



**C164**

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## Microcontrollers

### C166 Family

16-Bit Single-Chip Microcontroller

C164

Data Sheet 1999-08

Preliminary



# C166 Family of High-Performance CMOS 16-Bit Microcontrollers

C164

## Preliminary

### C164 16-Bit Microcontroller

- High Performance 16-bit CPU with 4-Stage Pipeline
  - 80 ns Instruction Cycle Time at 25 MHz CPU Clock
  - 400 ns Multiplication (16 × 16 bit), 800 ns Division (32 / 16 bit)
  - Enhanced Boolean Bit Manipulation Facilities
  - Additional Instructions to Support HLL and Operating Systems
  - Register-Based Design with Multiple Variable Register Banks
  - Single-Cycle Context Switching Support
  - 16 MBytes Total Linear Address Space for Code and Data
  - 1024 Bytes On-Chip Special Function Register Area
- 16-Priority-Level Interrupt System with 32/33 Sources, Sample-Rate down to 40 ns
- 8-Channel Interrupt-Driven Single-Cycle Data Transfer Facilities via Peripheral Event Controller (PEC)
- Clk. Generation via on-chip PLL (1:1.5/2/2.5/3/4/5), via prescaler or via direct clk. inp.
- On-Chip Memory Modules
  - 2 KBytes On-Chip Internal RAM (IRAM)
  - 2 KBytes On-Chip Extension RAM (XRAM)
  - 64 KBytes On-Chip **ROM** or Program **Flash**<sup>1)</sup> (Endur: 100 Prog./Er. Cycles min.)
  - 4 KBytes On-Chip DataFlash/EEPROM<sup>1)</sup> (Endur.: 100,000 Prog./Er. Cycles min.)
- On-Chip Peripheral Modules
  - 8-Channel 10-bit A/D Converter with Programm. Conversion Time down to 7.8 μs
  - Two Multi-Functional General Purpose Timer Units with 5 Timers
  - Two Serial Channels (Synchronous/Asynchronous and High-Speed-Synchronous)
  - 8-Channel 16-bit General Purpose Capture/Compare Unit (CAPCOM2)
  - Capture/Compare Unit for flexible PWM Signal Generation (CAPCOM6) (3/6 Capture/Compare Channels and 1 Compare Channel)
  - On-Chip CAN Interface (Rev. 2.0B active) with 15 Message Objects (Full-CAN / Basic CAN)
- Up to 4 MBytes External Address Space for Code and Data
  - Programmable External Bus Characteristics for Different Address Ranges
  - Multiplexed or Demultiplexed External Address/Data Buses with 8-Bit or 16-Bit Data Bus Width
  - Four Optional Programmable Chip-Select Signals
- Idle and Power Down Modes with Flexible Power Management
- Programmable Watchdog Timer and Oscillator Watchdog

1) Available only on devices in Flash technology.

- On-Chip Real Time Clock
- Up to 59 General Purpose I/O Lines, partly with Selectable Input Thresholds and Hysteresis
- Supported by a Large Range of Development Tools like C-Compilers, Macro-Assembler Packages, Emulators, Evaluation Boards, HLL-Debuggers, Simulators, Logic Analyzer Disassemblers, Programming Boards
- On-Chip Bootstrap Loader
- 80-Pin MQFP Package, 0.65 mm pitch

This document describes several derivatives of the C164 group. The table below enumerates these derivatives and summarizes the differences. As this document refers to all of these derivatives, some descriptions may not apply to a specific product.

**Table 1 C164 Derivative Synopsis**

| <b>Derivative</b> | <b>Program Memory</b> | <b>EEPROM</b> | <b>CAPCOM6</b> | <b>CAN Interf.</b> |
|-------------------|-----------------------|---------------|----------------|--------------------|
| SAK-C164CI-8RM    | 64 KByte ROM          | ---           | Full function  | CAN1               |
| SAK-C164SI-8RM    | 64 KByte ROM          | ---           | Full function  | ---                |
| SAK-C164CL-8RM    | 64 KByte ROM          | ---           | Reduced fct.   | CAN1               |
| SAK-C164SL-8RM    | 64 KByte ROM          | ---           | Reduced fct.   | ---                |
| SAK-C164CH-8FM    | 64 KByte Flash        | 4 KByte       | Full function  | CAN1               |
| SAK-C164SH-8FM    | 64 KByte Flash        | 4 KByte       | Full function  | ---                |

For simplicity all versions are referred to by the term **C164** throughout this document.

### Ordering Information

The ordering code for Infineon microcontrollers provides an exact reference to the required product. This ordering code identifies:

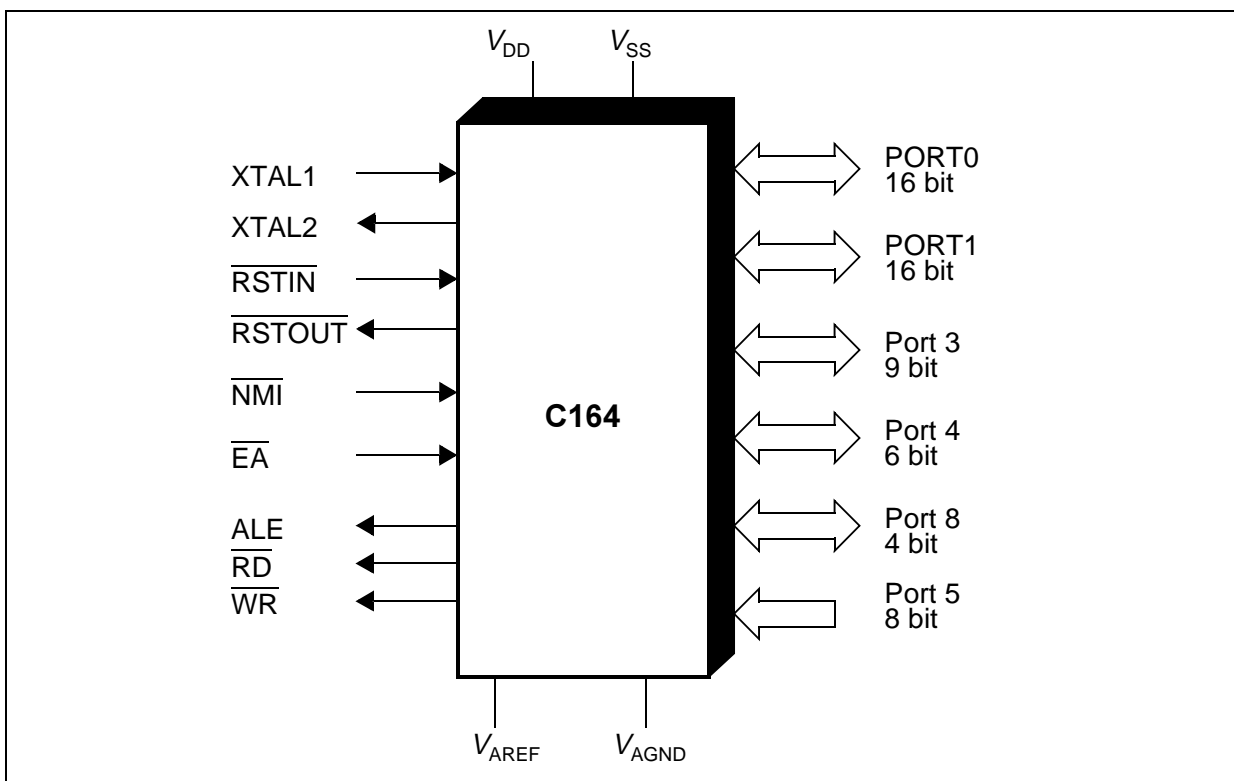
- the derivative itself, i.e. its function set
- the specified temperature range
- the package
- the type of delivery.

For the available ordering codes for the **C164** please refer to the „**Product Catalog Microcontrollers**“, which summarizes all available microcontroller variants.

*Note: The ordering codes for Mask-ROM versions are defined for each product after verification of the respective ROM code.*

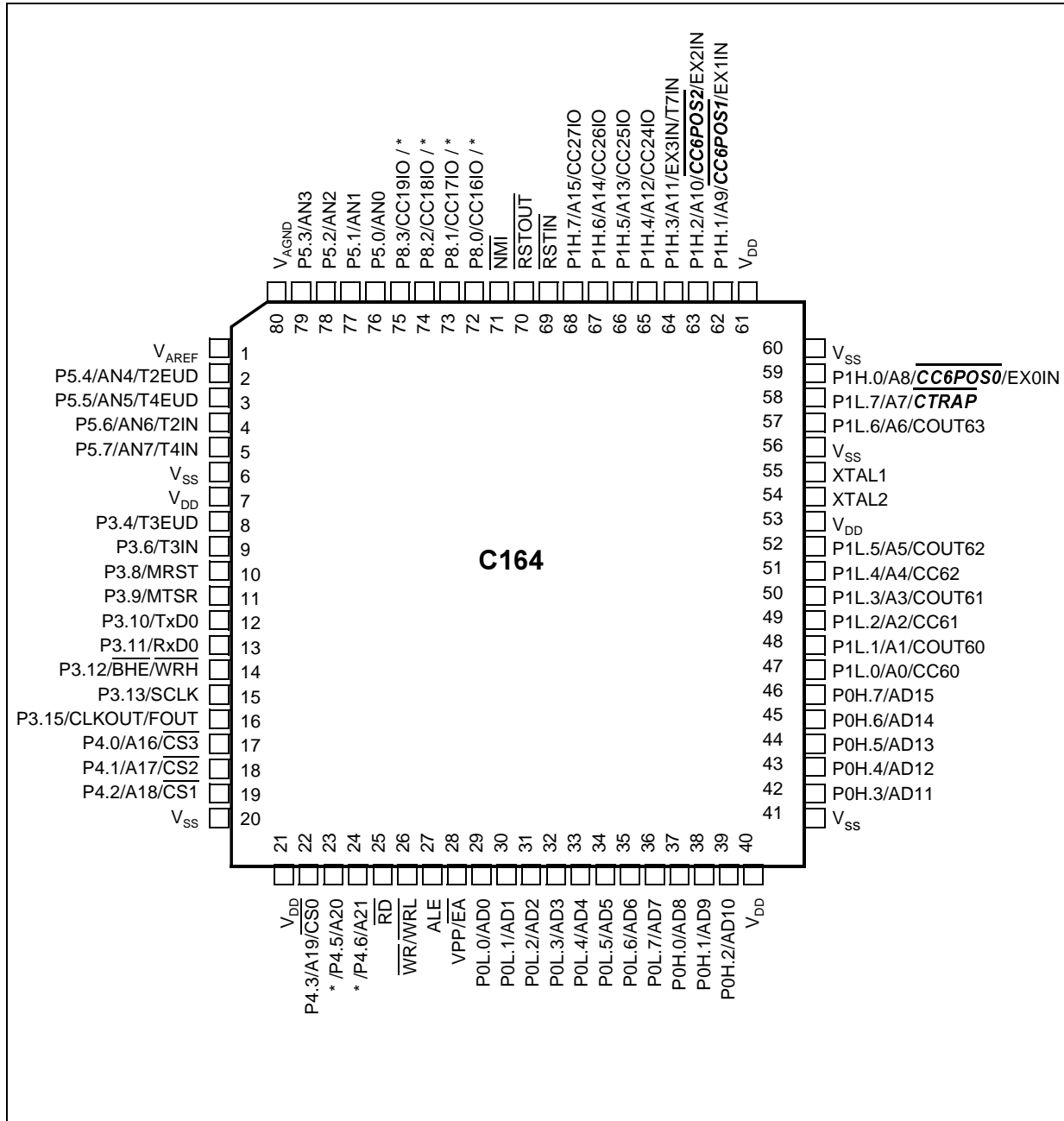
### Introduction

The C164 is a derivative of the Infineon C166 Family of 16-bit single-chip CMOS microcontrollers. It combines high CPU performance (up to 12.5 million instructions per second) with high peripheral functionality and enhanced IO-capabilities. It also provides on-chip program/data memory. The C164 derivative is especially suited for cost sensitive applications.



**Figure 1** Logic Symbol

**Pin Configuration MQFP Package**  
(top view)



**Figure 2**

\*) The marked pins of Port 4 and Port 8 can have CAN interface lines assigned to them. **Table 2** on the pages below lists the possible assignments.

The **marked input signals** are available only in devices with a full function CAPCOM6. They are not available in devices with a reduced CAPCOM6.

**Table 2 Pin Definitions and Functions**

| Symbol    | Pin Num. | Input<br>Outp. | Function   |
|-----------|----------|----------------|--|
| <b>P5</b> |          | I              | Port 5 is an 8-bit input-only port with Schmitt-Trigger charact. The pins of Port 5 also serve as analog input channels for the A/D converter, or they serve as timer inputs:  |
| P5.0      | 76       | I              | AN0  |
| P5.1      | 77       | I              | AN1  |
| P5.2      | 78       | I              | AN2  |
| P5.3      | 79       | I              | AN3  |
| P5.4      | 2        | I              | AN4, T2EUD GPT1 Timer T5 Ext. Up/Down Ctrl. Inp.   |
| P5.5      | 3        | I              | AN5, T4EUD GPT1 Timer T4 Ext. Up/Down Ctrl. Inp.   |
| P5.6      | 4        | I              | AN6, T2IN GPT1 Timer T2 Input for Count/Gate/Reload/Capture  |
| P5.7      | 5        | I              | AN7, T4IN GPT1 Timer T4 Input for Count/Gate/Reload/Capture  |
| <b>P3</b> |          | IO             | Port 3 is a 9-bit bidirectional I/O port. It is bit-wise programmable for input or output via direction bits. For a pin configured as input, the output driver is put into high-impedance state. Port 3 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 3 is selectable (TTL or special).<br>The following Port 3 pins also serve for alternate functions: |
| P3.4      | 8        | I              | T3EUD GPT1 Timer T3 External Up/Down Control Input   |
| P3.6      | 9        | I              | T3IN GPT1 Timer T3 Count/Gate Input  |
| P3.8      | 10       | I/O            | MRST SSC Master-Receive/Slave-Transmit Inp./Outp.  |
| P3.9      | 11       | I/O            | MTRSR SSC Master-Transmit/Slave-Receive Outp./Inp.   |
| P3.10     | 12       | O              | TxD0 ASC0 Clock/Data Output (Async./Sync.)   |
| P3.11     | 13       | I/O            | RxD0 ASC0 Data Input (Async.) or Inp./Outp. (Sync.)  |
| P3.12     | 14       | O              | <u>BHE</u> External Memory High Byte Enable Signal,  |
|           |          | O              | WRH External Memory High Byte Write Strobe   |
| P3.13     | 15       | I/O            | SCLK SSC Master Clock Output / Slave Clock Input.  |
| P3.15     | 16       | O              | CLKOUT System Clock Output (=CPU Clock)  |
|           |          | O              | FOUT Programmable Frequency Output   |

**Table 2 Pin Definitions and Functions (continued)**

| Symbol                          | Pin Num. | Input<br>Outp. | Function   |
|---------------------------------|----------|----------------|--|
| <b>P4</b>                       |          | IO             | Port 4 is a 6-bit bidirectional I/O port. It is bit-wise programmable for input or output via direction bits. For a pin configured as input, the output driver is put into high-impedance state. Port 4 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 4 is selectable (TTL or special).<br>Port 4 can be used to output the segment address lines, the optional chip select lines, and for serial interface lines: <sup>1)</sup> |
| P4.0                            | 17       | O              | <u>A16</u> Least Significant Segment Address Line,   |
|                                 |          | O              | <u>CS3</u> Chip Select 3 Output  |
| P4.1                            | 18       | O              | <u>A17</u> Segment Address Line,   |
|                                 |          | O              | <u>CS2</u> Chip Select 2 Output  |
| P4.2                            | 19       | O              | <u>A18</u> Segment Address Line,   |
|                                 |          | O              | <u>CS1</u> Chip Select 1 Output  |
| P4.3                            | 22       | O              | <u>A19</u> Segment Address Line,   |
|                                 |          | O              | <u>CS0</u> Chip Select 0 Output  |
| P4.5                            | 23       | O              | A20 Segment Address Line,  |
|                                 |          | I              | CAN1_RxD CAN 1 Receive Data Input  |
| P4.6                            | 24       | O              | A21 Most Significant Segment Address Line,   |
|                                 |          | O              | CAN1_TxD CAN 1 Transmit Data Output  |
| $\overline{\text{RD}}$          | 25       | O              | External Memory Read Strobe. $\overline{\text{RD}}$ is activated for every external instruction or data read access.   |
| $\overline{\text{WR}}$ /<br>WRL | 26       | O              | External Memory Write Strobe. In $\overline{\text{WR}}$ -mode this pin is activated for every external data write access. In WRL-mode this pin is activated for low byte data write accesses on a 16-bit bus, and for every data write access on an 8-bit bus. See WRCFG in register SYSCON for mode selection.  |
| ALE                             | 27       | O              | Address Latch Enable Output. Can be used for latching the address into external memory or an address latch in the multiplexed bus modes.   |
| $\overline{\text{EA}}$          | 28       | I              | External Access Enable pin. A low level at this pin during and after Reset forces the C164 to begin instruction execution out of external memory. A high level forces execution out of the internal program memory.<br>"ROMless" versions must have this pin tied to '0'.  |



**Table 2 Pin Definitions and Functions (continued)**

| Symbol                             | Pin Num.                      | Input<br>Outp. | Function  |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
|------------------------------------|-------------------------------|----------------|---|------------------|-------|--------|----------------|---------|---------|----------------|-----|----------|------------------|-------|--------|----------------|-----------|-----------|----------------|----------|------------|
| <b>PORT0</b><br>P0L.0-7<br>P0H.0-7 | 29 -<br>36<br>37-39,<br>42-46 | IO             | <p>PORT0 consists of the two 8-bit bidirectional I/O ports P0L and P0H. It is bit-wise programmable for input or output via direction bits. For a pin configured as input, the output driver is put into high-impedance state.</p> <p>In case of an external bus configuration, PORT0 serves as the address (A) and address/data (AD) bus in multiplexed bus modes and as the data (D) bus in demultiplexed bus modes.</p> <p><b>Demultiplexed bus modes:</b></p> <table> <tr> <td>Data Path Width:</td> <td>8-bit</td> <td>16-bit</td> </tr> <tr> <td>P0L.0 – P0L.7:</td> <td>D0 – D7</td> <td>D0 - D7</td> </tr> <tr> <td>P0H.0 – P0H.7:</td> <td>I/O</td> <td>D8 - D15</td> </tr> </table> <p><b>Multiplexed bus modes:</b></p> <table> <tr> <td>Data Path Width:</td> <td>8-bit</td> <td>16-bit</td> </tr> <tr> <td>P0L.0 – P0L.7:</td> <td>AD0 – AD7</td> <td>AD0 - AD7</td> </tr> <tr> <td>P0H.0 – P0H.7:</td> <td>A8 - A15</td> <td>AD8 - AD15</td> </tr> </table> | Data Path Width: | 8-bit | 16-bit | P0L.0 – P0L.7: | D0 – D7 | D0 - D7 | P0H.0 – P0H.7: | I/O | D8 - D15 | Data Path Width: | 8-bit | 16-bit | P0L.0 – P0L.7: | AD0 – AD7 | AD0 - AD7 | P0H.0 – P0H.7: | A8 - A15 | AD8 - AD15 |
| Data Path Width:                   | 8-bit                         | 16-bit         |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
| P0L.0 – P0L.7:                     | D0 – D7                       | D0 - D7        |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
| P0H.0 – P0H.7:                     | I/O                           | D8 - D15       |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
| Data Path Width:                   | 8-bit                         | 16-bit         |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
| P0L.0 – P0L.7:                     | AD0 – AD7                     | AD0 - AD7      |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |
| P0H.0 – P0H.7:                     | A8 - A15                      | AD8 - AD15     |   |                  |       |        |                |         |         |                |     |          |                  |       |        |                |           |           |                |          |            |

**Table 2 Pin Definitions and Functions (continued)**

| Symbol       | Pin Num.     | Input Outp. | Function   |
|--------------|--------------|-------------|--|
| <b>PORT1</b> |              | IO          | PORT1 consists of the two 8-bit bidirectional I/O ports P1L and P1H. It is bit-wise programmable for input or output via direction bits. For a pin configured as input, the output driver is put into high-impedance state. PORT1 is used as the 16-bit address bus (A) in demultiplexed bus modes and also after switching from a demultiplexed bus mode to a multiplexed bus mode. |
| P1L.0-7      | 47-52, 57-59 |             |  |
| P1H.0-7      | 59, 62-68    |             |  |
| P1L.0        | 47           | I/O         | CC60 CAPCOM6: Input / Output of Channel 0  |
| P1L.1        | 48           | O           | COUT60 CAPCOM6: Output of Channel 0  |
| P1L.2        | 49           | I/O         | CC61 CAPCOM6: Input / Output of Channel 1  |
| P1L.3        | 50           | O           | COUT61 CAPCOM6: Output of Channel 1  |
| P1L.4        | 51           | I/O         | CC62 CAPCOM6: Input / Output of Channel 2  |
| P1L.5        | 52           | O           | COUT62 CAPCOM6: Output of Channel 2  |
| P1L.6        | 57           | O           | COUT63 Output of 10-bit Compare Channel  |
| P1L.7        | 58           | I           | <u>CTRAP</u> CAPCOM6: Trap Input **)<br><u>CTRAP</u> is an input pin with an internal pullup resistor. A low level on this pin switches the compare outputs of the CAPCOM6 unit to the logic level defined by software.  |
| P1H.0        | 59           | I           | <u>CC6POS0</u> CAPCOM6: Position 0 Input, **)<br><u>EX0IN</u> Fast External Interrupt 0 Input  |
| P1H.1        | 62           | I           | <u>CC6POS1</u> CAPCOM6: Position 1 Input, **)<br><u>EX1IN</u> Fast External Interrupt 1 Input  |
| P1H.2        | 63           | I           | <u>CC6POS2</u> CAPCOM6: Position 2 Input, **)<br><u>EX2IN</u> Fast External Interrupt 2 Input  |
| P1H.3        | 64           | I           | <u>EX3IN</u> Fast External Interrupt 3 Input,<br><u>T7IN</u> CAPCOM2: Timer T7 Count Input   |
| P1H.4        | 65           | I/O         | CC24IO CAPCOM2: CC24 Capture Inp./Compare Outp.  |
| P1H.5        | 66           | I/O         | CC25IO CAPCOM2: CC25 Capture Inp./Compare Outp.  |
| P1H.6        | 67           | I/O         | CC26IO CAPCOM2: CC26 Capture Inp./Compare Outp.  |
| P1H.7        | 68           | I/O         | CC27IO CAPCOM2: CC27 Capture Inp./Compare Outp.  |
|              |              |             | <i>Note: The marked (**) input signals are available only in devices with a full function CAPCOM6.</i>   |

