67. External Clock

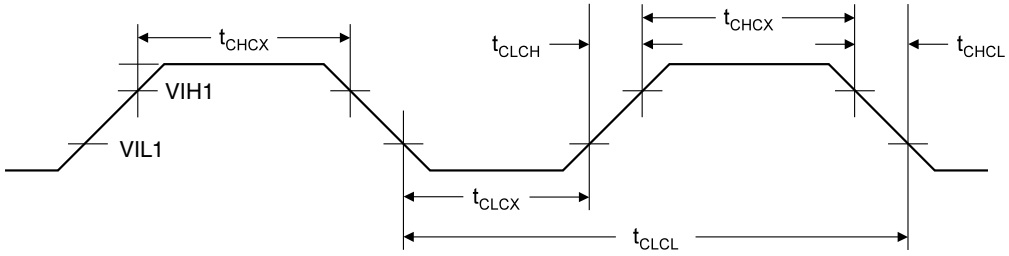
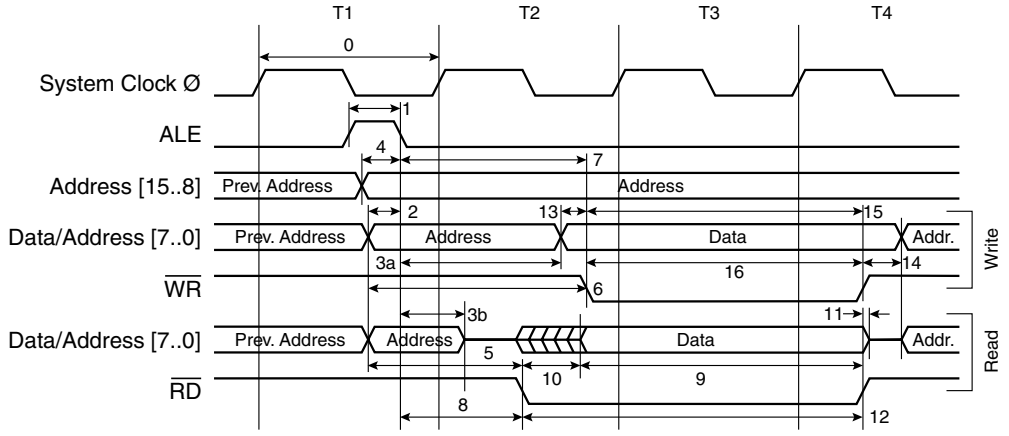


Table 36. External Clock Drive

Symbol	Parameter	V_{CC} = 2.7V to 4.0V		V_{CC} = 4.0V to 6.0V		Units
		Min	Max	Min	Max	
$1/t_{CLCL}$	Oscillator Frequency	0	4.0	0	8.0	MHz
t_{CLCL}	Clock Period	250.0		125.0		ns
t_{CHCX}	High Time	100.0		50.0		ns
t_{CLCX}	Low Time	100.0		50.0		ns
t_{CLCH}	Rise Time		1.6		0.5	µs
t_{CHCL}	Fall Time		1.6		0.5	µs

Note: See “External Data Memory Timing” for a description of how the duty cycle influences the timing for the external data memory.

Figure 68. External RAM Timing



Note: Clock cycle T3 is only present when external SRAM wait state is enabled.