**Table 2 Pin Definitions and Functions (continued)**

| Symbol                     | Pin Num. | Input<br>Output. | Function   |
|----------------------------|----------|------------------|--|
| XTAL2<br>XTAL1             | 54<br>55 | O<br>I           | <p>XTAL2: Output of the oscillator amplifier circuit.</p> <p>XTAL1: Input to the oscillator amplifier and input to the internal clock generator</p> <p>To clock the device from an external source, drive XTAL1, while leaving XTAL2 unconnected. Minimum and maximum high/low and rise/fall times specified in the AC Characteristics must be observed.</p>   |
| $\overline{\text{RSTIN}}$  | 69       | I/O              | <p>Reset Input with Schmitt-Trigger characteristics. A low level at this pin while the oscillator is running resets the C164. An internal pullup resistor permits power-on reset using only a capacitor connected to <math>V_{SS}</math>.</p> <p>A spike filter suppresses input pulses &lt;10 ns. Input pulses &gt;100 ns safely pass the filter. The minimum duration for a safe recognition should be 100 ns + 2 CPU clock cycles.</p> <p>In bidirectional reset mode (enabled by setting bit BDRSTEN in register SYSCON) the <math>\overline{\text{RSTIN}}</math> line is internally pulled low for the duration of the internal reset sequence upon any reset (HW, SW, WDT). See note below this table.</p> |
| $\overline{\text{RSTOUT}}$ | 70       | O                | <p>Internal Reset Indication Output. This pin is set to a low level when the part is executing either a hardware-, a software- or a watchdog timer reset. <math>\overline{\text{RSTOUT}}</math> remains low until the EINIT (end of initialization) instruction is executed.</p>   |
| $\overline{\text{NMI}}$    | 71       | I                | <p>Non-Maskable Interrupt Input. A high to low transition at this pin causes the CPU to vector to the NMI trap routine. When the PWRDN (power down) instruction is executed, the <math>\overline{\text{NMI}}</math> pin must be low in order to force the C164 to go into power down mode. If <math>\overline{\text{NMI}}</math> is high, when PWRDN is executed, the part will continue to run in normal mode.</p> <p>If not used, pin <math>\overline{\text{NMI}}</math> should be pulled high externally.</p>   |

**Table 2 Pin Definitions and Functions (continued)**

| Symbol     | Pin Num.                | Input<br>Outp. | Function   |
|------------|-------------------------|----------------|--|
| <b>P8</b>  |                         | IO             | Port 8 is a 4-bit bidirectional I/O port. It is bit-wise programmable for input or output via direction bits. For a pin configured as input, the output driver is put into high-impedance state. Port 8 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 8 is selectable (TTL or special). Port 8 pins provide inputs/outputs for CAPCOM2 and serial interface lines. <sup>1)</sup> |
| P8.0       | 72                      | I/O<br>I       | CC16IO CAPCOM2: CC16 Capture Inp./Compare Outp.,<br>CAN1_RxD CAN 1 Receive Data Input  |
| P8.1       | 73                      | I/O<br>O       | CC17IO CAPCOM2: CC17 Capture Inp./Compare Outp.,<br>CAN1_TxD CAN 1 Transmit Data Output  |
| P8.2       | 74                      | I/O<br>I       | CC18IO CAPCOM2: CC18 Capture Inp./Compare Outp.,<br>CAN1_RxD CAN 1 Receive Data Input  |
| P8.3       | 75                      | I/O<br>O       | CC19IO CAPCOM2: CC19 Capture Inp./Compare Outp.,<br>CAN1_TxD CAN 1 Transmit Data Output  |
| $V_{AREF}$ | 1                       | -              | Reference voltage for the A/D converter.   |
| $V_{AGND}$ | 80                      | -              | Reference ground for the A/D converter.  |
| $V_{DD}$   | 7, 21,<br>40, 53,<br>61 | -              | Digital Supply Voltage:<br>+ 5 V during normal operation and idle mode.<br>≥ 2.5 V during power down mode.   |
| $V_{SS}$   | 6, 20,<br>41, 56,<br>60 | -              | Digital Ground.  |

1) The CAN interface lines are assigned to ports P4 and P8 under software control. Within the CAN module several assignments can be selected.

*Note: The following behaviour differences must be observed when the bidirectional reset is active:*

- Bit BDRSTEN in register SYSCON cannot be changed after EINIT and is cleared automatically after a reset.
- The reset indication flags always indicate a long hardware reset.
- The PORT0 configuration is treated like on a hardware reset. Especially the bootstrap loader may be activated when P0L.4 is low.
- Pin RSTIN may only be connected to external reset devices with an open drain output driver.
- A short hardware reset is extended to the duration of the internal reset sequence.



## Memory Organization

The memory space of the C164 is configured in a Von Neumann architecture which means that code memory, data memory, registers and I/O ports are organized within the same linear address space which includes 16 MBytes. The entire memory space can be accessed byte-wise or word-wise. Particular portions of the on-chip memory have additionally been made directly bit-addressable.

The C164 incorporates 64 KBytes of on-chip ROM or Flash memory for code or constant data. The Flash memory is organized as one 16 KByte sector, two 8 KByte sectors, and one 32 KByte sector. Each sector can be separately write protected, erased and programmed (in blocks of 64 Byte).

The lower 32 KBytes of the on-chip ROM or Flash memory can be mapped either to segment 0 or segment 1.

2 KBytes of on-chip Internal RAM (IRAM) are provided as a storage for user defined variables, for the system stack, general purpose register banks and even for code. A register bank can consist of up to 16 word-wide (R0 to R15) and/or byte-wide (RL0, RH0, ..., RL7, RH7) so-called General Purpose Registers (GPRs).

1024 bytes (2 \* 512 bytes) of the address space are reserved for the Special Function Register areas (SFR space and ESFR space). SFRs are word-wide registers which are used for controlling and monitoring functions of the different on-chip units. Unused SFR addresses are reserved for future members of the C166 Family.

2 KBytes of on-chip Extension RAM (XRAM) are provided to store user data, user stacks, or code. The XRAM is accessed like external memory and therefore cannot be used for the system stack or for register banks and is not bit-addressable. The XRAM permits 16-bit accesses with maximum speed.

4 KBytes of on-chip Data Flash memory, organized as four 1 KByte sectors, provide EEPROM functionality. Each byte/word can be erased or programmed separately. Each sector can be erased as a unit. The low granularity (byte/word) and the high endurance of the DataFlash/EEPROM support the non-volatile storage of changing system data.

*Note: The DataFlash/EEPROM is only incorporated in the Flash versions.*

In order to meet the needs of designs where more memory is required than is provided on chip, up to 4 MBytes of external RAM and/or ROM can be connected to the microcontroller.

## External Bus Controller

All of the external memory accesses are performed by a particular on-chip External Bus Controller (EBC). It can be programmed either to Single Chip Mode when no external memory is required, or to one of four different external memory access modes, which are as follows:

- 16-/18-/20-/22-bit Addresses, 16-bit Data, Demultiplexed
- 16-/18-/20-/22-bit Addresses, 16-bit Data, Multiplexed
- 16-/18-/20-/22-bit Addresses, 8-bit Data, Multiplexed
- 16-/18-/20-/22-bit Addresses, 8-bit Data, Demultiplexed

In the demultiplexed bus modes, addresses are output on PORT1 and data is input/output on PORT0 or P0L, respectively. In the multiplexed bus modes both addresses and data use PORT0 for input/output.

Important timing characteristics of the external bus interface (Memory Cycle Time, Memory Tri-State Time, Length of ALE and Read Write Delay) have been made programmable to allow the user the adaption of a wide range of different types of memories and external peripherals.

In addition, up to 4 independent address windows may be defined (via register pairs ADDRSELx / BUSCONx) which allow to access different resources with different bus characteristics. These address windows are arranged hierarchically where BUSCON4 overrides BUSCON3 and BUSCON2 overrides BUSCON1. All accesses to locations not covered by these 4 address windows are controlled by BUSCON0.

Up to 4 external  $\overline{CS}$  signals (3 windows plus default) can be generated in order to save external glue logic. The C164 offers the possibility to switch the  $\overline{CS}$  outputs to an unlatched mode. In this mode the internal filter logic is switched off and the  $\overline{CS}$  signals are directly generated from the address. The unlatched  $\overline{CS}$  mode is enabled by setting CSCFG (SYSCON.6).

For applications which require less than 4 MBytes of external memory space, this address space can be restricted to 1 MByte, 256 KByte or to 64 KByte. In this case Port 4 outputs four, two, or no address lines at all. It outputs all 6 address lines, if an address space of 4 MBytes is used.

*Note: When the on-chip CAN Module is activated on Port 4 the segment address output is limited to 4 bits (i.e. A19...A16) due to the CAN interface pins.*

### Central Processing Unit (CPU)

The main core of the CPU consists of a 4-stage instruction pipeline, a 16-bit arithmetic and logic unit (ALU) and dedicated SFRs. Additional hardware has been spent for a separate multiply and divide unit, a bit-mask generator and a barrel shifter.

Based on these hardware provisions, most of the C164's instructions can be executed in just one machine cycle which requires 2 CPU clocks (4 TCL). For example, shift and rotate instructions are always processed during one machine cycle independent of the number of bits to be shifted. All multiple-cycle instructions have been optimized so that they can be executed very fast as well: branches in 2 cycles, a  $16 \times 16$  bit multiplication in 5 cycles and a 32-/16 bit division in 10 cycles. Another pipeline optimization, the so-called 'Jump Cache', reduces the execution time of repeatedly performed jumps in a loop from 2 cycles to 1 cycle.

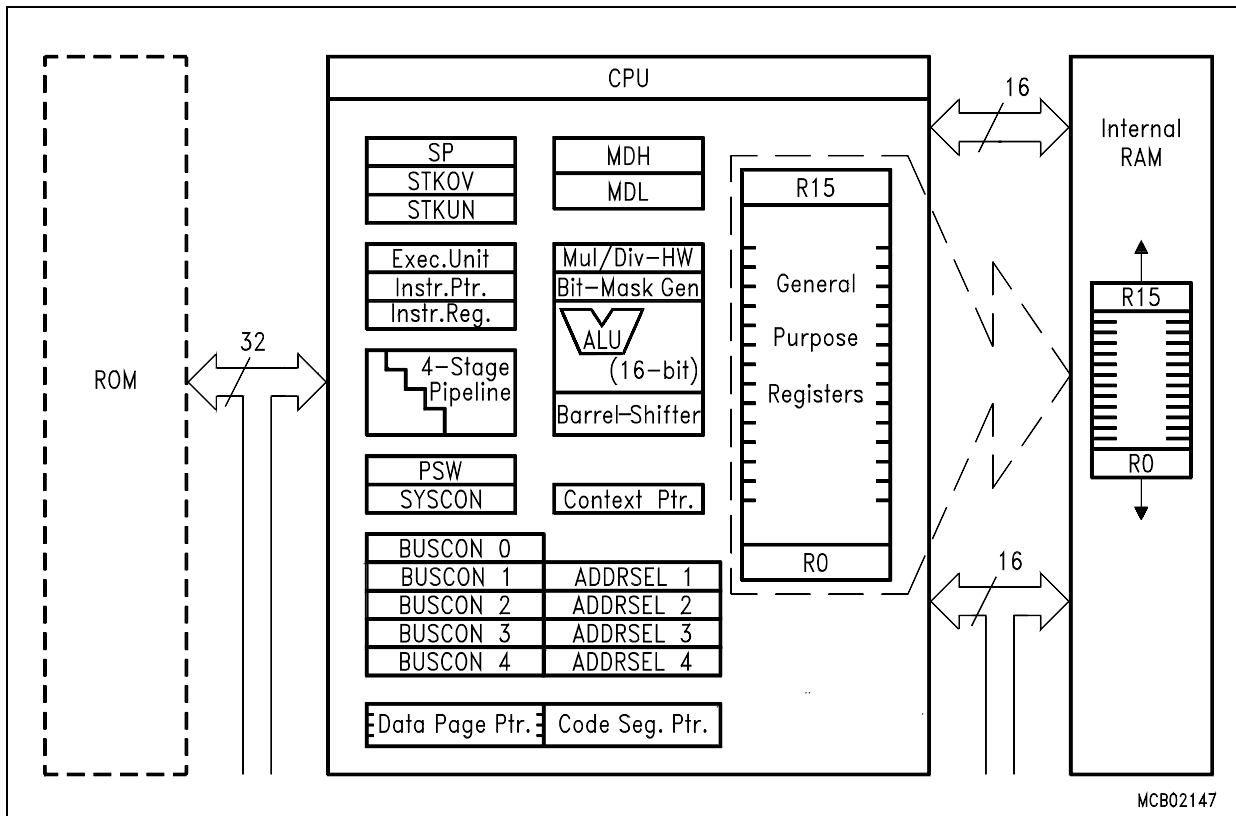


Figure 4 CPU Block Diagram



The CPU has a register context consisting of up to 16 wordwide GPRs at its disposal. These 16 GPRs are physically allocated within the on-chip RAM area. A Context Pointer (CP) register determines the base address of the active register bank to be accessed by the CPU at any time. The number of register banks is only restricted by the available internal RAM space. For easy parameter passing, a register bank may overlap others.

A system stack of up to 2048 bytes is provided as a storage for temporary data. The system stack is allocated in the on-chip RAM area, and it is accessed by the CPU via the stack pointer (SP) register. Two separate SFRs, STKOV and STKUN, are implicitly compared against the stack pointer value upon each stack access for the detection of a stack overflow or underflow.

The high performance offered by the hardware implementation of the CPU can efficiently be utilized by a programmer via the highly efficient C164 instruction set which includes the following instruction classes:

- Arithmetic Instructions
- Logical Instructions
- Boolean Bit Manipulation Instructions
- Compare and Loop Control Instructions
- Shift and Rotate Instructions
- Prioritize Instruction
- Data Movement Instructions
- System Stack Instructions
- Jump and Call Instructions
- Return Instructions
- System Control Instructions
- Miscellaneous Instructions

The basic instruction length is either 2 or 4 bytes. Possible operand types are bits, bytes and words. A variety of direct, indirect or immediate addressing modes are provided to specify the required operands.

## Interrupt System

With an interrupt response time within a range from just 5 to 12 CPU clocks (in case of internal program execution), the C164 is capable of reacting very fast to the occurrence of non-deterministic events.

The architecture of the C164 supports several mechanisms for fast and flexible response to service requests that can be generated from various sources internal or external to the microcontroller. Any of these interrupt requests can be programmed to being serviced by the Interrupt Controller or by the Peripheral Event Controller (PEC).

In contrast to a standard interrupt service where the current program execution is suspended and a branch to the interrupt vector table is performed, just one cycle is 'stolen' from the current CPU activity to perform a PEC service. A PEC service implies a single byte or word data transfer between any two memory locations with an additional increment of either the PEC source or the destination pointer. An individual PEC transfer counter is implicitly decremented for each PEC service except when performing in the continuous transfer mode. When this counter reaches zero, a standard interrupt is performed to the corresponding source related vector location. PEC services are very well suited, for example, for supporting the transmission or reception of blocks of data. The C164 has 8 PEC channels each of which offers such fast interrupt-driven data transfer capabilities.

A separate control register which contains an interrupt request flag, an interrupt enable flag and an interrupt priority bitfield exists for each of the possible interrupt sources. Via its related register, each source can be programmed to one of sixteen interrupt priority levels. Once having been accepted by the CPU, an interrupt service can only be interrupted by a higher prioritized service request. For the standard interrupt processing, each of the possible interrupt sources has a dedicated vector location.

Fast external interrupt inputs are provided to service external interrupts with high precision requirements. These fast interrupt inputs feature programmable edge detection (rising edge, falling edge or both edges).

Software interrupts are supported by means of the 'TRAP' instruction in combination with an individual trap (interrupt) number.

The following table shows all of the possible C164 interrupt sources and the corresponding hardware-related interrupt flags, vectors, vector locations and trap (interrupt) numbers.

*Note: Interrupt nodes which are not used by associated peripherals, may be used to generate software controlled interrupt requests by setting the respective interrupt request bit (xIR).*

**Table 3 C164 Interrupt Nodes**

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location      | Trap Number     |
|--|--------------|-------------|------------------|----------------------|-----------------|
| External Interrupt 0                       | CC8IR        | CC8IE       | CC8INT           | 00'0060 <sub>H</sub> | 18 <sub>H</sub> |
| External Interrupt 1                       | CC9IR        | CC9IE       | CC9INT           | 00'0064 <sub>H</sub> | 19 <sub>H</sub> |
| External Interrupt 2                       | CC10IR       | CC10IE      | CC10INT          | 00'0068 <sub>H</sub> | 1A <sub>H</sub> |
| External Interrupt 3                       | CC11IR       | CC11IE      | CC11INT          | 00'006C <sub>H</sub> | 1B <sub>H</sub> |
| GPT1 Timer 2                               | T2IR         | T2IE        | T2INT            | 00'0088 <sub>H</sub> | 22 <sub>H</sub> |
| GPT1 Timer 3                               | T3IR         | T3IE        | T3INT            | 00'008C <sub>H</sub> | 23 <sub>H</sub> |
| GPT1 Timer 4                               | T4IR         | T4IE        | T4INT            | 00'0090 <sub>H</sub> | 24 <sub>H</sub> |
| A/D Conversion Complete                    | ADCIR        | ADCIE       | ADCINT           | 00'00A0 <sub>H</sub> | 28 <sub>H</sub> |
| A/D Overrun Error                          | ADEIR        | ADEIE       | ADEINT           | 00'00A4 <sub>H</sub> | 29 <sub>H</sub> |
| ASC0 Transmit                              | S0TIR        | S0TIE       | S0TINT           | 00'00A8 <sub>H</sub> | 2A <sub>H</sub> |
| ASC0 Transmit Buffer                       | S0TBIR       | S0TBIE      | S0TBINT          | 00'011C <sub>H</sub> | 47 <sub>H</sub> |
| ASC0 Receive                               | S0RIR        | S0RIE       | S0RINT           | 00'00AC <sub>H</sub> | 2B <sub>H</sub> |
| ASC0 Error                                 | S0EIR        | S0EIE       | S0EINT           | 00'00B0 <sub>H</sub> | 2C <sub>H</sub> |
| SSC Transmit                               | SCTIR        | SCTIE       | SCTINT           | 00'00B4 <sub>H</sub> | 2D <sub>H</sub> |
| SSC Receive                                | SCRIR        | SCRIE       | SCRINT           | 00'00B8 <sub>H</sub> | 2E <sub>H</sub> |
| SSC Error                                  | SCEIR        | SCEIE       | SCEINT           | 00'00BC <sub>H</sub> | 2F <sub>H</sub> |
| CAPCOM Register 16                         | CC16IR       | CC16IE      | CC16INT          | 00'00C0 <sub>H</sub> | 30 <sub>H</sub> |
| CAPCOM Register 17                         | CC17IR       | CC17IE      | CC17INT          | 00'00C4 <sub>H</sub> | 31 <sub>H</sub> |
| CAPCOM Register 18                         | CC18IR       | CC18IE      | CC18INT          | 00'00C8 <sub>H</sub> | 32 <sub>H</sub> |
| CAPCOM Register 19                         | CC19IR       | CC19IE      | CC19INT          | 00'00CC <sub>H</sub> | 33 <sub>H</sub> |
| CAPCOM Register 20                         | CC20IR       | CC20IE      | CC20INT          | 00'00D0 <sub>H</sub> | 34 <sub>H</sub> |
| CAPCOM Register 21                         | CC21IR       | CC21IE      | CC21INT          | 00'00D4 <sub>H</sub> | 35 <sub>H</sub> |
| CAPCOM Register 22                         | CC22IR       | CC22IE      | CC22INT          | 00'00D8 <sub>H</sub> | 36 <sub>H</sub> |
| CAPCOM Register 23                         | CC23IR       | CC23IE      | CC23INT          | 00'00DC <sub>H</sub> | 37 <sub>H</sub> |
| CAPCOM Register 24                         | CC24IR       | CC24IE      | CC24INT          | 00'00E0 <sub>H</sub> | 38 <sub>H</sub> |
| CAPCOM Register 25                         | CC25IR       | CC25IE      | CC25INT          | 00'00E4 <sub>H</sub> | 39 <sub>H</sub> |
| CAPCOM Register 26                         | CC26IR       | CC26IE      | CC426NT          | 00'00E8 <sub>H</sub> | 3A <sub>H</sub> |
| CAPCOM Register 27                         | CC27IR       | CC27IE      | CC27INT          | 00'00EC <sub>H</sub> | 3B <sub>H</sub> |
| CAPCOM Register 28                         | CC28IR       | CC28IE      | CC28INT          | 00'00E0 <sub>H</sub> | 3C <sub>H</sub> |

**Table 3 C164 Interrupt Nodes (continued)**

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location      | Trap Number                   |
|--|--------------|-------------|------------------|----------------------|-------------------------------|
| CAPCOM Register 29                         | CC29IR       | CC29IE      | CC29INT          | 00'0110 <sub>H</sub> | 44 <sub>H</sub>               |
| CAPCOM Register 30                         | CC30IR       | CC30IE      | CC30INT          | 00'0114 <sub>H</sub> | 45 <sub>H</sub>               |
| CAPCOM Register 31                         | CC31IR       | CC31IE      | CC31INT          | 00'0118 <sub>H</sub> | 46 <sub>H</sub>               |
| CAPCOM Timer 7                             | T7IR         | T7IE        | T7INT            | 00'00F4 <sub>H</sub> | 3D <sub>H</sub>               |
| CAPCOM Timer 8                             | T8IR         | T8IE        | T8INT            | 00'00F8 <sub>H</sub> | 3E <sub>H</sub>               |
| CAPCOM 6 Interrupt                         | CC6IR        | CC6IE       | CC6INT           | 00'00FC <sub>H</sub> | 3F <sub>H</sub>               |
| CAPCOM 6 Timer 12                          | T12IR        | T12IE       | T12INT           | 00'0134 <sub>H</sub> | 4D <sub>H</sub>               |
| CAPCOM 6 Timer 13                          | T13IR        | T13IE       | T13INT           | 00'0138 <sub>H</sub> | 4E <sub>H</sub>               |
| CAPCOM 6 Emergency                         | CC6EIR       | CC6EIE      | CC6EINT          | 00'013C <sub>H</sub> | 4F <sub>H</sub>               |
| CAN Interface 1                            | XP0IR        | XP0IE       | XP0INT           | 00'0100 <sub>H</sub> | 40 <sub>H</sub>               |
| DataFlash Termination                      | XP1IR        | XP1IE       | XP1INT           | 00'0104 <sub>H</sub> | 41 <sub>H</sub> <sup>1)</sup> |
| PLL Unlock / RTC                           | XP3IR        | XP3IE       | XP3INT           | 00'010C <sub>H</sub> | 43 <sub>H</sub>               |

1) This interrupt node is only available in the Flash devices.

The C164 also provides an excellent mechanism to identify and to process exceptions or error conditions that arise during run-time, so-called 'Hardware Traps'. Hardware traps cause immediate non-maskable system reaction which is similar to a standard interrupt service (branching to a dedicated vector table location). The occurrence of a hardware trap is additionally signified by an individual bit in the trap flag register (TFR). Except when another higher prioritized trap service is in progress, a hardware trap will interrupt any actual program execution. In turn, hardware trap services can normally not be interrupted by standard or PEC interrupts.

The following table shows all of the possible exceptions or error conditions that can arise during run-time:

**Table 4 Hardware Trap Summary**

| Exception Condition            | Trap Flag | Trap Vector | Vector Location   | Trap Number                                    | Trap Prio                  |
|--------------------------------|-----------|-------------|---|--|----------------------------|
| <b>Reset Functions:</b>        |           |             |   |  |                            |
| Hardware Reset                 |           | RESET       | 00'0000 <sub>H</sub>  | 00 <sub>H</sub>                                | III                        |
| Software Reset                 |           | RESET       | 00'0000 <sub>H</sub>  | 00 <sub>H</sub>                                | III                        |
| Watchdog Timer Overflow        |           | RESET       | 00'0000 <sub>H</sub>  | 00 <sub>H</sub>                                | III                        |
| <b>Class A Hardware Traps:</b> |           |             |   |  |                            |
| Non-Maskable Interrupt         | NMI       | NMITRAP     | 00'0008 <sub>H</sub>  | 02 <sub>H</sub>                                | II                         |
| Stack Overflow                 | STKOF     | STOTRAP     | 00'0010 <sub>H</sub>  | 04 <sub>H</sub>                                | II                         |
| Stack Underflow                | STKUF     | STUTRAP     | 00'0018 <sub>H</sub>  | 06 <sub>H</sub>                                | II                         |
| <b>Class B Hardware Traps:</b> |           |             |   |  |                            |
| Undefined Opcode               | UNDOPC    | BTRAP       | 00'0028 <sub>H</sub>  | 0A <sub>H</sub>                                | I                          |
| Protected Instruction Fault    | PRTFLT    | BTRAP       | 00'0028 <sub>H</sub>  | 0A <sub>H</sub>                                | I                          |
| Illegal Word Operand Access    | ILLOPA    | BTRAP       | 00'0028 <sub>H</sub>  | 0A <sub>H</sub>                                | I                          |
| Illegal Instruction Access     | ILLINA    | BTRAP       | 00'0028 <sub>H</sub>  | 0A <sub>H</sub>                                | I                          |
| Illegal External Bus Access    | ILLBUS    | BTRAP       | 00'0028 <sub>H</sub>  | 0A <sub>H</sub>                                | I                          |
| Reserved                       |           |             | [2C <sub>H</sub> – 3C <sub>H</sub> ]  | [0B <sub>H</sub> – 0F <sub>H</sub> ]           |                            |
| <b>Software Traps:</b>         |           |             |   |  |                            |
| TRAP Instruction               |           |             | Any<br>[00'0000 <sub>H</sub> –<br>00'01FC <sub>H</sub> ]<br>in steps<br>of 4 <sub>H</sub> | Any<br>[00 <sub>H</sub> –<br>7F <sub>H</sub> ] | Current<br>CPU<br>Priority |

## The Capture/Compare Unit CAPCOM2

The general purpose CAPCOM2 unit supports generation and control of timing sequences on up to 8 channels with a maximum resolution of 16 TCL. The CAPCOM units are typically used to handle high speed I/O tasks such as pulse and waveform generation, pulse width modulation (PMW), Digital to Analog (D/A) conversion, software timing, or time recording relative to external events.

Two 16-bit timers (T7/T8) with reload registers provide two independent time bases for the capture/compare register array.

Each dual purpose capture/compare register, which may be individually allocated to either CAPCOM timer and programmed for capture or compare function, has one port pin associated with it which serves as an input pin for triggering the capture function, or as an output pin to indicate the occurrence of a compare event.

When a capture/compare register has been selected for capture mode, the current contents of the allocated timer will be latched ('capture'd) into the capture/compare register in response to an external event at the port pin which is associated with this register. In addition, a specific interrupt request for this capture/compare register is generated. Either a positive, a negative, or both a positive and a negative external signal transition at the pin can be selected as the triggering event. The contents of all registers which have been selected for one of the five compare modes are continuously compared with the contents of the allocated timers. When a match occurs between the timer value and the value in a capture/compare register, specific actions will be taken based on the selected compare mode.

**Table 5 Compare Modes (CAPCOM)**

| Compare Modes        | Function   |
|----------------------|--|
| Mode 0               | Interrupt-only compare mode; several compare interrupts per timer period are possible  |
| Mode 1               | Pin toggles on each compare match; several compare events per timer period are possible  |
| Mode 2               | Interrupt-only compare mode; only one compare interrupt per timer period is generated  |
| Mode 3               | Pin set '1' on match; pin reset '0' on compare time overflow; only one compare event per timer period is generated   |
| Double Register Mode | Two registers operate on one pin; pin toggles on each compare match; several compare events per timer period are possible.<br>Registers CC16 & CC24 → pin CC16IO<br>Registers CC17 & CC25 → pin CC17IO<br>Registers CC18 & CC26 → pin CC18IO<br>Registers CC19 & CC27 → pin CC19IO |

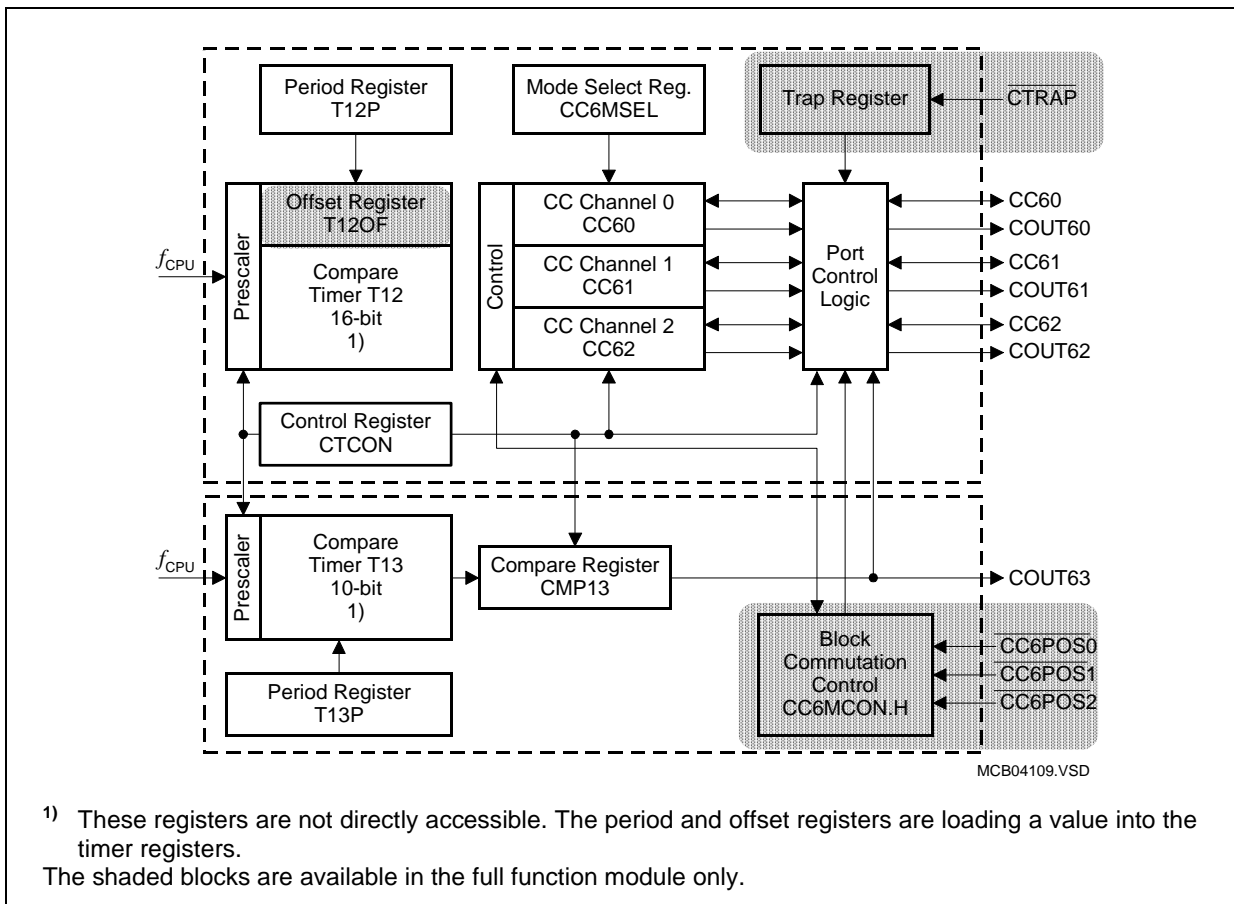
### The Capture/Compare Unit CAPCOM6

The CAPCOM6 unit supports generation and control of timing sequences on up to three 16-bit capture/compare channels plus one 10-bit compare channel.

In compare mode the CAPCOM6 unit provides two output signals per channel which have inverted polarity and non-overlapping pulse transitions. The compare channel can generate a single PWM output signal and is further used to modulate the capture/compare output signals.

In capture mode the contents of compare timer 12 is stored in the capture registers upon a signal transition at pins CCx.

Compare timers T12 (16-bit) and T13 (10-bit) are free running timers which are clocked by the prescaled CPU clock.



**Figure 5 CAPCOM6 Block Diagram**

For motor control applications both subunits may generate versatile multichannel PWM signals which are basically either controlled by compare timer 12 or by a typical hall sensor pattern at the interrupt inputs (block commutation).

*Note: Multichannel signal generation is provided only in devices with a full CAPCOM6.*

## General Purpose Timer (GPT) Unit

The GPT unit represents a very flexible multifunctional timer/counter structure which may be used for many different time related tasks such as event timing and counting, pulse width and duty cycle measurements, pulse generation, or pulse multiplication.

The GPT unit incorporates three 16-bit timers (GPT1). Each timer in each module may operate independently in a number of different modes, or may be concatenated with another timer of the same module.

Each of the three timers T2, T3, T4 of **module GPT1** can be configured individually for one of four basic modes of operation, which are Timer, Gated Timer, Counter, and Incremental Interface Mode. In Timer Mode, the input clock for a timer is derived from the CPU clock, divided by a programmable prescaler, while Counter Mode allows a timer to be clocked in reference to external events.

Pulse width or duty cycle measurement is supported in Gated Timer Mode, where the operation of a timer is controlled by the 'gate' level on an external input pin. For these purposes, each timer has one associated port pin (TxIN) which serves as gate or clock input. The maximum resolution of the timers in module GPT1 is 16 TCL.

The count direction (up/down) for each timer is programmable by software or may additionally be altered dynamically by an external signal on a port pin (TxEUD) to facilitate e.g. position tracking.

In Incremental Interface Mode the GPT1 timers (T2, T3, T4) can be directly connected to the incremental position sensor signals A and B via their respective inputs TxIN and TxEUD. Direction and count signals are internally derived from these two input signals, so the contents of the respective timer Tx corresponds to the sensor position. The third position sensor signal TOP0 can be connected to an interrupt input.

Timer T3 has an output toggle latch (T3OTL) which changes its state on each timer overflow/underflow. The state of this latch may be output on a port pin (T3OUT) e.g. for time out monitoring of external hardware components, or may be used internally to clock timers T2 and T4 for measuring long time periods with high resolution.

In addition to their basic operating modes, timers T2 and T4 may be configured as reload or capture registers for timer T3. When used as capture or reload registers, timers T2 and T4 are stopped. The contents of timer T3 are captured into T2 or T4 in response to a signal at their associated input pins (TxIN). Timer T3 is reloaded with the contents of T2 or T4 triggered either by an external signal or by a selectable state transition of its toggle latch T3OTL. When both T2 and T4 are configured to alternately reload T3 on opposite state transitions of T3OTL with the low and high times of a PWM signal, this signal can be constantly generated without software intervention.



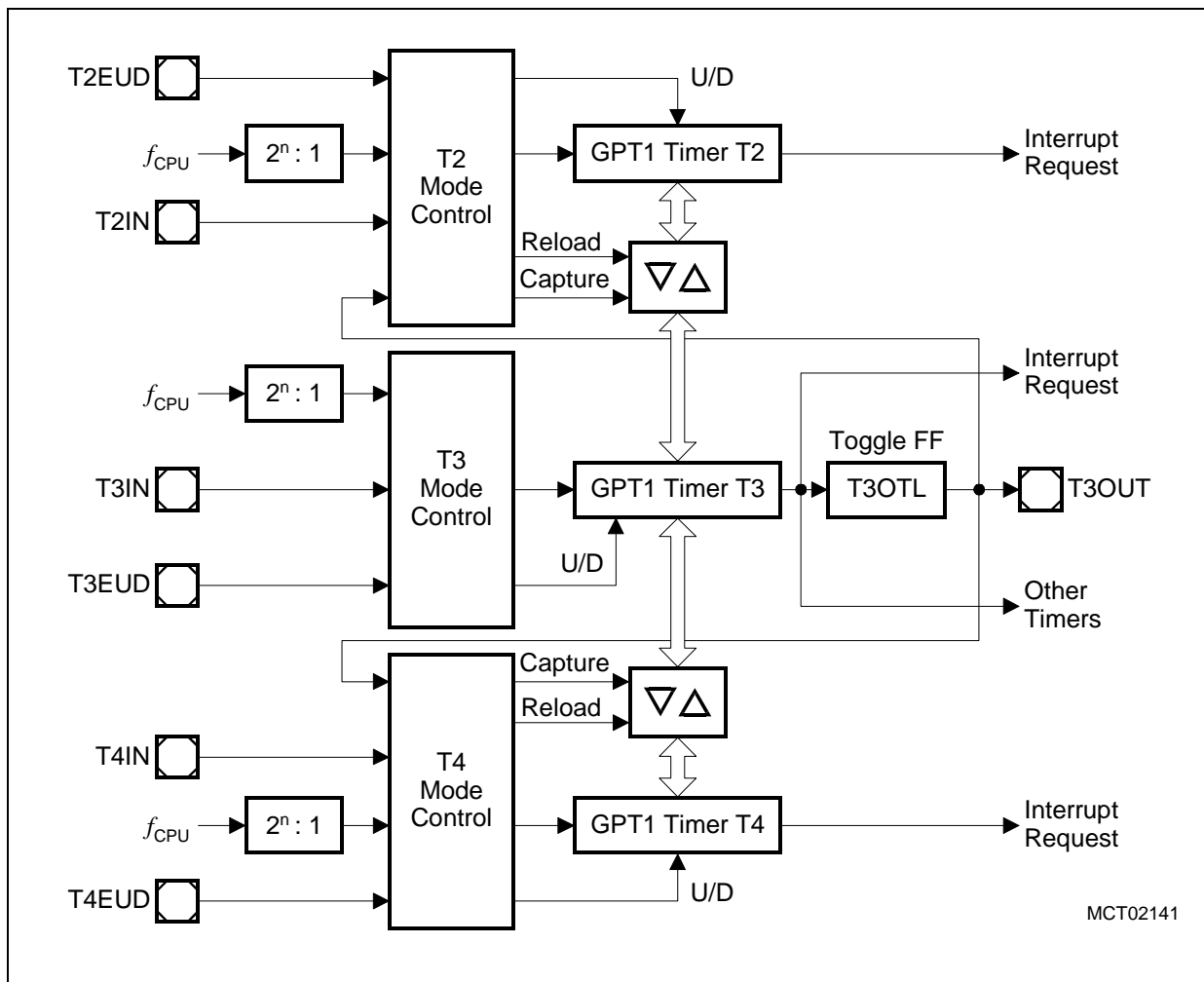


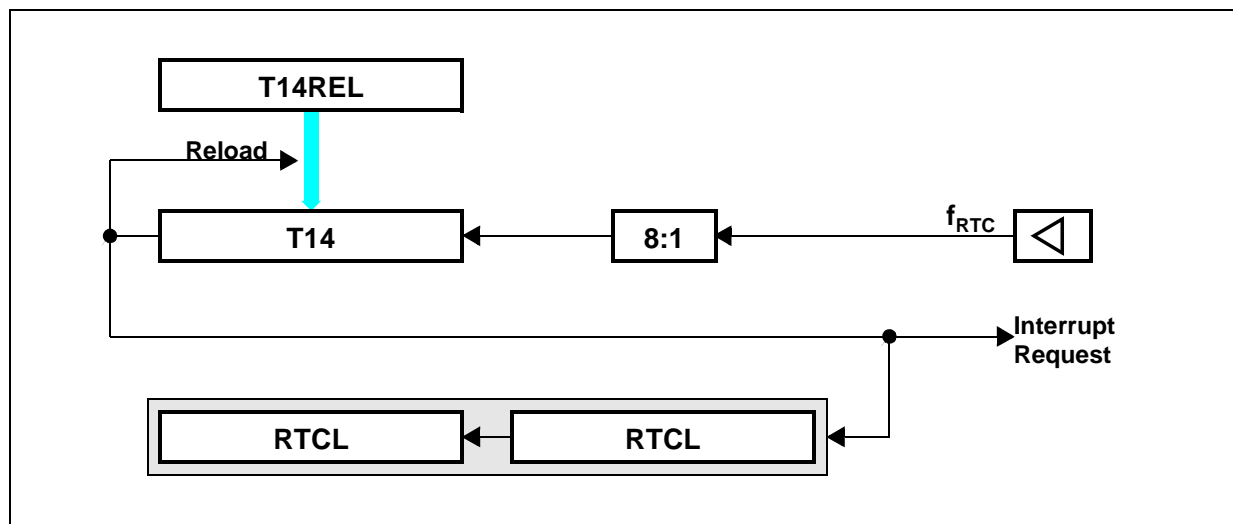
Figure 6 Block Diagram of GPT1

### Real Time Clock

The Real Time Clock (RTC) module of the C164 consists of a chain of 3 divider blocks, a fixed 8:1 divider, the reloadable 16-bit timer T14, and the 32-bit RTC timer (accessible via registers RTCH and RTCL). The RTC module is directly clocked with the on-chip oscillator frequency divided by 32 via a separate clock driver ( $f_{RTC} = f_{OSC} / 32$ ) and is therefore independent from the selected clock generation mode of the C164. All timers count up.

The RTC module can be used for different purposes:

- System clock to determine the current time and date
- Cyclic time based interrupt
- 48-bit timer for long term measurements



**Figure 7** RTC Block Diagram

*Note: The registers associated with the RTC are not effected by a reset in order to maintain the correct system time even when intermediate resets are executed.*

## A/D Converter

For analog signal measurement, a 10-bit A/D converter with 8 multiplexed input channels and a sample and hold circuit has been integrated on-chip. It uses the method of successive approximation. The sample time (for loading the capacitors) and the conversion time is programmable and can so be adjusted to the external circuitry.

Overflow error detection/protection is provided for the conversion result register (ADDAT): either an interrupt request will be generated when the result of a previous conversion has not been read from the result register at the time the next conversion is complete, or the next conversion is suspended in such a case until the previous result has been read.

For applications which require less than 8 analog input channels, the remaining channel inputs can be used as digital input port pins.

The A/D converter of the C164 supports four different conversion modes. In the standard Single Channel conversion mode, the analog level on a specified channel is sampled once and converted to a digital result. In the Single Channel Continuous mode, the analog level on a specified channel is repeatedly sampled and converted without software intervention. In the Auto Scan mode, the analog levels on a prespecified number of channels are sequentially sampled and converted. In the Auto Scan Continuous mode, the number of prespecified channels is repeatedly sampled and converted. In addition, the conversion of a specific channel can be inserted (injected) into a running sequence without disturbing this sequence. This is called Channel Injection Mode.

The Peripheral Event Controller (PEC) may be used to automatically store the conversion results into a table in memory for later evaluation, without requiring the overhead of entering and exiting interrupt routines for each data transfer.

After each reset and also during normal operation the ADC automatically performs calibration cycles. This automatic self-calibration constantly adjusts the converter to changing operating conditions (e.g. temperature) and compensates process variations.

These calibration cycles are part of the conversion cycle, so they do not affect the normal operation of the A/D converter.

In order to decouple analog inputs from digital noise and to avoid input trigger noise those pins used for analog input can be disconnected from the digital IO or input stages under software control. This can be selected for each pin separately via registers P5DIDIS (Port 5 Digital Input Disable).

## Serial Channels

Serial communication with other microcontrollers, processors, terminals or external peripheral components is provided by two serial interfaces with different functionality, an Asynchronous/Synchronous Serial Channel (**ASC0**) and a High-Speed Synchronous Serial Channel (**SSC**).

**The ASC0** is upward compatible with the serial ports of the Infineon 8-bit microcontroller families and supports full-duplex asynchronous communication at up to 780 KBaud and half-duplex synchronous communication at up to 3.1 MBaud @ 25 MHz CPU clock.