Table 39. External Data Memory Characteristics, 2.7V - 4.0V, No Wait State

			4 MHz Oscillator		Variable Oscillator		
	Symbol	Parameter	Min	Max	Min	Max	Unit
0	$1/t_{CLCL}$	Oscillator Frequency			0.0	4.0	MHz
1	t_{LHLL}	ALE Pulse Width	70.0		0.5 t_{CLCL} - 55.0(1)		ns
2	t_{AVLL}	Address Valid A to ALE Low	60.0		0.5 t_{CLCL} - 65.0(1)		ns
3a	t_{LLAX_ST}	Address Hold after ALE Low, ST/STD/STS Instructions	130.0		0.5 t_{CLCL} + 5.0(2)		ns
3b	t_{LLAX_LD}	Address Hold after ALE Low, LD/LDD/LDS Instructions	15.0		15.0		ns
4	t_{AVLLC}	Address Valid C to ALE Low	60.0		0.5 t_{CLCL} - 65.0(1)		ns
5	t_{AVRL}	Address Valid to RD Low	200.0		1.0 t_{CLCL} - 50.0		ns
6	t_{AVWL}	Address Valid to WR Low	325.0		1.5 t_{CLCL} - 50.0(1)		ns
7	t_{LLWL}	ALE Low to WR Low	230.0	270.0	1.0 t_{CLCL} - 20.0	1.0 t_{CLCL} + 20.0	ns
8	t_{LLRL}	ALE Low to RD Low	105.0	145.0	0.5 t_{CLCL} - 20.0(2)	0.5 t_{CLCL} + 20.0(2)	ns
9	t_{DVRH}	Data Setup to RD High	95.0		95.0		ns
10	t_{RLDV}	Read Low to Data Valid		170.0		1.0 t_{CLCL} - 80.0	ns
11	t_{RHDX}	Data Hold after RD High	0.0		0.0		ns
12	t_{RLRH}	RD Pulse Width	230.0		1.0 t_{CLCL} - 20.0		ns
13	t_{DVWL}	Data Setup to WR Low	70.0		0.5 t_{CLCL} - 55.0(1)		ns
14	t_{WHDX}	Data Hold after WR High	0.0		0.0		ns
15	t_{DVWH}	Data Valid to WR High	210.0		1.0 t_{CLCL} - 40.0		ns
16	t_{WLWH}	WR Pulse Width	105.0		0.5 t_{CLCL} - 20.0(2)		ns

Table 40. External Data Memory Characteristics, 2.7V - 4.0V, One Cycle Wait State

			4 MHz Oscillator		Variable Oscillator		
	Symbol	Parameter	Min	Max	Min	Max	Unit
0	$1/t_{CLCL}$	Oscillator Frequency			0.0	4.0	MHz
10	t_{RLDV}	Read Low to Data Valid		420.00		2.0 t_{CLCL} - 80.0	ns
12	t_{RLRH}	RD Pulse Width	480.0		2.0 t_{CLCL} - 20.0		ns
15	t_{DVWH}	Data Valid to WR High	460.0		2.0 t_{CLCL} - 40.0		ns
16	t_{WLWH}	WR Pulse Width	355.0		1.5 t_{CLCL} - 20.0(2)		ns

Notes: 1. This assumes 50% clock duty cycle. The half-period is actually the high time of the external clock, XTAL1.
2. This assumes 50% clock duty cycle. The half-period is actually the low time of the external clock, XTAL1.

Figure 74. Power-down Supply Current vs. V_{CC}

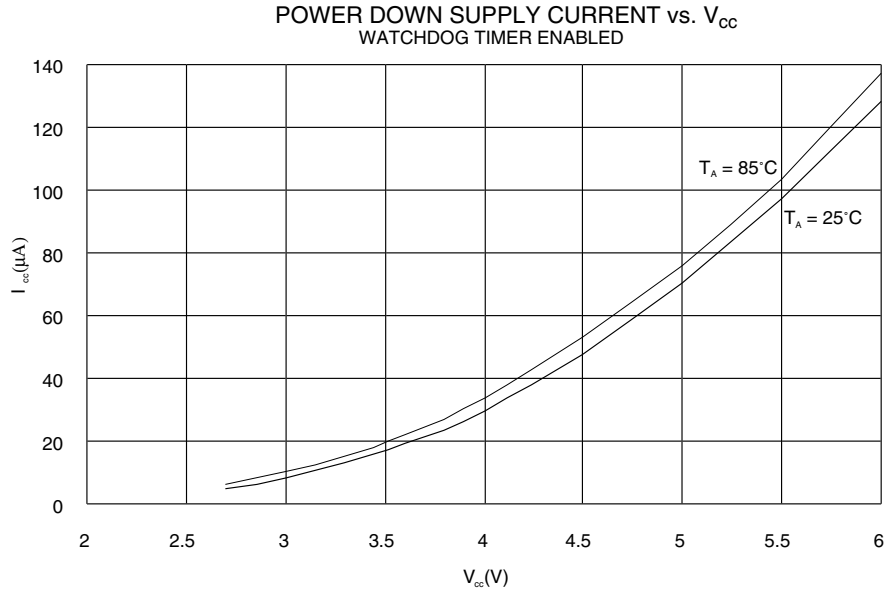


Figure 75. Analog Comparator Current vs. V_{CC}