A dedicated baud rate generator allows to set up all standard baud rates without oscillator tuning. For transmission, reception and error handling 4 separate interrupt vectors are provided. In asynchronous mode, 8- or 9-bit data frames are transmitted or received, preceded by a start bit and terminated by one or two stop bits. For multiprocessor communication, a mechanism to distinguish address from data bytes has been included (8-bit data plus wake up bit mode).

In synchronous mode, the ASC0 transmits or receives bytes (8 bits) synchronously to a shift clock which is generated by the ASC0. The ASC0 always shifts the LSB first. A loop back option is available for testing purposes.

A number of optional hardware error detection capabilities has been included to increase the reliability of data transfers. A parity bit can automatically be generated on transmission or be checked on reception. Framing error detection allows to recognize data frames with missing stop bits. An overrun error will be generated, if the last character received has not been read out of the receive buffer register at the time the reception of a new character is complete.

**The SSC** supports full-duplex synchronous communication at up to 6.25 Mbaud @ 25 MHz CPU clock. It may be configured so it interfaces with serially linked peripheral components. A dedicated baud rate generator allows to set up all standard baud rates without oscillator tuning. For transmission, reception and error handling 3 separate interrupt vectors are provided.

The SSC transmits or receives characters of 2...16 bits length synchronously to a shift clock which can be generated by the SSC (master mode) or by an external master (slave mode). The SSC can start shifting with the LSB or with the MSB and allows the selection of shifting and latching clock edges as well as the clock polarity.

A number of optional hardware error detection capabilities has been included to increase the reliability of data transfers. Transmit and receive error supervise the correct handling of the data buffer. Phase and baudrate error detect incorrect serial data.

## CAN-Module

The integrated CAN-Module handles the completely autonomous transmission and reception of CAN frames in accordance with the CAN specification V2.0 part B (active), i.e. the on-chip CAN-Module can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers.

The module provides Full CAN functionality on up to 15 message objects. Message object 15 may be configured for Basic CAN functionality. Both modes provide separate masks for acceptance filtering which allows to accept a number of identifiers in Full CAN mode and also allows to disregard a number of identifiers in Basic CAN mode. All message objects can be updated independent from the other objects and are equipped for the maximum message length of 8 bytes.

The bit timing is derived from the CPU clock signal and is programmable up to a data rate of 1 MBaud. The CAN-Module uses two pins of Port 4 or Port 8 to interface to an external bus transceiver. The interface pins are assigned via software.

*Note: When the CAN interface is assigned to Port 4, the respective segment address lines on Port 4 cannot be used. This will limit the external address space.*

## Watchdog Timer

The Watchdog Timer represents one of the fail-safe mechanisms which have been implemented to prevent the controller from malfunctioning for longer periods of time.

The Watchdog Timer is always enabled after a reset of the chip, and can only be disabled in the time interval until the EINIT (end of initialization) instruction has been executed. Thus, the chip's start-up procedure is always monitored. The software has to be designed to service the Watchdog Timer before it overflows. If, due to hardware or software related failures, the software fails to do so, the Watchdog Timer overflows and generates an internal hardware reset and pulls the  $\overline{\text{RSTOUT}}$  pin low in order to allow external hardware components to be reset.

The Watchdog Timer is a 16-bit timer, clocked with the system clock divided either by 2/4/128/256. The high byte of the Watchdog Timer register can be set to a prespecified reload value (stored in WDTREL) in order to allow further variation of the monitored time interval. Each time it is serviced by the application software, the high byte of the Watchdog Timer is reloaded. Thus, time intervals between 20  $\mu\text{s}$  and 336 ms can be monitored (@ 25 MHz).

The default Watchdog Timer interval after reset is 5.24 ms (@ 25 MHz).

## Parallel Ports

The C164 provides up to 59 IO lines which are organized into five input/output ports and one input port. All port lines are bit-addressable, and all input/output lines are individually (bit-wise) programmable as inputs or outputs via direction registers. The I/O ports are true bidirectional ports which are switched to high impedance state when configured as inputs. The output drivers of three IO ports can be configured (pin by pin) for push/pull operation or open-drain operation via control registers. The other IO ports operate in push/pull mode. During the internal reset, all port pins are configured as inputs.

All port lines have programmable alternate input or output functions associated with them. All port lines that are not used for these alternate functions may be used as general purpose IO lines.

PORT0 and PORT1 may be used as address and data lines when accessing external memory, while Port 4 outputs the additional segment address bits A21/19/17...A16 in systems where segmentation is enabled to access more than 64 KBytes of memory.

Ports P1L, P1H, and P8 are associated with the capture inputs or compare outputs of the CAPCOM unit, and/or serve as external interrupt inputs.

Port 3 includes alternate functions of timers, serial interfaces, the optional bus control signal  $\overline{\text{BHE}}$  and the system clock output CLKOUT (or the programmable frequency output FOUT).

Port 5 is used for the analog input channels to the A/D converter or timer control signals.

Port 4 or port 8 may be used for the CAN interface lines.

The edge characteristics (transition time) and driver characteristics (output current) of the C164's port drivers can be selected via the Port Output Control registers (POCONx).

## Instruction Set Summary

The table below lists the instructions of the C164 in a condensed way.

The various addressing modes that can be used with a specific instruction, the operation of the instructions, parameters for conditional execution of instructions, and the opcodes for each instruction can be found in the “**C166 Family Instruction Set Manual**”.

This document also provides a detailed description of each instruction.

**Table 6 Instruction Set Summary**

| <b>Mnemonic</b>    | <b>Description</b>  | <b>Bytes</b> |
|--------------------|---|--------------|
| ADD(B)             | Add word (byte) operands  | 2 / 4        |
| ADDC(B)            | Add word (byte) operands with Carry   | 2 / 4        |
| SUB(B)             | Subtract word (byte) operands   | 2 / 4        |
| SUBC(B)            | Subtract word (byte) operands with Carry  | 2 / 4        |
| MUL(U)             | (Un)Signed multiply direct GPR by direct GPR (16-/16-bit)   | 2            |
| DIV(U)             | (Un)Signed divide register MDL by direct GPR (16-/16-bit)   | 2            |
| DIVL(U)            | (Un)Signed long divide reg. MD by direct GPR (32-/16-bit)   | 2            |
| CPL(B)             | Complement direct word (byte) GPR   | 2            |
| NEG(B)             | Negate direct word (byte) GPR   | 2            |
| AND(B)             | Bitwise AND, (word/byte operands)   | 2 / 4        |
| OR(B)              | Bitwise OR, (word/byte operands)  | 2 / 4        |
| XOR(B)             | Bitwise XOR, (word/byte operands)   | 2 / 4        |
| BCLR               | Clear direct bit  | 2            |
| BSET               | Set direct bit  | 2            |
| BMOV(N)            | Move (negated) direct bit to direct bit   | 4            |
| BAND, BOR,<br>BXOR | AND/OR/XOR direct bit with direct bit   | 4            |
| BCMP               | Compare direct bit to direct bit  | 4            |
| BFLDH/L            | Bitwise modify masked high/low byte of bit-addressable direct word memory with immediate data     | 4            |
| CMP(B)             | Compare word (byte) operands  | 2 / 4        |
| CMPD1/2            | Compare word data to GPR and decrement GPR by 1/2   | 2 / 4        |
| CMPI1/2            | Compare word data to GPR and increment GPR by 1/2   | 2 / 4        |
| PRIOR              | Determine number of shift cycles to normalize direct word GPR and store result in direct word GPR | 2            |
| SHL / SHR          | Shift left/right direct word GPR  | 2            |
| ROL / ROR          | Rotate left/right direct word GPR   | 2            |
| ASHR               | Arithmetic (sign bit) shift right direct word GPR   | 2            |

**Table 6 Instruction Set Summary (continued)**

| <b>Mnemonic</b>        | <b>Description</b>  | <b>Bytes</b> |
|------------------------|---|--------------|
| MOV(B)                 | Move word (byte) data   | 2 / 4        |
| MOVBS                  | Move byte operand to word operand with sign extension                               | 2 / 4        |
| MOVBZ                  | Move byte operand to word operand. with zero extension                              | 2 / 4        |
| JMPA, JMPI,<br>JMPR    | Jump absolute/indirect/relative if condition is met                                 | 4            |
| JMPS                   | Jump absolute to a code segment   | 4            |
| J(N)B                  | Jump relative if direct bit is (not) set  | 4            |
| JBC                    | Jump relative and clear bit if direct bit is set                                    | 4            |
| JNBS                   | Jump relative and set bit if direct bit is not set                                  | 4            |
| CALLA, CALLI,<br>CALLR | Call absolute/indirect/relative subroutine if condition is met                      | 4            |
| CALLS                  | Call absolute subroutine in any code segment  | 4            |
| PCALL                  | Push direct word register onto system stack and call absolute subroutine            | 4            |
| TRAP                   | Call interrupt service routine via immediate trap number                            | 2            |
| PUSH, POP              | Push/pop direct word register onto/from system stack                                | 2            |
| SCXT                   | Push direct word register onto system stack und update register with word operand   | 4            |
| RET                    | Return from intra-segment subroutine  | 2            |
| RETS                   | Return from inter-segment subroutine  | 2            |
| RETP                   | Return from intra-segment subroutine and pop direct word register from system stack | 2            |
| RETI                   | Return from interrupt service subroutine  | 2            |
| SRST                   | Software Reset  | 4            |
| IDLE                   | Enter Idle Mode   | 4            |
| PWRDN                  | Enter Power Down Mode (supposes $\overline{\text{NMI}}$ -pin being low)             | 4            |
| SRVWDT                 | Service Watchdog Timer  | 4            |
| DISWDT                 | Disable Watchdog Timer  | 4            |
| EINIT                  | Signify End-of-Initialization on RSTOUT-pin   | 4            |
| ATOMIC                 | Begin ATOMIC sequence   | 2            |
| EXTR                   | Begin EXTended Register sequence  | 2            |
| EXTP(R)                | Begin EXTended Page (and Register) sequence   | 2 / 4        |
| EXTS(R)                | Begin EXTended Segment (and Register) sequence                                      | 2 / 4        |
| NOP                    | Null operation  | 2            |



## Special Function Registers Overview

The following table lists all SFRs which are implemented in the C164 in alphabetical order.

**Bit-addressable** SFRs are marked with the letter “b” in column “Name”. SFRs within the **Extended SFR-Space** (ESFRs) are marked with the letter “E” in column “Physical Address”. Registers within on-chip X-Peripherals are marked with the letter “X” in column “Physical Address”.

An SFR can be specified via its individual mnemonic name. Depending on the selected addressing mode, an SFR can be accessed via its physical address (using the Data Page Pointers), or via its short 8-bit address (without using the Data Page Pointers).

**Table 7 C164 Registers, Ordered by Name**

| Name            | Physical Address           | 8-Bit Addr.              | Description  | Reset Value       |
|-----------------|----------------------------|--------------------------|--|-------------------|
| <b>ADCIC</b>    | <b>b</b> FF98 <sub>H</sub> | CC <sub>H</sub>          | A/D Converter End of Conversion Interrupt Control Register | 0000 <sub>H</sub> |
| <b>ADCON</b>    | <b>b</b> FFA0 <sub>H</sub> | D0 <sub>H</sub>          | A/D Converter Control Register                             | 0000 <sub>H</sub> |
| <b>ADDAT</b>    | FEA0 <sub>H</sub>          | 50 <sub>H</sub>          | A/D Converter Result Register                              | 0000 <sub>H</sub> |
| <b>ADDAT2</b>   | F0A0 <sub>H</sub>          | <b>E</b> 50 <sub>H</sub> | A/D Converter 2 Result Register                            | 0000 <sub>H</sub> |
| <b>ADDRSEL1</b> | FE18 <sub>H</sub>          | 0C <sub>H</sub>          | Address Select Register 1                                  | 0000 <sub>H</sub> |
| <b>ADDRSEL2</b> | FE1A <sub>H</sub>          | 0D <sub>H</sub>          | Address Select Register 2                                  | 0000 <sub>H</sub> |
| <b>ADDRSEL3</b> | FE1C <sub>H</sub>          | 0E <sub>H</sub>          | Address Select Register 3                                  | 0000 <sub>H</sub> |
| <b>ADDRSEL4</b> | FE1E <sub>H</sub>          | 0F <sub>H</sub>          | Address Select Register 4                                  | 0000 <sub>H</sub> |
| <b>ADEIC</b>    | <b>b</b> FF9A <sub>H</sub> | CD <sub>H</sub>          | A/D Converter Overrun Error Interrupt Control Register     | 0000 <sub>H</sub> |
| <b>BUSCON0</b>  | <b>b</b> FF0C <sub>H</sub> | 86 <sub>H</sub>          | Bus Configuration Register 0                               | 0000 <sub>H</sub> |
| <b>BUSCON1</b>  | <b>b</b> FF14 <sub>H</sub> | 8A <sub>H</sub>          | Bus Configuration Register 1                               | 0000 <sub>H</sub> |
| <b>BUSCON2</b>  | <b>b</b> FF16 <sub>H</sub> | 8B <sub>H</sub>          | Bus Configuration Register 2                               | 0000 <sub>H</sub> |
| <b>BUSCON3</b>  | <b>b</b> FF18 <sub>H</sub> | 8C <sub>H</sub>          | Bus Configuration Register 3                               | 0000 <sub>H</sub> |
| <b>BUSCON4</b>  | <b>b</b> FF1A <sub>H</sub> | 8D <sub>H</sub>          | Bus Configuration Register 4                               | 0000 <sub>H</sub> |
| <b>C1BTR</b>    | EF04 <sub>H</sub>          | <b>X</b> ---             | CAN1 Bit Timing Register                                   | UUUU <sub>H</sub> |
| <b>C1CSR</b>    | EF00 <sub>H</sub>          | <b>X</b> ---             | CAN1 Control / Status Register                             | XX01 <sub>H</sub> |
| <b>C1GMS</b>    | EF06 <sub>H</sub>          | <b>X</b> ---             | CAN1 Global Mask Short                                     | UFUU <sub>H</sub> |
| <b>C1LARn</b>   | EFn4 <sub>H</sub>          | <b>X</b> ---             | CAN Lower Arbitration Register (msg. n)                    | UUUU <sub>H</sub> |
| <b>C1LGML</b>   | EF0A <sub>H</sub>          | <b>X</b> ---             | CAN Lower Global Mask Long                                 | UUUU <sub>H</sub> |

**Table 7 C164 Registers, Ordered by Name (continued)**

| Name           | Physical Address                    | 8-Bit Addr.     | Description                                 | Reset Value       |
|----------------|-------------------------------------|-----------------|---|-------------------|
| <b>C1LMLM</b>  | EF0E <sub>H</sub> X                 | ---             | CAN Lower Mask of Last Message              | UUUU <sub>H</sub> |
| <b>C1MCFGn</b> | EFn6 <sub>H</sub> X                 | ---             | CAN Message Configuration Register (msg. n) | UU <sub>H</sub>   |
| <b>C1MCRn</b>  | EFn0 <sub>H</sub> X                 | ---             | CAN Message Control Register (msg. n)       | UUUU <sub>H</sub> |
| <b>C1PCIR</b>  | EF02 <sub>H</sub> X                 | ---             | CAN1 Port Control / Interrupt Register      | XXXX <sub>H</sub> |
| <b>C1UARn</b>  | EFn2 <sub>H</sub> X                 | ---             | CAN Upper Arbitration Register (msg. n)     | UUUU <sub>H</sub> |
| <b>C1UGML</b>  | EF08 <sub>H</sub> X                 | ---             | CAN Upper Global Mask Long                  | UUUU <sub>H</sub> |
| <b>C1UMLM</b>  | EF0C <sub>H</sub> X                 | ---             | CAN Upper Mask of Last Message              | UUUU <sub>H</sub> |
| <b>CC10IC</b>  | <b>b</b> FF8C <sub>H</sub>          | C6 <sub>H</sub> | External Interrupt 2 Control Register       | 0000 <sub>H</sub> |
| <b>CC11IC</b>  | <b>b</b> FF8E <sub>H</sub>          | C7 <sub>H</sub> | External Interrupt 3 Control Register       | 0000 <sub>H</sub> |
| <b>CC16</b>    | FE60 <sub>H</sub>                   | 30 <sub>H</sub> | CAPCOM Register 16                          | 0000 <sub>H</sub> |
| <b>CC16IC</b>  | <b>b</b> F160 <sub>H</sub> <b>E</b> | B0 <sub>H</sub> | CAPCOM Reg. 16 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC17</b>    | FE62 <sub>H</sub>                   | 31 <sub>H</sub> | CAPCOM Register 17                          | 0000 <sub>H</sub> |
| <b>CC17IC</b>  | <b>b</b> F162 <sub>H</sub> <b>E</b> | B1 <sub>H</sub> | CAPCOM Reg. 17 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC18</b>    | FE64 <sub>H</sub>                   | 32 <sub>H</sub> | CAPCOM Register 18                          | 0000 <sub>H</sub> |
| <b>CC18IC</b>  | <b>b</b> F164 <sub>H</sub> <b>E</b> | B2 <sub>H</sub> | CAPCOM Reg. 18 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC19</b>    | FE66 <sub>H</sub>                   | 33 <sub>H</sub> | CAPCOM Register 19                          | 0000 <sub>H</sub> |
| <b>CC19IC</b>  | <b>b</b> F166 <sub>H</sub> <b>E</b> | B3 <sub>H</sub> | CAPCOM Reg. 19 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC20</b>    | FE68 <sub>H</sub>                   | 34 <sub>H</sub> | CAPCOM Register 20                          | 0000 <sub>H</sub> |
| <b>CC20IC</b>  | <b>b</b> F168 <sub>H</sub> <b>E</b> | B4 <sub>H</sub> | CAPCOM Reg. 20 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC21</b>    | FE6A <sub>H</sub>                   | 35 <sub>H</sub> | CAPCOM Register 21                          | 0000 <sub>H</sub> |
| <b>CC21IC</b>  | <b>b</b> F16A <sub>H</sub> <b>E</b> | B5 <sub>H</sub> | CAPCOM Reg. 21 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC22</b>    | FE6C <sub>H</sub>                   | 36 <sub>H</sub> | CAPCOM Register 22                          | 0000 <sub>H</sub> |
| <b>CC22IC</b>  | <b>b</b> F16C <sub>H</sub> <b>E</b> | B6 <sub>H</sub> | CAPCOM Reg. 22 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC23</b>    | FE6E <sub>H</sub>                   | 37 <sub>H</sub> | CAPCOM Register 23                          | 0000 <sub>H</sub> |
| <b>CC23IC</b>  | <b>b</b> F16E <sub>H</sub> <b>E</b> | B7 <sub>H</sub> | CAPCOM Reg. 23 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC24</b>    | FE70 <sub>H</sub>                   | 38 <sub>H</sub> | CAPCOM Register 24                          | 0000 <sub>H</sub> |
| <b>CC24IC</b>  | <b>b</b> F170 <sub>H</sub> <b>E</b> | B8 <sub>H</sub> | CAPCOM Reg. 24 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |
| <b>CC25</b>    | FE72 <sub>H</sub>                   | 39 <sub>H</sub> | CAPCOM Register 25                          | 0000 <sub>H</sub> |
| <b>CC25IC</b>  | <b>b</b> F172 <sub>H</sub> <b>E</b> | B9 <sub>H</sub> | CAPCOM Reg. 25 Interrupt Ctrl. Reg.         | 0000 <sub>H</sub> |

**Table 7 C164 Registers, Ordered by Name (continued)**

| <b>Name</b>    | <b>Physical Address</b>    | <b>8-Bit Addr.</b>       | <b>Description</b>                            | <b>Reset Value</b> |
|----------------|----------------------------|--------------------------|---|--------------------|
| <b>CC26</b>    | FE74 <sub>H</sub>          | 3A <sub>H</sub>          | CAPCOM Register 26                            | 0000 <sub>H</sub>  |
| <b>CC26IC</b>  | <b>b</b> F174 <sub>H</sub> | <b>E</b> BA <sub>H</sub> | CAPCOM Reg. 26 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC27</b>    | FE76 <sub>H</sub>          | 3B <sub>H</sub>          | CAPCOM Register 27                            | 0000 <sub>H</sub>  |
| <b>CC27IC</b>  | <b>b</b> F176 <sub>H</sub> | <b>E</b> BB <sub>H</sub> | CAPCOM Reg. 27 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC28</b>    | FE78 <sub>H</sub>          | 3C <sub>H</sub>          | CAPCOM Register 28                            | 0000 <sub>H</sub>  |
| <b>CC28IC</b>  | <b>b</b> F178 <sub>H</sub> | <b>E</b> BC <sub>H</sub> | CAPCOM Reg. 28 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC29</b>    | FE7A <sub>H</sub>          | 3D <sub>H</sub>          | CAPCOM Register 29                            | 0000 <sub>H</sub>  |
| <b>CC29IC</b>  | <b>b</b> F184 <sub>H</sub> | <b>E</b> C2 <sub>H</sub> | CAPCOM Reg. 29 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC30</b>    | FE7C <sub>H</sub>          | 3E <sub>H</sub>          | CAPCOM Register 30                            | 0000 <sub>H</sub>  |
| <b>CC30IC</b>  | <b>b</b> F18C <sub>H</sub> | <b>E</b> C6 <sub>H</sub> | CAPCOM Reg. 30 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC31</b>    | FE7E <sub>H</sub>          | 3F <sub>H</sub>          | CAPCOM Register 31                            | 0000 <sub>H</sub>  |
| <b>CC31IC</b>  | <b>b</b> F194 <sub>H</sub> | <b>E</b> CA <sub>H</sub> | CAPCOM Reg. 31 Interrupt Ctrl. Reg.           | 0000 <sub>H</sub>  |
| <b>CC60</b>    | FE30 <sub>H</sub>          | 18 <sub>H</sub>          | CAPCOM 6 Register 0                           | 0000 <sub>H</sub>  |
| <b>CC61</b>    | FE32 <sub>H</sub>          | 19 <sub>H</sub>          | CAPCOM 6 Register 1                           | 0000 <sub>H</sub>  |
| <b>CC62</b>    | FE34 <sub>H</sub>          | 1A <sub>H</sub>          | CAPCOM 6 Register 2                           | 0000 <sub>H</sub>  |
| <b>CC6EIC</b>  | <b>b</b> F188 <sub>H</sub> | <b>E</b> C4 <sub>H</sub> | CAPCOM 6 Emergency Interrupt Control Register | 0000 <sub>H</sub>  |
| <b>CC6IC</b>   | <b>b</b> F17E <sub>H</sub> | <b>E</b> BF <sub>H</sub> | CAPCOM 6 Interrupt Control Register           | 0000 <sub>H</sub>  |
| <b>CC6MCON</b> | <b>b</b> FF32 <sub>H</sub> | 99 <sub>H</sub>          | CAPCOM 6 Mode Control Register                | 00FF <sub>H</sub>  |
| <b>CC6MIC</b>  | <b>b</b> FF36 <sub>H</sub> | 9B <sub>H</sub>          | CAPCOM 6 Mode Interrupt Ctrl. Reg.            | 0000 <sub>H</sub>  |
| <b>CC6MSEL</b> | F036 <sub>H</sub>          | <b>E</b> 1B <sub>H</sub> | CAPCOM 6 Mode Select Register                 | 0000 <sub>H</sub>  |
| <b>CC8IC</b>   | <b>b</b> FF88 <sub>H</sub> | C4 <sub>H</sub>          | External Interrupt 0 Control Register         | 0000 <sub>H</sub>  |
| <b>CC9IC</b>   | <b>b</b> FF8A <sub>H</sub> | C5 <sub>H</sub>          | External Interrupt 1 Control Register         | 0000 <sub>H</sub>  |
| <b>CCM4</b>    | <b>b</b> FF22 <sub>H</sub> | 91 <sub>H</sub>          | CAPCOM Mode Control Register 4                | 0000 <sub>H</sub>  |
| <b>CCM5</b>    | <b>b</b> FF24 <sub>H</sub> | 92 <sub>H</sub>          | CAPCOM Mode Control Register 5                | 0000 <sub>H</sub>  |
| <b>CCM6</b>    | <b>b</b> FF26 <sub>H</sub> | 93 <sub>H</sub>          | CAPCOM Mode Control Register 6                | 0000 <sub>H</sub>  |
| <b>CCM7</b>    | <b>b</b> FF28 <sub>H</sub> | 94 <sub>H</sub>          | CAPCOM Mode Control Register 7                | 0000 <sub>H</sub>  |
| <b>CMP13</b>   | FE36 <sub>H</sub>          | 1B <sub>H</sub>          | CAPCOM 6 Timer 13 Compare Reg.                | 0000 <sub>H</sub>  |
| <b>CP</b>      | FE10 <sub>H</sub>          | 08 <sub>H</sub>          | CPU Context Pointer Register                  | FC00 <sub>H</sub>  |

**Table 7 C164 Registers, Ordered by Name (continued)**

| Name           | Physical Address           | 8-Bit Addr.              | Description  | Reset Value       |
|----------------|----------------------------|--------------------------|--|-------------------|
| <b>CSP</b>     | FE08 <sub>H</sub>          | 04 <sub>H</sub>          | CPU Code Segment Pointer Register (8 bits, not directly writeable) | 0000 <sub>H</sub> |
| <b>CTCON</b>   | <b>b</b> FF30 <sub>H</sub> | 98 <sub>H</sub>          | CAPCOM 6 Compare Timer Ctrl. Reg.                                  | 1010 <sub>H</sub> |
| <b>DP0H</b>    | <b>b</b> F102 <sub>H</sub> | <b>E</b> 81 <sub>H</sub> | P0H Direction Control Register                                     | 00 <sub>H</sub>   |
| <b>DP0L</b>    | <b>b</b> F100 <sub>H</sub> | <b>E</b> 80 <sub>H</sub> | P0L Direction Control Register                                     | 00 <sub>H</sub>   |
| <b>DP1H</b>    | <b>b</b> F106 <sub>H</sub> | <b>E</b> 83 <sub>H</sub> | P1H Direction Control Register                                     | 00 <sub>H</sub>   |
| <b>DP1L</b>    | <b>b</b> F104 <sub>H</sub> | <b>E</b> 82 <sub>H</sub> | P1L Direction Control Register                                     | 00 <sub>H</sub>   |
| <b>DP3</b>     | <b>b</b> FFC6 <sub>H</sub> | E3 <sub>H</sub>          | Port 3 Direction Control Register                                  | 0000 <sub>H</sub> |
| <b>DP4</b>     | <b>b</b> FFCA <sub>H</sub> | E5 <sub>H</sub>          | Port 4 Direction Control Register                                  | 00 <sub>H</sub>   |
| <b>DP8</b>     | <b>b</b> FFD6 <sub>H</sub> | EB <sub>H</sub>          | Port 8 Direction Control Register                                  | 00 <sub>H</sub>   |
| <b>DPP0</b>    | FE00 <sub>H</sub>          | 00 <sub>H</sub>          | CPU Data Page Pointer 0 Reg. (10 bits)                             | 0000 <sub>H</sub> |
| <b>DPP1</b>    | FE02 <sub>H</sub>          | 01 <sub>H</sub>          | CPU Data Page Pointer 1 Reg. (10 bits)                             | 0001 <sub>H</sub> |
| <b>DPP2</b>    | FE04 <sub>H</sub>          | 02 <sub>H</sub>          | CPU Data Page Pointer 2 Reg. (10 bits)                             | 0002 <sub>H</sub> |
| <b>DPP3</b>    | FE06 <sub>H</sub>          | 03 <sub>H</sub>          | CPU Data Page Pointer 3 Reg. (10 bits)                             | 0003 <sub>H</sub> |
| <b>EXICON</b>  | <b>b</b> F1C0 <sub>H</sub> | <b>E</b> E0 <sub>H</sub> | External Interrupt Control Register                                | 0000 <sub>H</sub> |
| <b>EXISEL</b>  | <b>b</b> F1DA <sub>H</sub> | <b>E</b> ED <sub>H</sub> | External Interrupt Source Select Reg.                              | 0000 <sub>H</sub> |
| <b>IDCHIP</b>  | F07C <sub>H</sub>          | <b>E</b> 3E <sub>H</sub> | Identifier   | XXXX <sub>H</sub> |
| <b>IDMANUF</b> | F07E <sub>H</sub>          | <b>E</b> 3F <sub>H</sub> | Identifier   | 1820 <sub>H</sub> |
| <b>IDMEM</b>   | F07A <sub>H</sub>          | <b>E</b> 3D <sub>H</sub> | Identifier   | XXXX <sub>H</sub> |
| <b>IDPROG</b>  | F078 <sub>H</sub>          | <b>E</b> 3C <sub>H</sub> | Identifier   | XXXX <sub>H</sub> |
| <b>ISNC</b>    | <b>b</b> F1DE <sub>H</sub> | <b>E</b> EF <sub>H</sub> | Interrupt Subnode Control Register                                 | 0000 <sub>H</sub> |
| <b>MDC</b>     | <b>b</b> FF0E <sub>H</sub> | 87 <sub>H</sub>          | CPU Multiply Divide Control Register                               | 0000 <sub>H</sub> |
| <b>MDH</b>     | FE0C <sub>H</sub>          | 06 <sub>H</sub>          | CPU Multiply Divide Reg. – High Word                               | 0000 <sub>H</sub> |
| <b>MDL</b>     | FE0E <sub>H</sub>          | 07 <sub>H</sub>          | CPU Multiply Divide Reg. – Low Word                                | 0000 <sub>H</sub> |
| <b>ODP3</b>    | <b>b</b> F1C6 <sub>H</sub> | <b>E</b> E3 <sub>H</sub> | Port 3 Open Drain Control Register                                 | 0000 <sub>H</sub> |
| <b>ODP4</b>    | <b>b</b> F1CA <sub>H</sub> | <b>E</b> E5 <sub>H</sub> | Port 4 Open Drain Control Register                                 | 00 <sub>H</sub>   |
| <b>ODP8</b>    | <b>b</b> F1D6 <sub>H</sub> | <b>E</b> EB <sub>H</sub> | Port 8 Open Drain Control Register                                 | 00 <sub>H</sub>   |
| <b>ONES</b>    | <b>b</b> FF1E <sub>H</sub> | 8F <sub>H</sub>          | Constant Value 1's Register (read only)                            | FFFF <sub>H</sub> |
| <b>P0H</b>     | <b>b</b> FF02 <sub>H</sub> | 81 <sub>H</sub>          | Port 0 High Reg. (Upper half of PORT0)                             | 00 <sub>H</sub>   |
| <b>P0L</b>     | <b>b</b> FF00 <sub>H</sub> | 80 <sub>H</sub>          | Port 0 Low Reg. (Lower half of PORT0)                              | 00 <sub>H</sub>   |

**Table 7 C164 Registers, Ordered by Name (continued)**

| <b>Name</b>    |          | <b>Physical Address</b> | <b>8-Bit Addr.</b>       | <b>Description</b>                     | <b>Reset Value</b> |
|----------------|----------|-------------------------|--------------------------|--|--------------------|
| <b>P1H</b>     | <b>b</b> | FF06 <sub>H</sub>       | 83 <sub>H</sub>          | Port 1 High Reg. (Upper half of PORT1) | 00 <sub>H</sub>    |
| <b>P1L</b>     | <b>b</b> | FF04 <sub>H</sub>       | 82 <sub>H</sub>          | Port 1 Low Reg. (Lower half of PORT1)  | 00 <sub>H</sub>    |
| <b>P3</b>      | <b>b</b> | FFC4 <sub>H</sub>       | E2 <sub>H</sub>          | Port 3 Register                        | 0000 <sub>H</sub>  |
| <b>P4</b>      | <b>b</b> | FFC8 <sub>H</sub>       | E4 <sub>H</sub>          | Port 4 Register (7 bits)               | 00 <sub>H</sub>    |
| <b>P5</b>      | <b>b</b> | FFA2 <sub>H</sub>       | D1 <sub>H</sub>          | Port 5 Register (read only)            | XXXX <sub>H</sub>  |
| <b>P5DIDIS</b> | <b>b</b> | FFA4 <sub>H</sub>       | D2 <sub>H</sub>          | Port 5 Digital Input Disable Register  | 0000 <sub>H</sub>  |
| <b>P8</b>      | <b>b</b> | FFD4 <sub>H</sub>       | EA <sub>H</sub>          | Port 8 Register (8 bits)               | 00 <sub>H</sub>    |
| <b>PECC0</b>   |          | FEC0 <sub>H</sub>       | 60 <sub>H</sub>          | PEC Channel 0 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC1</b>   |          | FEC2 <sub>H</sub>       | 61 <sub>H</sub>          | PEC Channel 1 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC2</b>   |          | FEC4 <sub>H</sub>       | 62 <sub>H</sub>          | PEC Channel 2 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC3</b>   |          | FEC6 <sub>H</sub>       | 63 <sub>H</sub>          | PEC Channel 3 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC4</b>   |          | FEC8 <sub>H</sub>       | 64 <sub>H</sub>          | PEC Channel 4 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC5</b>   |          | FECA <sub>H</sub>       | 65 <sub>H</sub>          | PEC Channel 5 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC6</b>   |          | FECC <sub>H</sub>       | 66 <sub>H</sub>          | PEC Channel 6 Control Register         | 0000 <sub>H</sub>  |
| <b>PECC7</b>   |          | FECE <sub>H</sub>       | 67 <sub>H</sub>          | PEC Channel 7 Control Register         | 0000 <sub>H</sub>  |
| <b>PICON</b>   | <b>b</b> | F1C4 <sub>H</sub>       | <b>E</b> E2 <sub>H</sub> | Port Input Threshold Control Register  | 0000 <sub>H</sub>  |
| <b>POCON0H</b> |          | F082 <sub>H</sub>       | <b>E</b> 41 <sub>H</sub> | Port P0H Output Control Register       | 0000 <sub>H</sub>  |
| <b>POCON0L</b> |          | F080 <sub>H</sub>       | <b>E</b> 40 <sub>H</sub> | Port P0L Output Control Register       | 0000 <sub>H</sub>  |
| <b>POCON1H</b> |          | F086 <sub>H</sub>       | <b>E</b> 43 <sub>H</sub> | Port P1H Output Control Register       | 0000 <sub>H</sub>  |
| <b>POCON1L</b> |          | F084 <sub>H</sub>       | <b>E</b> 42 <sub>H</sub> | Port P1L Output Control Register       | 0000 <sub>H</sub>  |
| <b>POCON20</b> |          | F0AA <sub>H</sub>       | <b>E</b> 55 <sub>H</sub> | Dedicated Pin Output Control Register  | 0000 <sub>H</sub>  |
| <b>POCON3</b>  |          | F08A <sub>H</sub>       | <b>E</b> 45 <sub>H</sub> | Port P3 Output Control Register        | 0000 <sub>H</sub>  |
| <b>POCON4</b>  |          | F08C <sub>H</sub>       | <b>E</b> 46 <sub>H</sub> | Port P4 Output Control Register        | 0000 <sub>H</sub>  |
| <b>POCON8</b>  |          | F092 <sub>H</sub>       | <b>E</b> 49 <sub>H</sub> | Port P8 Output Control Register        | 0000 <sub>H</sub>  |
| <b>PSW</b>     | <b>b</b> | FF10 <sub>H</sub>       | 88 <sub>H</sub>          | CPU Program Status Word                | 0000 <sub>H</sub>  |
| <b>PTCR</b>    |          | F0AE <sub>H</sub>       | <b>E</b> 57 <sub>H</sub> | Port Temperature Compensation Reg.     | 0000 <sub>H</sub>  |
| <b>RP0H</b>    | <b>b</b> | F108 <sub>H</sub>       | <b>E</b> 84 <sub>H</sub> | System Startup Config. Reg. (Rd. only) | XX <sub>H</sub>    |
| <b>RSTCON</b>  | <b>b</b> | F1E0 <sub>H</sub>       | <b>E</b> ---             | Reset Control Register                 | 00XX <sub>H</sub>  |
| <b>RTCH</b>    |          | F0D6 <sub>H</sub>       | <b>E</b> 6B <sub>H</sub> | RTC High Register                      | no                 |
| <b>RTCL</b>    |          | F0D4 <sub>H</sub>       | <b>E</b> 6A <sub>H</sub> | RTC Low Register                       | no                 |

**Table 7 C164 Registers, Ordered by Name (continued)**

| <b>Name</b>    | <b>Physical Address</b>    | <b>8-Bit Addr.</b>       | <b>Description</b>  | <b>Reset Value</b>              |
|----------------|----------------------------|--------------------------|---|---------------------------------|
| <b>S0BG</b>    | FEB4 <sub>H</sub>          | 5A <sub>H</sub>          | Serial Channel 0 Baud Rate Generator Reload Register        | 0000 <sub>H</sub>               |
| <b>S0CON</b>   | <b>b</b> FFB0 <sub>H</sub> | D8 <sub>H</sub>          | Serial Channel 0 Control Register                           | 0000 <sub>H</sub>               |
| <b>S0EIC</b>   | <b>b</b> FF70 <sub>H</sub> | B8 <sub>H</sub>          | Serial Channel 0 Error Interrupt Ctrl. Reg.                 | 0000 <sub>H</sub>               |
| <b>S0RBUF</b>  | FEB2 <sub>H</sub>          | 59 <sub>H</sub>          | Serial Channel 0 Receive Buffer Reg. (read only)            | XXXX <sub>H</sub>               |
| <b>S0RIC</b>   | <b>b</b> FF6E <sub>H</sub> | B7 <sub>H</sub>          | Serial Channel 0 Receive Interrupt Control Register         | 0000 <sub>H</sub>               |
| <b>S0TBIC</b>  | <b>b</b> F19C <sub>H</sub> | <b>E</b> CE <sub>H</sub> | Serial Channel 0 Transmit Buffer Interrupt Control Register | 0000 <sub>H</sub>               |
| <b>S0TBUF</b>  | FEB0 <sub>H</sub>          | 58 <sub>H</sub>          | Serial Channel 0 Transmit Buffer Reg. (write only)          | 0000 <sub>H</sub>               |
| <b>S0TIC</b>   | <b>b</b> FF6C <sub>H</sub> | B6 <sub>H</sub>          | Serial Channel 0 Transmit Interrupt Control Register        | 0000 <sub>H</sub>               |
| <b>SP</b>      | FE12 <sub>H</sub>          | 09 <sub>H</sub>          | CPU System Stack Pointer Register                           | FC00 <sub>H</sub>               |
| <b>SSCBR</b>   | F0B4 <sub>H</sub>          | <b>E</b> 5A <sub>H</sub> | SSC Baudrate Register                                       | 0000 <sub>H</sub>               |
| <b>SSCCON</b>  | <b>b</b> FFB2 <sub>H</sub> | D9 <sub>H</sub>          | SSC Control Register  | 0000 <sub>H</sub>               |
| <b>SSCEIC</b>  | <b>b</b> FF76 <sub>H</sub> | BB <sub>H</sub>          | SSC Error Interrupt Control Register                        | 0000 <sub>H</sub>               |
| <b>SSCRB</b>   | F0B2 <sub>H</sub>          | <b>E</b> 59 <sub>H</sub> | SSC Receive Buffer  | XXXX <sub>H</sub>               |
| <b>SSCRIC</b>  | <b>b</b> FF74 <sub>H</sub> | BA <sub>H</sub>          | SSC Receive Interrupt Control Register                      | 0000 <sub>H</sub>               |
| <b>SSCTB</b>   | F0B0 <sub>H</sub>          | <b>E</b> 58 <sub>H</sub> | SSC Transmit Buffer   | 0000 <sub>H</sub>               |
| <b>SSCTIC</b>  | <b>b</b> FF72 <sub>H</sub> | B9 <sub>H</sub>          | SSC Transmit Interrupt Control Register                     | 0000 <sub>H</sub>               |
| <b>STKOV</b>   | FE14 <sub>H</sub>          | 0A <sub>H</sub>          | CPU Stack Overflow Pointer Register                         | FA00 <sub>H</sub>               |
| <b>STKUN</b>   | FE16 <sub>H</sub>          | 0B <sub>H</sub>          | CPU Stack Underflow Pointer Register                        | FC00 <sub>H</sub>               |
| <b>SYSCON</b>  | <b>b</b> FF12 <sub>H</sub> | 89 <sub>H</sub>          | CPU System Configuration Register                           | <sup>1)</sup> 0xx0 <sub>H</sub> |
| <b>SYSCON1</b> | <b>b</b> F1DC <sub>H</sub> | <b>E</b> EE <sub>H</sub> | CPU System Configuration Register 1                         | 0000 <sub>H</sub>               |
| <b>SYSCON2</b> | <b>b</b> F1D0 <sub>H</sub> | <b>E</b> E8 <sub>H</sub> | CPU System Configuration Register 2                         | 0000 <sub>H</sub>               |
| <b>SYSCON3</b> | <b>b</b> F1D4 <sub>H</sub> | <b>E</b> EA <sub>H</sub> | CPU System Configuration Register 3                         | 0000 <sub>H</sub>               |
| <b>T12IC</b>   | <b>b</b> F190 <sub>H</sub> | <b>E</b> C8 <sub>H</sub> | CAPCOM 6 Timer 12 Interrupt Ctrl. Reg.                      | 0000 <sub>H</sub>               |
| <b>T12OF</b>   | F034 <sub>H</sub>          | <b>E</b> 1A <sub>H</sub> | CAPCOM 6 Timer 12 Offset Register                           | 0000 <sub>H</sub>               |

**Table 7 C164 Registers, Ordered by Name (continued)**

| Name          |          | Physical Address  | 8-Bit Addr.       | Description                              | Reset Value                     |
|---------------|----------|-------------------|-------------------|--|---------------------------------|
| <b>T12P</b>   |          | F030 <sub>H</sub> | E 18 <sub>H</sub> | CAPCOM 6 Timer 12 Period Register        | 0000 <sub>H</sub>               |
| <b>T13IC</b>  | <b>b</b> | F198 <sub>H</sub> | E CC <sub>H</sub> | CAPCOM 6 Timer 13 Interrupt Ctrl. Reg.   | 0000 <sub>H</sub>               |
| <b>T13P</b>   |          | F032 <sub>H</sub> | E 19 <sub>H</sub> | CAPCOM 6 Timer 13 Period Register        | 0000 <sub>H</sub>               |
| <b>T14</b>    |          | F0D2 <sub>H</sub> | E 69 <sub>H</sub> | RTC Timer 14 Register                    | no                              |
| <b>T14REL</b> |          | F0D0 <sub>H</sub> | E 68 <sub>H</sub> | RTC Timer 14 Reload Register             | no                              |
| <b>T2</b>     |          | FE40 <sub>H</sub> | 20 <sub>H</sub>   | GPT1 Timer 2 Register                    | 0000 <sub>H</sub>               |
| <b>T2CON</b>  | <b>b</b> | FF40 <sub>H</sub> | A0 <sub>H</sub>   | GPT1 Timer 2 Control Register            | 0000 <sub>H</sub>               |
| <b>T2IC</b>   | <b>b</b> | FF60 <sub>H</sub> | B0 <sub>H</sub>   | GPT1 Timer 2 Interrupt Control Register  | 0000 <sub>H</sub>               |
| <b>T3</b>     |          | FE42 <sub>H</sub> | 21 <sub>H</sub>   | GPT1 Timer 3 Register                    | 0000 <sub>H</sub>               |
| <b>T3CON</b>  | <b>b</b> | FF42 <sub>H</sub> | A1 <sub>H</sub>   | GPT1 Timer 3 Control Register            | 0000 <sub>H</sub>               |
| <b>T3IC</b>   | <b>b</b> | FF62 <sub>H</sub> | B1 <sub>H</sub>   | GPT1 Timer 3 Interrupt Control Register  | 0000 <sub>H</sub>               |
| <b>T4</b>     |          | FE44 <sub>H</sub> | 22 <sub>H</sub>   | GPT1 Timer 4 Register                    | 0000 <sub>H</sub>               |
| <b>T4CON</b>  | <b>b</b> | FF44 <sub>H</sub> | A2 <sub>H</sub>   | GPT1 Timer 4 Control Register            | 0000 <sub>H</sub>               |
| <b>T4IC</b>   | <b>b</b> | FF64 <sub>H</sub> | B2 <sub>H</sub>   | GPT1 Timer 4 Interrupt Control Register  | 0000 <sub>H</sub>               |
| <b>T7</b>     |          | F050 <sub>H</sub> | E 28 <sub>H</sub> | CAPCOM Timer 7 Register                  | 0000 <sub>H</sub>               |
| <b>T78CON</b> | <b>b</b> | FF20 <sub>H</sub> | 90 <sub>H</sub>   | CAPCOM Timer 7 and 8 Ctrl. Reg.          | 0000 <sub>H</sub>               |
| <b>T7IC</b>   | <b>b</b> | F17A <sub>H</sub> | E BD <sub>H</sub> | CAPCOM Timer 7 Interrupt Ctrl. Reg.      | 0000 <sub>H</sub>               |
| <b>T7REL</b>  |          | F054 <sub>H</sub> | E 2A <sub>H</sub> | CAPCOM Timer 7 Reload Register           | 0000 <sub>H</sub>               |
| <b>T8</b>     |          | F052 <sub>H</sub> | E 29 <sub>H</sub> | CAPCOM Timer 8 Register                  | 0000 <sub>H</sub>               |
| <b>T8IC</b>   | <b>b</b> | F17C <sub>H</sub> | E BE <sub>H</sub> | CAPCOM Timer 8 Interrupt Ctrl. Reg.      | 0000 <sub>H</sub>               |
| <b>T8REL</b>  |          | F056 <sub>H</sub> | E 2B <sub>H</sub> | CAPCOM Timer 8 Reload Register           | 0000 <sub>H</sub>               |
| <b>TFR</b>    | <b>b</b> | FFAC <sub>H</sub> | D6 <sub>H</sub>   | Trap Flag Register                       | 0000 <sub>H</sub>               |
| <b>TRCON</b>  | <b>b</b> | FF34 <sub>H</sub> | 9A <sub>H</sub>   | CAPCOM 6 Trap Enable Ctrl. Reg.          | 00XX <sub>H</sub>               |
| <b>WDT</b>    |          | FEAE <sub>H</sub> | 57 <sub>H</sub>   | Watchdog Timer Register (read only)      | 0000 <sub>H</sub>               |
| <b>WDTCON</b> |          | FFAE <sub>H</sub> | D7 <sub>H</sub>   | Watchdog Timer Control Register          | <sup>2)</sup> 00xx <sub>H</sub> |
| <b>XP0IC</b>  | <b>b</b> | F186 <sub>H</sub> | E C3 <sub>H</sub> | CAN1 Module Interrupt Control Register   | 0000 <sub>H</sub>               |
| <b>XP1IC</b>  | <b>b</b> | F18E <sub>H</sub> | E C7 <sub>H</sub> | Flash Termination Interrupt Control Reg. | 0000 <sub>H</sub>               |
| <b>XP3IC</b>  | <b>b</b> | F19E <sub>H</sub> | E CF <sub>H</sub> | PLL/RTC Interrupt Control Register       | 0000 <sub>H</sub>               |
| <b>ZEROS</b>  | <b>b</b> | FF1C <sub>H</sub> | 8E <sub>H</sub>   | Constant Value 0's Register (read only)  | 0000 <sub>H</sub>               |

1) The system configuration is selected during reset.

2) The reset value depends on the indicated reset source.



## Absolute Maximum Ratings

**Table 8 Absolute Maximum Rating Parameters**

| Parameter  | Symbol     | Limit Values |              | Unit | Notes |
|--|------------|--------------|--------------|------|-------|
|  |            | min.         | max.         |      |       |
| Storage temperature  | $T_{ST}$   | -65          | 150          | °C   |       |
| Voltage on $V_{DD}$ pins with respect to ground ( $V_{SS}$ ) | $V_{DD}$   | -0.5         | 6.5          | V    |       |
| Voltage on any pin with respect to ground ( $V_{SS}$ )       | $V_{IN}$   | -0.5         | $V_{DD}+0.5$ | V    |       |
| Input current on any pin during overload condition           |            | -10          | 10           | mA   |       |
| Absolute sum of all input currents during overload condition |            | -            | 100          | mA   |       |
| Power dissipation  | $P_{DISS}$ | -            | 1.5          | W    |       |

*Note: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. During absolute maximum rating overload conditions ( $V_{IN} > V_{DD}$  or  $V_{IN} < V_{SS}$ ) the voltage on  $V_{DD}$  pins with respect to ground ( $V_{SS}$ ) must not exceed the values defined by the absolute maximum ratings.*

## Operating Conditions

The following operating conditions must not be exceeded in order to ensure correct operation of the C164. All parameters specified in the following sections refer to these operating conditions, unless otherwise noticed.

**Table 9 Operating Condition Parameters**

| Parameter                         | Symbol           | Limit Values      |         | Unit | Notes  |
|-----------------------------------|------------------|-------------------|---------|------|--|
|                                   |                  | min.              | max.    |      |  |
| Standard digital supply voltage   | $V_{DD}$         | 4.5               | 5.5     | V    | Active mode,<br>$f_{CPUmax} = 25$ MHz              |
|                                   |                  | 2.5 <sup>1)</sup> | 5.5     | V    | PowerDown mode                                     |
| Digital ground voltage            | $V_{SS}$         | 0                 |         | V    | Reference voltage                                  |
| Overload current                  | $I_{OV}$         | -                 | $\pm 5$ | mA   | Per pin <sup>2)</sup> <sup>3)</sup>                |
| Absolute sum of overload currents | $\Sigma I_{OV} $ | -                 | 50      | mA   | <sup>3)</sup>                                      |
| External Load Capacitance         | $C_L$            | -                 | 100     | pF   | Pin drivers in <b>fast edge</b> mode <sup>4)</sup> |
| Ambient temperature               | $T_A$            | 0                 | 70      | °C   | SAB-C164...  |
|                                   |                  | -40               | 85      | °C   | SAF-C164...  |
|                                   |                  | -40               | 125     | °C   | SAK-C164...  |

1) Output voltages and output currents will be reduced when  $V_{DD}$  leaves the range defined for active mode.

2) Overload conditions occur if the standard operating conditions are exceeded, i.e. the voltage on any pin exceeds the specified range (i.e.  $V_{OV} > V_{DD} + 0.5V$  or  $V_{OV} < V_{SS} - 0.5V$ ). The absolute sum of input overload currents on all port pins may not exceed **50 mA**. The supply voltage must remain within the specified limits.

3) Not 100% tested, guaranteed by design characterization.

4) The timing is valid for pin drivers in high current or dynamic current mode. The reduced static output current in dynamic current mode must be respected when designing the system.

## Parameter Interpretation

The parameters listed in the following partly represent the characteristics of the C164 and partly its demands on the system. To aid in interpreting the parameters right, when evaluating them for a design, they are marked in column “Symbol”:

### CC (Controller Characteristics):

The logic of the C164 will provide signals with the respective timing characteristics.

### SR (System Requirement):

The external system must provide signals with the respective timing characteristics to the C164.

## DC Characteristics

(Operating Conditions apply)

| Parameter   | Symbol       | Limit Values          |                       | Unit | Test Condition    |
|---|--------------|-----------------------|-----------------------|------|-------------------|
|   |              | min.                  | max.                  |      |                   |
| Input low voltage XTAL1, P3.0, P3.1, P6.5, P6.6, P6.7                       | $V_{IL1}$ SR | - 0.5                 | 0.3 $V_{DD}$          | V    | -                 |
| Input low voltage (TTL)   | $V_{IL}$ SR  | - 0.5                 | 0.2 $V_{DD}$<br>- 0.1 | V    | -                 |
| Input low voltage (Special Threshold)                                       | $V_{ILS}$ SR | - 0.5                 | 2.0                   | V    | -                 |
| Input high voltage $\overline{RSTIN}$                                       | $V_{IH1}$ SR | 0.6 $V_{DD}$          | $V_{DD} + 0.5$        | V    | -                 |
| Input high voltage XTAL1, P3.0, P3.1, P6.5, P6.6, P6.7                      | $V_{IH2}$ SR | 0.7 $V_{DD}$          | $V_{DD} + 0.5$        | V    | -                 |
| Input high voltage (TTL)  | $V_{IH}$ SR  | 0.2 $V_{DD}$<br>+ 0.9 | $V_{DD} + 0.5$        | V    | -                 |
| Input high voltage (Special Threshold)                                      | $V_{IHS}$ SR | 0.8 $V_{DD}$<br>- 0.2 | $V_{DD} + 0.5$        | V    | -                 |
| Input Hysteresis (Special Threshold)  | HYS          | 400                   | -                     | mV   | -                 |
| Output low voltage (PORT0, PORT1, Port 4, ALE, RD, WR, BHE, CLKOUT, RSTOUT) | $V_{OL}$ CC  | -                     | 0.45                  | V    | $I_{OL} = 2.4$ mA |
| Output low voltage (P3.0, P3.1, P6.5, P6.6, P6.7)                           | $V_{OL2}$ CC | -                     | 0.4                   | V    | $I_{OL2} = 3$ mA  |

**DC Characteristics (continued)**  
 (Operating Conditions apply)

| Parameter  | Symbol                   | Limit Values |           | Unit          | Test Condition   |
|--|--------------------------|--------------|-----------|---------------|--|
|  |                          | min.         | max.      |               |  |
| Output low voltage<br>(all other outputs)  | $V_{OL1}$ CC             | –            | 0.45      | V             | $I_{OL} = 1.6 \text{ mA}$                                |
| Output high voltage <sup>1)</sup><br>( <u>PORT0</u> , <u>PORT1</u> , Port 4, ALE,<br><u>RD</u> , <u>WR</u> , <u>BHE</u> , <u>CLKOUT</u> ,<br><u>RSTOUT</u> ) | $V_{OH}$ CC              | 2.4          | –         | V             | $I_{OH} = -2.4 \text{ mA}$                               |
|  |                          | $0.9 V_{DD}$ | –         | V             | $I_{OH} = -0.5 \text{ mA}$                               |
| Output high voltage <sup>1)</sup><br>(all other outputs)   | $V_{OH1}$ CC             | 2.4          | –         | V             | $I_{OH} = -1.6 \text{ mA}$                               |
|  |                          | $0.9 V_{DD}$ | –         | V             | $I_{OH} = -0.5 \text{ mA}$                               |
| Input leakage current (Port 5)   | $I_{OZ1}$ CC             | –            | $\pm 200$ | nA            | $0.45\text{V} < V_{IN} < V_{DD}$                         |
| Input leakage current (all other)  | $I_{OZ2}$ CC             | –            | $\pm 500$ | nA            | $0.45\text{V} < V_{IN} < V_{DD}$                         |
| <u>RSTIN</u> inactive current <sup>2)</sup>  | $I_{RSTH}$ <sup>3)</sup> | –            | -10       | $\mu\text{A}$ | $V_{IN} = V_{IH1}$                                       |
| <u>RSTIN</u> active current <sup>2)</sup>  | $I_{RSTL}$ <sup>4)</sup> | -100         | –         | $\mu\text{A}$ | $V_{IN} = V_{IL}$  |
| Read/Write inactive current <sup>5)</sup>  | $I_{RWH}$ <sup>3)</sup>  | –            | -40       | $\mu\text{A}$ | $V_{OUT} = 2.4 \text{ V}$                                |
| Read/Write active current <sup>5)</sup>  | $I_{RWL}$ <sup>4)</sup>  | -500         | –         | $\mu\text{A}$ | $V_{OUT} = V_{OLmax}$                                    |
| ALE inactive current <sup>5)</sup>   | $I_{ALEL}$ <sup>3)</sup> | –            | 40        | $\mu\text{A}$ | $V_{OUT} = V_{OLmax}$                                    |
| ALE active current <sup>5)</sup>   | $I_{ALEH}$ <sup>4)</sup> | 500          | –         | $\mu\text{A}$ | $V_{OUT} = 2.4 \text{ V}$                                |
| Port 4 inactive current <sup>5)</sup>  | $I_{P4H}$ <sup>3)</sup>  | –            | -40       | $\mu\text{A}$ | $V_{OUT} = 2.4 \text{ V}$                                |
| Port 4 active current <sup>5)</sup>  | $I_{P4L}$ <sup>4)</sup>  | -500         | –         | $\mu\text{A}$ | $V_{OUT} = V_{OL1max}$                                   |
| PORT0 configuration current <sup>5)</sup>  | $I_{P0H}$ <sup>3)</sup>  | –            | -10       | $\mu\text{A}$ | $V_{IN} = V_{IHmin}$                                     |
|  | $I_{P0L}$ <sup>4)</sup>  | -100         | –         | $\mu\text{A}$ | $V_{IN} = V_{ILmax}$                                     |
| XTAL1 input current  | $I_{IL}$ CC              | –            | $\pm 20$  | $\mu\text{A}$ | $0 \text{ V} < V_{IN} < V_{DD}$                          |
| Pin capacitance <sup>6)</sup><br>(digital inputs/outputs)  | $C_{IO}$ CC              | –            | 10        | pF            | $f = 1 \text{ MHz}$<br>$T_A = 25 \text{ }^\circ\text{C}$ |

1) This specification is not valid for outputs which are switched to open drain mode. In this case the respective output will float and the voltage results from the external circuitry.

2) These parameters describe the RSTIN pullup, which equals a resistance of ca. 50 to 250 K $\Omega$ .

3) The maximum current may be drawn while the respective signal line remains inactive.

4) The minimum current must be drawn in order to drive the respective signal line active.

5) This specification is only valid during Reset, or during Adapt-mode. The Port 4 current values are only valid for pins P4.3-0, which can act as chip select outputs.

6) Not 100% tested, guaranteed by design characterization.

**Power Consumption C164-8R (ROM)**

(Operating Conditions apply)

| Parameter  | Symbol                   | Limit Values |                          | Unit | Test Condition   |
|--|--------------------------|--------------|--------------------------|------|--|
|  |                          | min.         | max.                     |      |  |
| Power supply current (5V active) with all peripherals active                             | $I_{DD5}$                | –            | $1 + 2.5 \cdot f_{CPU}$  | mA   | $\overline{RSTIN} = V_{IL2}$<br>$f_{CPU}$ in [MHz] <sup>1)</sup> |
| Idle mode supply current (5V) with all peripherals active                                | $I_{IDX5}$               | –            | $1 + 1.1 \cdot f_{CPU}$  | mA   | $\overline{RSTIN} = V_{IH1}$<br>$f_{CPU}$ in [MHz] <sup>1)</sup> |
| Idle mode supply current (5V) with all peripherals deactivated, PLL off, SDD factor = 32 | $I_{IDO5}$ <sup>2)</sup> | –            | $500 + 50 \cdot f_{OSC}$ | μA   | $\overline{RSTIN} = V_{IH1}$<br>$f_{OSC}$ in [MHz] <sup>1)</sup> |
| Power-down mode supply current (5V) with RTC running                                     | $I_{PDR5}$ <sup>2)</sup> | –            | $200 + 25 \cdot f_{OSC}$ | μA   | $V_{DD} = V_{DDmax}$<br>$f_{OSC}$ in [MHz] <sup>3)</sup>         |
| Power-down mode supply current (5V) with RTC disabled                                    | $I_{PDO5}$               | –            | 50                       | μA   | $V_{DD} = V_{DDmax}$ <sup>3)</sup>                               |

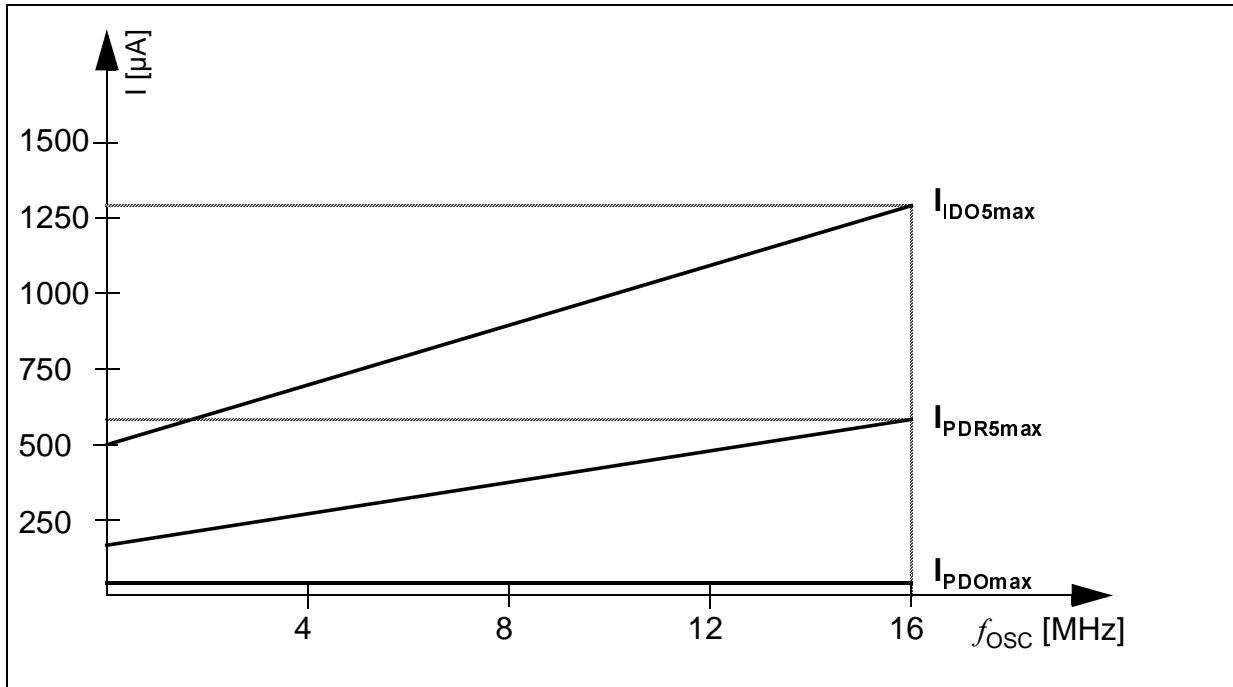
- 1) The supply current is a function of the operating frequency. This dependency is illustrated in the figure below. These parameters are tested at  $V_{DDmax}$  and maximum CPU clock with all outputs disconnected and all inputs at  $V_{IL}$  or  $V_{IH}$ . The oscillator also contributes to the total supply current. The given values refer to the worst case, i.e.  $I_{PDRmax}$ . For lower oscillator frequencies the respective supply current can be reduced accordingly.
- 2) This parameter is determined mainly by the current consumed by the oscillator. This current, however, is influenced by the external oscillator circuitry (crystal, capacitors). The values given refer to a typical circuitry and may change in case of a not optimized external oscillator circuitry.
- 3) This parameter is tested including leakage currents. All inputs (including pins configured as inputs) at 0 V to 0.1 V or at  $V_{DD} - 0.1$  V to  $V_{DD}$ ,  $V_{REF} = 0$  V, all outputs (including pins configured as outputs) disconnected.

**Power Consumption C164-8F (Flash)**

(Operating Conditions apply)

| Parameter   | Symbol                   | Limit Values |                             | Unit | Test Condition   |
|---|--------------------------|--------------|-----------------------------|------|--|
|   |                          | min.         | max.                        |      |  |
| Power supply current (5V active) with all peripherals active  | $I_{DD5}$                | –            | 40 +<br>$3.5 \cdot f_{CPU}$ | mA   | $\overline{RSTIN} = V_{IL2}$<br>$f_{CPU}$ in [MHz] <sup>1)</sup> |
| Idle mode supply current (5V) with all peripherals active   | $I_{IDX5}$               | –            | 40 +<br>$1.4 \cdot f_{CPU}$ | mA   | $\overline{RSTIN} = V_{IH1}$<br>$f_{CPU}$ in [MHz] <sup>1)</sup> |
| Idle mode supply current (5V) with all peripherals deactivated, PLL off, SDD factor = 32, Flash modules off | $I_{IDO5}$ <sup>2)</sup> | –            | 500 +<br>$50 \cdot f_{OSC}$ | μA   | $\overline{RSTIN} = V_{IH1}$<br>$f_{OSC}$ in [MHz] <sup>1)</sup> |
| Power-down mode supply current (5V) with RTC running  | $I_{PDR5}$ <sup>2)</sup> | –            | 200 +<br>$25 \cdot f_{OSC}$ | μA   | $V_{DD} = V_{DDmax}$<br>$f_{OSC}$ in [MHz] <sup>3)</sup>         |
| Power-down mode supply current (5V) with RTC disabled   | $I_{PDO5}$               | –            | 50                          | μA   | $V_{DD} = V_{DDmax}$ <sup>3)</sup>                               |

- 1) The supply current is a function of the operating frequency. This dependency is illustrated in the figure below. These parameters are tested at  $V_{DDmax}$  and maximum CPU clock with all outputs disconnected and all inputs at  $V_{IL}$  or  $V_{IH}$ . The oscillator also contributes to the total supply current. The given values refer to the worst case, i.e.  $I_{PDRmax}$ . For lower oscillator frequencies the respective supply current can be reduced accordingly.
- 2) This parameter is determined mainly by the current consumed by the oscillator. This current, however, is influenced by the external oscillator circuitry (crystal, capacitors). The values given refer to a typical circuitry and may change in case of a not optimized external oscillator circuitry.
- 3) This parameter is tested including leakage currents. All inputs (including pins configured as inputs) at 0 V to 0.1 V or at  $V_{DD} - 0.1$  V to  $V_{DD}$ ,  $V_{REF} = 0$  V, all outputs (including pins configured as outputs) disconnected.



**Figure 8** Idle and Power Down Supply Current as a Function of Oscillator Frequency

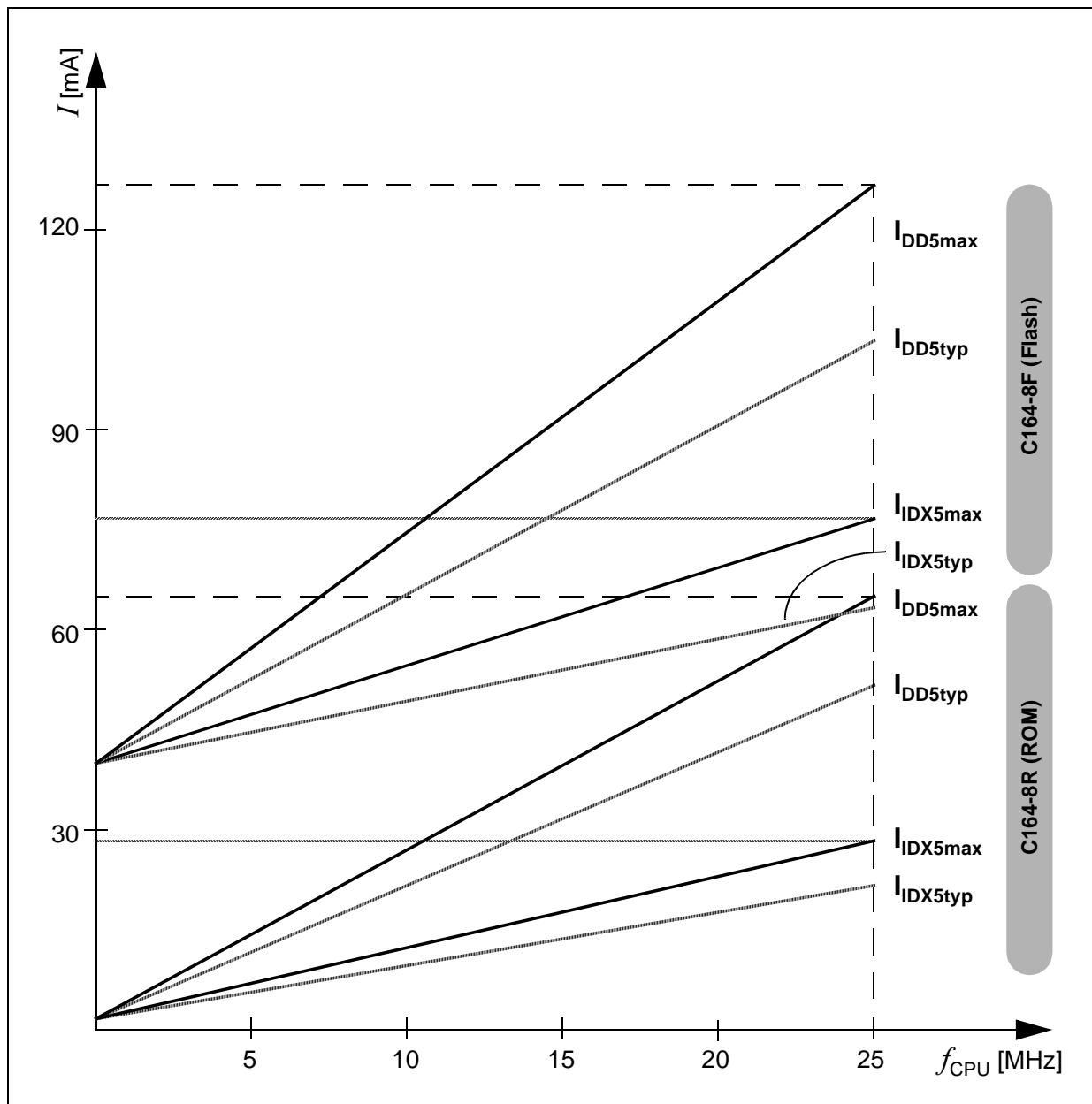


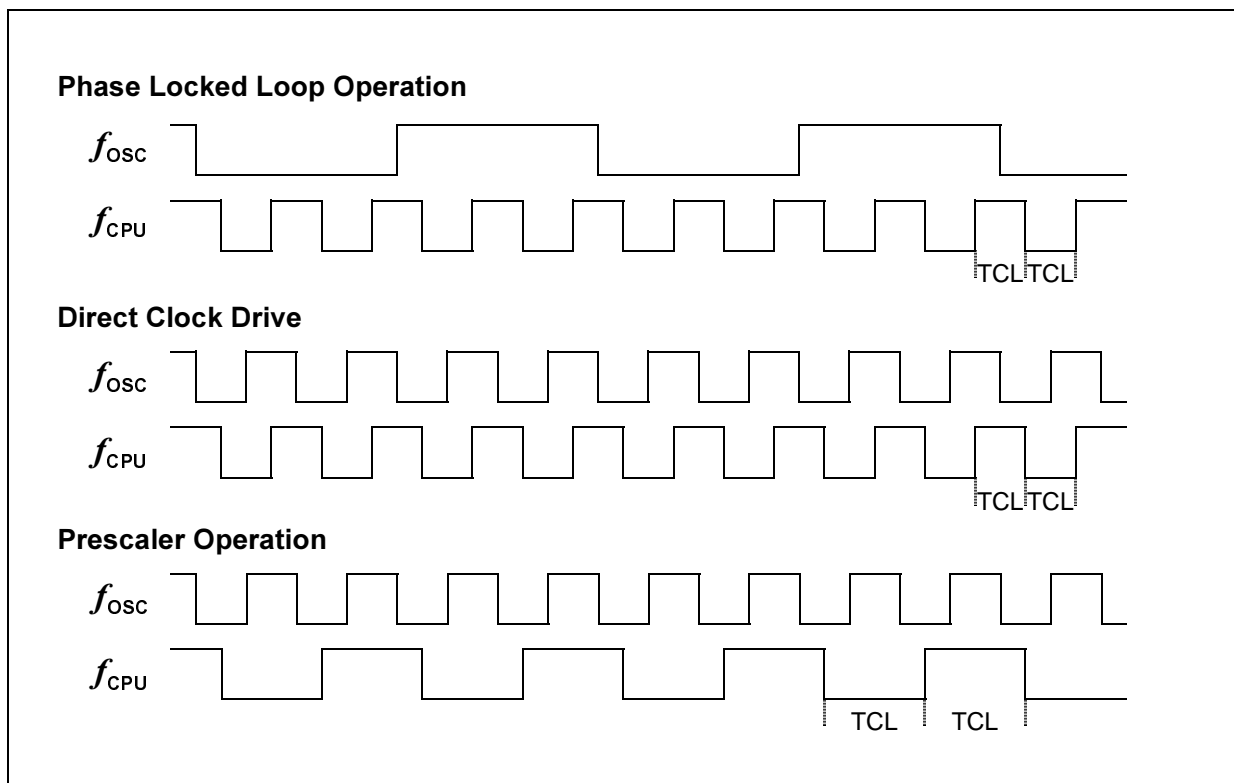
Figure 9 Supply/Idle Current as a Function of Operating Frequency



**AC Characteristics**  
**Definition of Internal Timing**

The internal operation of the C164 is controlled by the internal CPU clock  $f_{CPU}$ . Both edges of the CPU clock can trigger internal (e.g. pipeline) or external (e.g. bus cycles) operations.

The specification of the external timing (AC Characteristics) therefore depends on the time between two consecutive edges of the CPU clock, called "TCL" (see figure below).



**Figure 10 Generation Mechanisms for the CPU Clock**

The CPU clock signal  $f_{CPU}$  can be generated from the oscillator clock signal  $f_{OSC}$  via different mechanisms. The duration of TCLs and their variation (and also the derived external timing) depends on the used mechanism to generate  $f_{CPU}$ . This influence must be regarded when calculating the timings for the C164.

*Note: The example for PLL operation shown in the fig. above refers to a PLL factor of 4.*

The used mechanism to generate the CPU clock is selected during reset via the logic levels on pins P0.15-13 (P0H.7-5).

The table below associates the combinations of these three bits with the respective clock generation mode.

**Table 10 C164 Clock Generation Modes**

| P0.15-13 (P0H.7-5) | CPU Frequency<br>$f_{CPU} = f_{OSC} * F$ | External Clock Input Range <sup>1)</sup> | Notes                      |
|--------------------|--|--|----------------------------|
| 1 1 1              | $f_{OSC} * 4$                            | 2.5 to 6.25 MHz                          | Default configuration      |
| 1 1 0              | $f_{OSC} * 3$                            | 3.33 to 8.33 MHz                         |                            |
| 1 0 1              | $f_{OSC} * 2$                            | 5 to 12.5 MHz                            |                            |
| 1 0 0              | $f_{OSC} * 5$                            | 2 to 5 MHz                               |                            |
| 0 1 1              | $f_{OSC} * 1$                            | 1 to 25 MHz                              | Direct drive <sup>2)</sup> |
| 0 1 0              | $f_{OSC} * 1.5$                          | 6.66 to 16.6 MHz                         |                            |
| 0 0 1              | $f_{OSC} / 2$                            | 2 to 50 MHz                              | CPU clock via prescaler    |
| 0 0 0              | $f_{OSC} * 2.5$                          | 4 to 10 MHz                              |                            |

1) The external clock input range refers to a CPU clock range of 10...25 MHz.

2) The maximum frequency depends on the duty cycle of the external clock signal.

### Prescaler Operation

When pins P0.15-13 (P0H.7-5) equal 001<sub>B</sub> during reset the CPU clock is derived from the internal oscillator (input clock signal) by a 2:1 prescaler.

The frequency of  $f_{CPU}$  is half the frequency of  $f_{OSC}$  and the high and low time of  $f_{CPU}$  (i.e. the duration of an individual TCL) is defined by the period of the input clock  $f_{OSC}$ .

The timings listed in the AC Characteristics that refer to TCLs therefore can be calculated using the period of  $f_{OSC}$  for any TCL.

### Phase Locked Loop

For all combinations of pins P0.15-13 (P0H.7-5) except for 001<sub>B</sub> and 011<sub>B</sub> the on-chip phase locked loop is enabled and provides the CPU clock (see table above). The PLL multiplies the input frequency by the factor **F** which is selected via the combination of pins P0.15-13 (i.e.  $f_{CPU} = f_{OSC} * F$ ). With every **F**'th transition of  $f_{OSC}$  the PLL circuit synchronizes the CPU clock to the input clock. This synchronization is done smoothly, i.e. the CPU clock frequency does not change abruptly.

Due to this adaptation to the input clock the frequency of  $f_{CPU}$  is constantly adjusted so it is locked to  $f_{OSC}$ . The slight variation causes a jitter of  $f_{CPU}$  which also effects the duration of individual TCLs.

The timings listed in the AC Characteristics that refer to TCLs therefore must be calculated using the minimum TCL that is possible under the respective circumstances.

The actual minimum value for TCL depends on the jitter of the PLL. As the PLL is constantly adjusting its output frequency so it corresponds to the applied input frequency (crystal or oscillator) the relative deviation for periods of more than one TCL is lower than for one single TCL (see formula and figure below).

For a period of  $N * TCL$  the minimum value is computed using the corresponding deviation  $D_N$ :

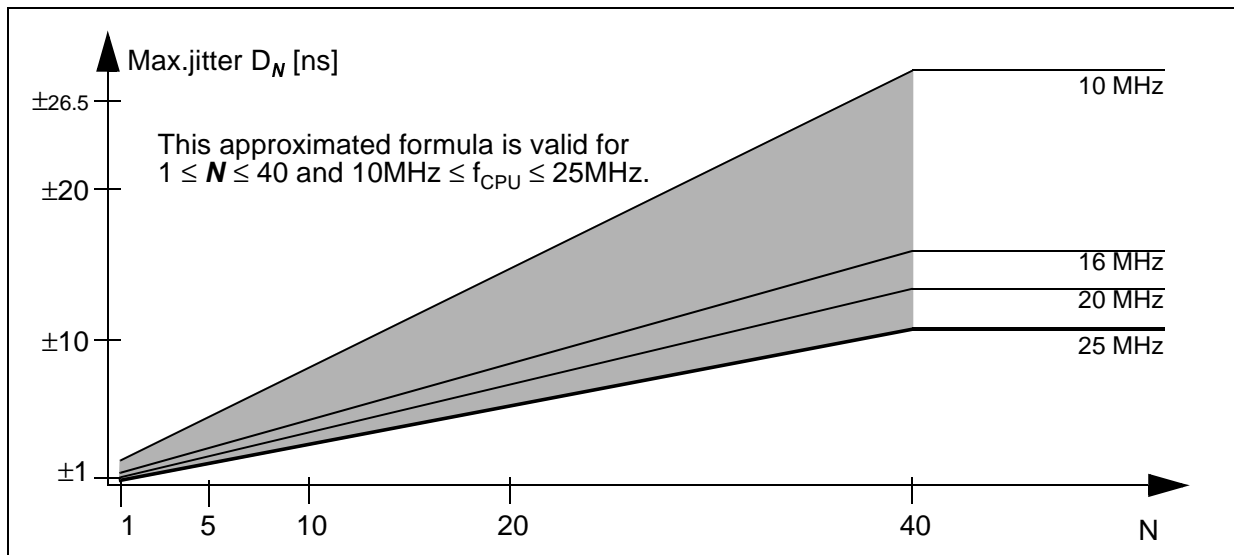
$$(N * TCL)_{\min} = N * TCL_{\text{NOM}} - D_N \quad D_N [\text{ns}] = \pm(13.3 + N*6.3) / f_{\text{CPU}} [\text{MHz}],$$

where  $N$  = number of consecutive TCLs and  $1 \leq N \leq 40$ .

So for a period of 3 TCLs @ 25 MHz (i.e.  $N = 3$ ):  $D_3 = (13.3 + 3 * 6.3) / 25 = 1.288 \text{ ns}$ , and  $(3TCL)_{\min} = 3TCL_{\text{NOM}} - 1.288 \text{ ns} = 58.7 \text{ ns}$  (@  $f_{\text{CPU}} = 25 \text{ MHz}$ ).

This is especially important for bus cycles using waitstates and e.g. for the operation of timers, serial interfaces, etc. For all slower operations and longer periods (e.g. pulse train generation or measurement, lower baudrates, etc.) the deviation caused by the PLL jitter is neglectable.

*Note: For all periods longer than 40 TCL the  $N=40$  value can be used (see figure below).*



**Figure 11**      **Approximated Maximum Accumulated PLL Jitter**

## Direct Drive

When pins P0.15-13 (P0H.7-5) equal 011<sub>B</sub> during reset the on-chip phase locked loop is disabled and the CPU clock is directly driven from the internal oscillator with the input clock signal.

The frequency of  $f_{\text{CPU}}$  directly follows the frequency of  $f_{\text{OSC}}$  so the high and low time of  $f_{\text{CPU}}$  (i.e. the duration of an individual TCL) is defined by the duty cycle of the input clock  $f_{\text{OSC}}$ .

The timings listed below that refer to TCLs therefore must be calculated using the minimum TCL that is possible under the respective circumstances. This minimum value can be calculated via the following formula:

$$\text{TCL}_{\min} = 1/f_{\text{OSC}} * \text{DC}_{\min} \quad (\text{DC} = \text{duty cycle})$$

For two consecutive TCLs the deviation caused by the duty cycle of  $f_{\text{OSC}}$  is compensated so the duration of 2TCL is always  $1/f_{\text{OSC}}$ . The minimum value  $\text{TCL}_{\min}$  therefore has to be used only once for timings that require an odd number of TCLs (1,3,...). Timings that require an even number of TCLs (2,4,...) may use the formula  $2\text{TCL} = 1/f_{\text{OSC}}$ .

*Note: The address float timings in Multiplexed bus mode ( $t_{11}$  and  $t_{45}$ ) use the maximum duration of TCL ( $\text{TCL}_{\max} = 1/f_{\text{OSC}} * \text{DC}_{\max}$ ) instead of  $\text{TCL}_{\min}$ .*

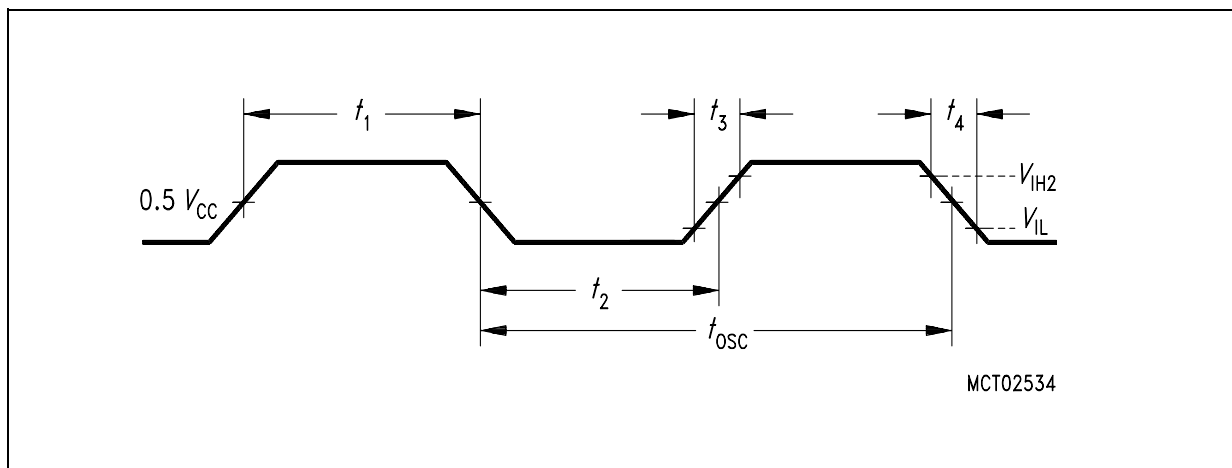
## AC Characteristics

### External Clock Drive XTAL1

(Operating Conditions apply)

| Parameter               | Symbol       | Direct Drive<br>1:1 |      | Prescaler<br>2:1 |      | PLL<br>1:N       |                   | Unit |
|-------------------------|--------------|---------------------|------|------------------|------|------------------|-------------------|------|
|                         |              | min.                | max. | min.             | max. | min.             | max.              |      |
| Oscillator period       | $t_{OSC}$ SR | 40                  | –    | 20               | –    | 60 <sup>1)</sup> | 500 <sup>1)</sup> | ns   |
| High time <sup>2)</sup> | $t_1$ SR     | 20 <sup>3)</sup>    | –    | 6                | –    | 10               | –                 | ns   |
| Low time <sup>2)</sup>  | $t_2$ SR     | 20 <sup>3)</sup>    | –    | 6                | –    | 10               | –                 | ns   |
| Rise time <sup>2)</sup> | $t_3$ SR     | –                   | 10   | –                | 6    | –                | 10                | ns   |
| Fall time <sup>2)</sup> | $t_4$ SR     | –                   | 10   | –                | 6    | –                | 10                | ns   |

- 1) The minimum and maximum oscillator periods for PLL operation depend on the selected CPU clock generation mode. Please see respective table above.
- 2) The clock input signal must reach the defined levels  $V_{IL}$  and  $V_{IH2}$ .
- 3) The minimum high and low time refers to a duty cycle of 50%. The maximum operating frequency ( $f_{CPU}$ ) in direct drive mode depends on the duty cycle of the clock input signal.



**Figure 12 External Clock Drive XTAL1**

*Note: The main oscillator is optimized for oscillation with a crystal within a frequency range of 4...16 MHz. When driven by an external clock signal it will accept the specified frequency range. Operation at lower input frequencies is possible but is guaranteed by design only (not 100% tested).*

*It is strongly recommended to measure the oscillation allowance (or margin) in the final target system (layout) to determine the optimum parameters for the oscillator operation.*

## A/D Converter Characteristics

(Operating Conditions apply)

$4.0\text{V} (2.6\text{V}) \leq V_{\text{AREF}} \leq V_{\text{DD}} + 0.1\text{V}$  (Note the influence on TUE.)

$V_{\text{SS}} - 0.1\text{V} \leq V_{\text{AGND}} \leq V_{\text{SS}} + 0.2\text{V}$

| Parameter                                       | Symbol               | Limit Values      |   | Unit       | Test Condition                              |
|---|----------------------|-------------------|---|------------|---|
|   |                      | min.              | max.  |            |   |
| Analog input voltage range                      | $V_{\text{AIN}}$ SR  | $V_{\text{AGND}}$ | $V_{\text{AREF}}$                                   | V          | 1)  |
| Basic clock frequency                           | $f_{\text{BC}}$      | 0.5               | 6.25  | MHz        | 2)  |
| Conversion time                                 | $t_{\text{C}}$ CC    | –                 | $40 t_{\text{BC}} + t_{\text{S}} + 2t_{\text{CPU}}$ |            | 3)<br>$t_{\text{CPU}} = 1 / f_{\text{CPU}}$ |
| Total unadjusted error                          | TUE CC<br>4)         | –                 | $\pm 2$   | LSB        | $V_{\text{AREF}} \geq 4.0\text{V}$          |
|   |                      | –                 | $\pm 4$   | LSB        | $V_{\text{AREF}} \geq 2.6\text{V}$          |
| Internal resistance of reference voltage source | $R_{\text{AREF}}$ SR | –                 | $t_{\text{BC}} / 60 - 0.25$                         | k $\Omega$ | $t_{\text{BC}}$ in [ns] <sup>5) 6)</sup>    |
| Internal resistance of analog source            | $R_{\text{ASRC}}$ SR | –                 | $t_{\text{S}} / 450 - 0.25$                         | k $\Omega$ | $t_{\text{S}}$ in [ns] <sup>6) 7)</sup>     |
| ADC input capacitance                           | $C_{\text{AIN}}$ CC  | –                 | 33  | pF         | 6)  |

1)  $V_{\text{AIN}}$  may exceed  $V_{\text{AGND}}$  or  $V_{\text{AREF}}$  up to the absolute maximum ratings. However, the conversion result in these cases will be X000<sub>H</sub> or X3FF<sub>H</sub>, respectively.

2) The limit values for  $f_{\text{BC}}$  must not be exceeded when selecting the CPU frequency and the ADCTC setting.

3) This parameter includes the sample time  $t_{\text{S}}$ , the time for determining the digital result and the time to load the result register with the conversion result.

Values for the basic clock  $t_{\text{BC}}$  depend on the conversion time programming.

This parameter depends on the ADC control logic. It is not a real maximum value, but rather a fixum.

4) TUE is tested at  $V_{\text{AREF}}=5.0\text{V}$  (3.3V),  $V_{\text{AGND}}=0\text{V}$ ,  $V_{\text{DD}}=4.9\text{V}$  (3.2V). It is guaranteed by design for all other voltages within the defined voltage range.

The specified TUE is guaranteed only if an overload condition (see  $I_{\text{OV}}$  specification) occurs on maximum 2 not selected analog input pins and the absolute sum of input overload currents on all analog input pins does not exceed 10 mA.

During the reset calibration sequence the maximum TUE may be  $\pm 4$  LSB ( $\pm 8$  LSB @ 3V).

5) During the conversion the ADC's capacitance must be repeatedly charged or discharged. The internal resistance of the reference voltage source must allow the capacitance to reach its respective voltage level within each conversion step. The maximum internal resistance results from the programmed conversion timing.

6) Not 100% tested, guaranteed by design.

7) During the sample time the input capacitance  $C_{\text{I}}$  can be charged/discharged by the external source. The internal resistance of the analog source must allow the capacitance to reach its final voltage level within  $t_{\text{S}}$ . After the end of the sample time  $t_{\text{S}}$ , changes of the analog input voltage have no effect on the conversion result. Values for the sample time  $t_{\text{S}}$  depend on programming and can be taken from the table below.

Sample time and conversion time of the C164's A/D Converter are programmable. The table below should be used to calculate the above timings.

The limit values for  $f_{BC}$  must not be exceeded when selecting ADCTC.

**Table 11 A/D Converter Computation Table**

| ADCON.15 14<br>(ADCTC) | A/D Converter<br>Basic clock $f_{BC}$ | ADCON.13 12<br>(ADSTC) | Sample time<br>$t_S$ |
|------------------------|---------------------------------------|------------------------|----------------------|
| 00                     | $f_{CPU} / 4$                         | 00                     | $t_{BC} * 8$         |
| 01                     | $f_{CPU} / 2$                         | 01                     | $t_{BC} * 16$        |
| 10                     | $f_{CPU} / 16$                        | 10                     | $t_{BC} * 32$        |
| 11                     | $f_{CPU} / 8$                         | 11                     | $t_{BC} * 64$        |

**Converter Timing Example:**

Assumptions:  $f_{CPU} = 25$  MHz (i.e.  $t_{CPU} = 40$  ns), ADCTC = '00', ADSTC = '00'.

Basic clock  $f_{BC} = f_{CPU} / 4 = 6.25$  MHz, i.e.  $t_{BC} = 160$  ns.

Sample time  $t_S = t_{BC} * 8 = 1280$  ns.

Conversion time  $t_C = t_S + 40 t_{BC} + 2 t_{CPU} = (1280 + 6400 + 80)$  ns = 7.8  $\mu$ s.

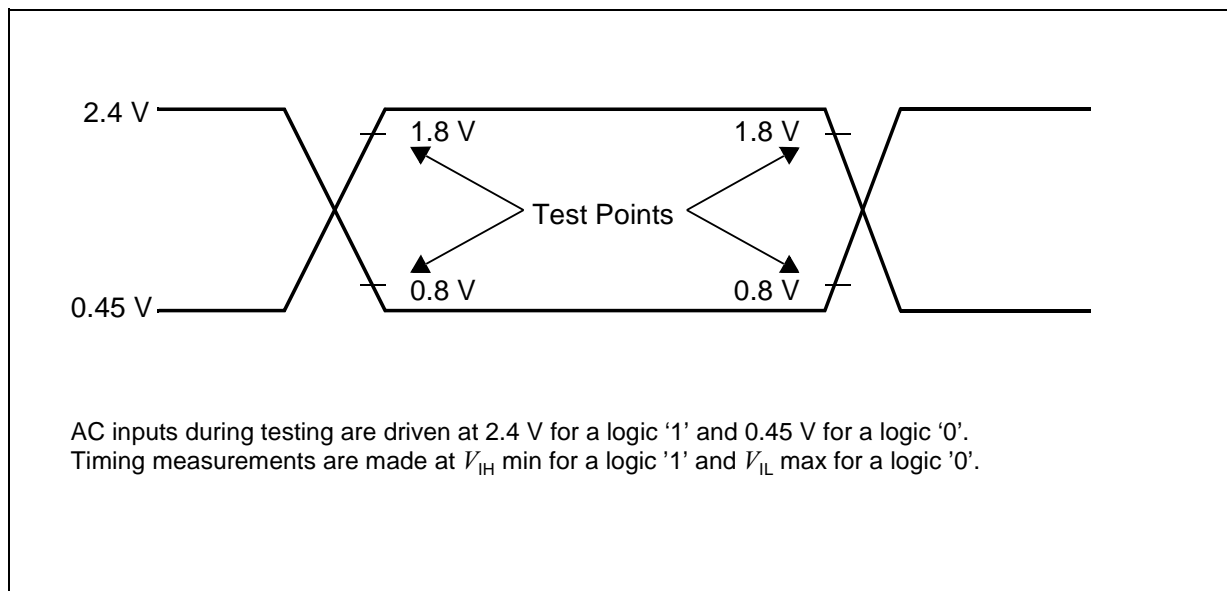
**Memory Cycle Variables**

The timing tables below use three variables which are derived from the BUSCONx registers and represent the special characteristics of the programmed memory cycle. The following table describes, how these variables are to be computed.

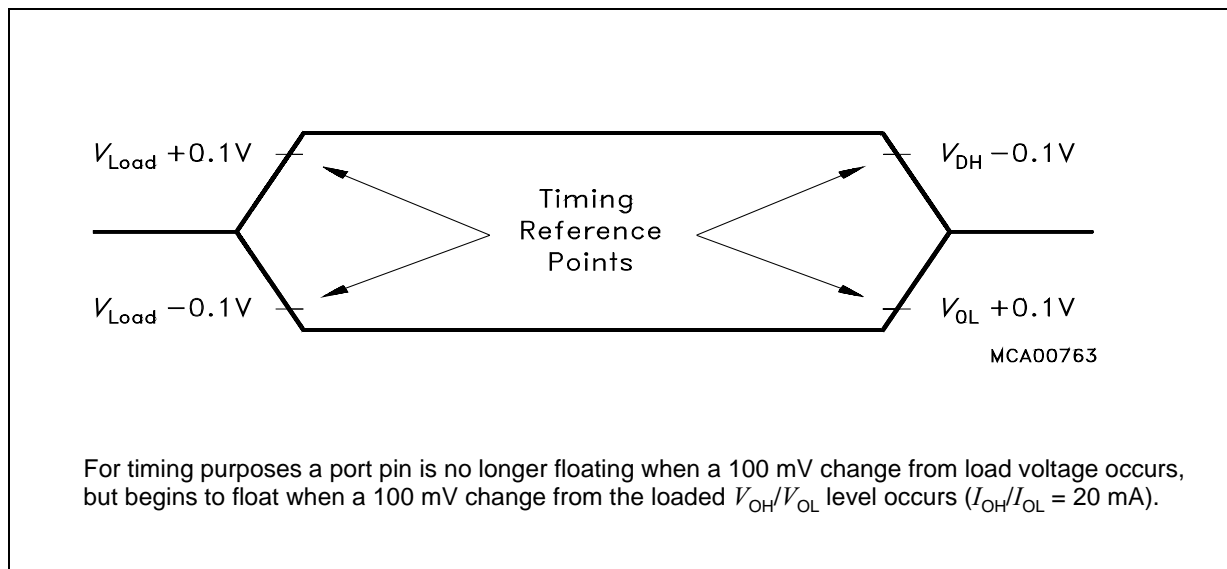
**Table 12 Memory Cycle Variables**

| Description                  | Symbol | Values                               |
|------------------------------|--------|--------------------------------------|
| ALE Extension                | $t_A$  | $TCL * \langle ALECTL \rangle$       |
| Memory Cycle Time Waitstates | $t_C$  | $2TCL * (15 - \langle MCTC \rangle)$ |
| Memory Tristate Time         | $t_F$  | $2TCL * (1 - \langle MTTC \rangle)$  |

### Testing Waveforms



**Figure 13** Input Output Waveforms



**Figure 14** Float Waveforms



**AC Characteristics**
**Multiplexed Bus**

(Operating Conditions apply)

 ALE cycle time =  $6 \text{ TCL} + 2t_A + t_C + t_F$  (120 ns at 25 MHz CPU clock without waitstates)

| Parameter  | Symbol      | Max. CPU Clock<br>= 25 MHz |                   | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |                                 | Unit |
|--|-------------|----------------------------|-------------------|--|---------------------------------|------|
|  |             | min.                       | max.              | min.   | max.                            |      |
| ALE high time  | $t_5$ CC    | $10 + t_A$                 | –                 | $\text{TCL} - 10 + t_A$                      | –                               | ns   |
| Address setup to ALE   | $t_6$ CC    | $4 + t_A$                  | –                 | $\text{TCL} - 16 + t_A$                      | –                               | ns   |
| Address hold after ALE   | $t_7$ CC    | $10 + t_A$                 | –                 | $\text{TCL} - 10 + t_A$                      | –                               | ns   |
| ALE falling edge to $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (with RW-delay) | $t_8$ CC    | $10 + t_A$                 | –                 | $\text{TCL} - 10 + t_A$                      | –                               | ns   |
| ALE falling edge to $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (no RW-delay)   | $t_9$ CC    | $-10 + t_A$                | –                 | $-10 + t_A$                                  | –                               | ns   |
| Address float after $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (with RW-delay) | $t_{10}$ CC | –                          | 6                 | –  | 6                               | ns   |
| Address float after $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (no RW-delay)   | $t_{11}$ CC | –                          | 26                | –  | $\text{TCL} + 6$                | ns   |
| $\overline{\text{RD}}$ , $\overline{\text{WR}}$ low time<br>(with RW-delay)            | $t_{12}$ CC | $30 + t_C$                 | –                 | $2\text{TCL} - 10 + t_C$                     | –                               | ns   |
| $\overline{\text{RD}}$ , $\overline{\text{WR}}$ low time<br>(no RW-delay)              | $t_{13}$ CC | $50 + t_C$                 | –                 | $3\text{TCL} - 10 + t_C$                     | –                               | ns   |
| $\overline{\text{RD}}$ to valid data in<br>(with RW-delay)                             | $t_{14}$ SR | –                          | $20 + t_C$        | –  | $2\text{TCL} - 20 + t_C$        | ns   |
| $\overline{\text{RD}}$ to valid data in<br>(no RW-delay)                               | $t_{15}$ SR | –                          | $40 + t_C$        | –  | $3\text{TCL} - 20 + t_C$        | ns   |
| ALE low to valid data in   | $t_{16}$ SR | –                          | $40 + t_A + t_C$  | –  | $3\text{TCL} - 20 + t_A + t_C$  | ns   |
| Address to valid data in   | $t_{17}$ SR | –                          | $50 + 2t_A + t_C$ | –  | $4\text{TCL} - 30 + 2t_A + t_C$ | ns   |
| Data hold after $\overline{\text{RD}}$<br>rising edge                                  | $t_{18}$ SR | 0                          | –                 | 0  | –                               | ns   |
| Data float after $\overline{\text{RD}}$  | $t_{19}$ SR | –                          | $26 + t_F$        | –  | $2\text{TCL} - 14 + t_F$        | ns   |

**Multiplexed Bus (continued)**

(Operating Conditions apply)

 ALE cycle time =  $6\text{ TCL} + 2t_A + t_C + t_F$  (120 ns at 25 MHz CPU clock without waitstates)

| Parameter   | Symbol      | Max. CPU Clock<br>= 25 MHz |                   | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |                                 | Unit |
|---|-------------|----------------------------|-------------------|--|---------------------------------|------|
|   |             | min.                       | max.              | min.   | max.                            |      |
| Data valid to $\overline{\text{WR}}$  | $t_{22}$ CC | $20 + t_C$                 | –                 | $2\text{TCL} - 20 + t_C$                     | –                               | ns   |
| Data hold after $\overline{\text{WR}}$  | $t_{23}$ CC | $26 + t_F$                 | –                 | $2\text{TCL} - 14 + t_F$                     | –                               | ns   |
| ALE rising edge after $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$                        | $t_{25}$ CC | $26 + t_F$                 | –                 | $2\text{TCL} - 14 + t_F$                     | –                               | ns   |
| Address hold after $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$                           | $t_{27}$ CC | $26 + t_F$                 | –                 | $2\text{TCL} - 14 + t_F$                     | –                               | ns   |
| ALE falling edge to $\overline{\text{CS}}$ <sup>1)</sup>  | $t_{38}$ CC | $-4 - t_A$                 | $10 - t_A$        | $-4 - t_A$                                   | $10 - t_A$                      | ns   |
| $\overline{\text{CS}}$ low to Valid Data In <sup>1)</sup>                                       | $t_{39}$ SR | –                          | $40 + t_C + 2t_A$ | –  | $3\text{TCL} - 20 + t_C + 2t_A$ | ns   |
| $\overline{\text{CS}}$ hold after $\overline{\text{RD}}$ , $\overline{\text{WR}}$ <sup>1)</sup> | $t_{40}$ CC | $46 + t_F$                 | –                 | $3\text{TCL} - 14 + t_F$                     | –                               | ns   |
| ALE fall. edge to $\overline{\text{RdCS}}$ ,<br>$\overline{\text{WrCS}}$ (with RW delay)        | $t_{42}$ CC | $16 + t_A$                 | –                 | $\text{TCL} - 4 + t_A$                       | –                               | ns   |
| ALE fall. edge to $\overline{\text{RdCS}}$ ,<br>$\overline{\text{WrCS}}$ (no RW delay)          | $t_{43}$ CC | $-4 + t_A$                 | –                 | $-4 + t_A$                                   | –                               | ns   |
| Address float after $\overline{\text{RdCS}}$ ,<br>$\overline{\text{WrCS}}$ (with RW delay)      | $t_{44}$ CC | –                          | 0                 | –  | 0                               | ns   |
| Address float after $\overline{\text{RdCS}}$ ,<br>$\overline{\text{WrCS}}$ (no RW delay)        | $t_{45}$ CC | –                          | 20                | –  | TCL                             | ns   |
| $\overline{\text{RdCS}}$ to Valid Data In<br>(with RW delay)                                    | $t_{46}$ SR | –                          | $16 + t_C$        | –  | $2\text{TCL} - 24 + t_C$        | ns   |
| $\overline{\text{RdCS}}$ to Valid Data In<br>(no RW delay)                                      | $t_{47}$ SR | –                          | $36 + t_C$        | –  | $3\text{TCL} - 24 + t_C$        | ns   |
| $\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ Low Time<br>(with RW delay)                 | $t_{48}$ CC | $30 + t_C$                 | –                 | $2\text{TCL} - 10 + t_C$                     | –                               | ns   |
| $\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ Low Time<br>(no RW delay)                   | $t_{49}$ CC | $50 + t_C$                 | –                 | $3\text{TCL} - 10 + t_C$                     | –                               | ns   |

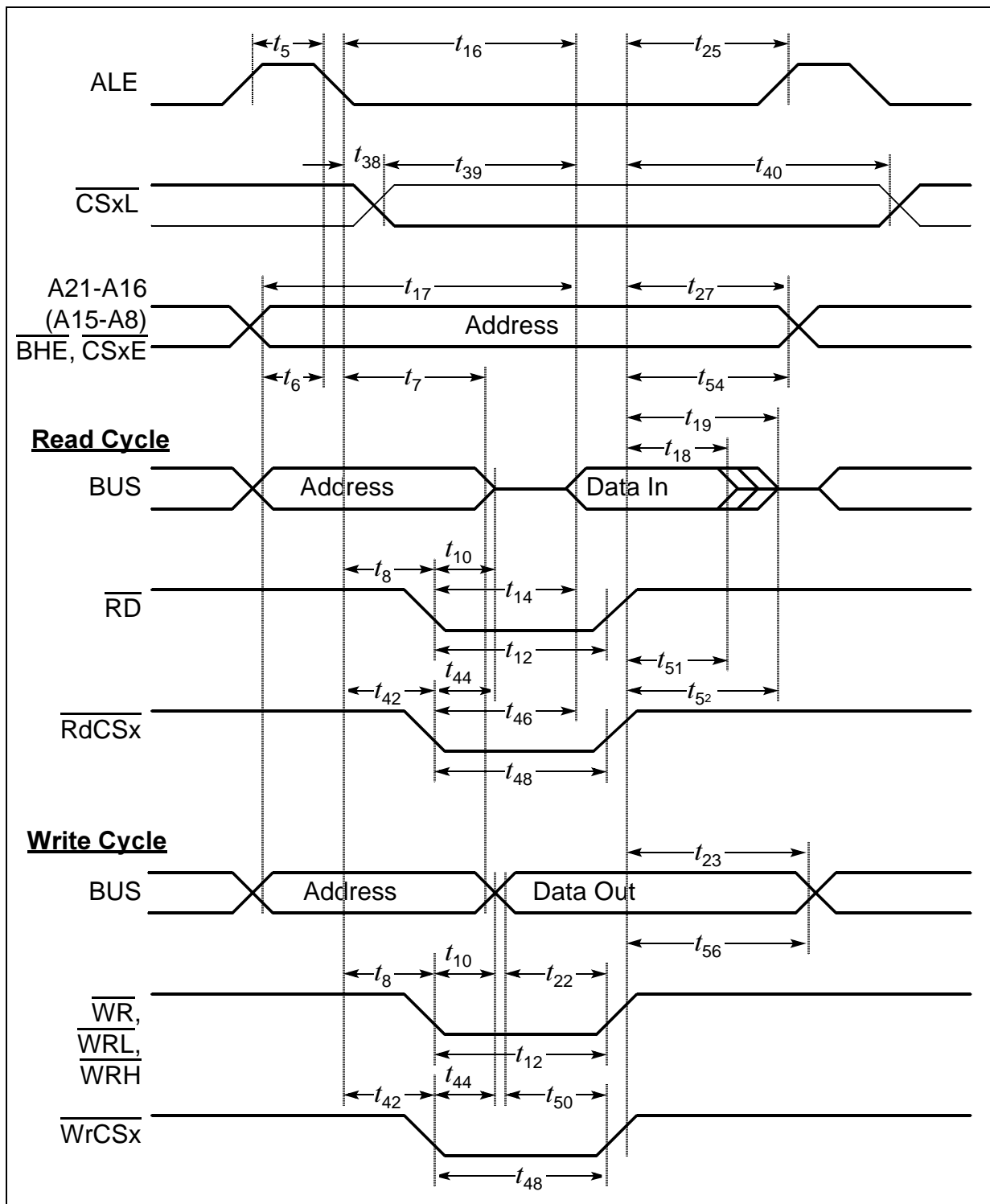
**Multiplexed Bus (continued)**

(Operating Conditions apply)

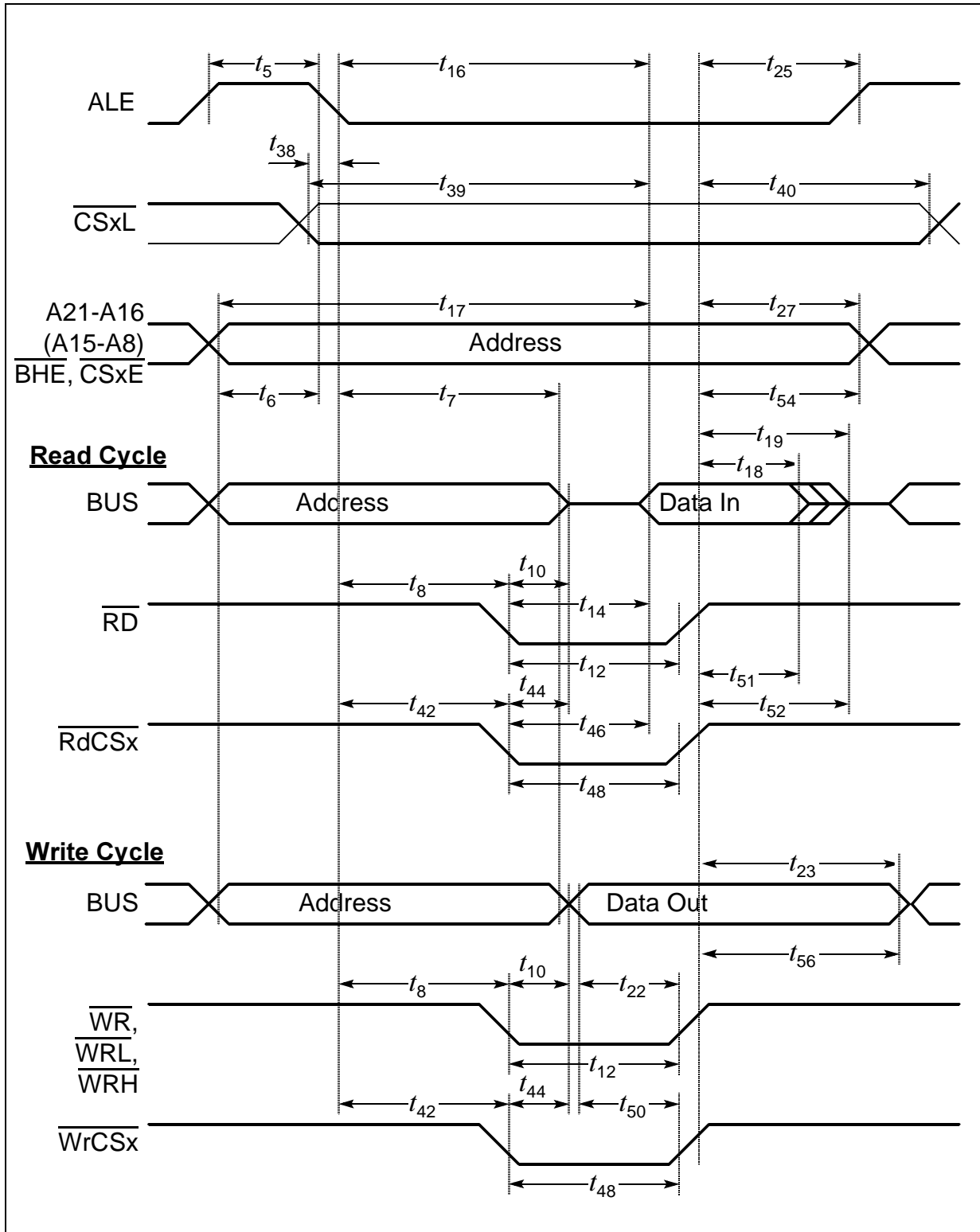
 ALE cycle time =  $6 \text{ TCL} + 2t_A + t_C + t_F$  (120 ns at 25 MHz CPU clock without waitstates)

| Parameter   | Symbol   |    | Max. CPU Clock<br>= 25 MHz |            | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |                          | Unit |
|---|----------|----|----------------------------|------------|--|--------------------------|------|
|   |          |    | min.                       | max.       | min.   | max.                     |      |
| Data valid to $\overline{\text{WrCS}}$                              | $t_{50}$ | CC | $26 + t_C$                 | –          | $2\text{TCL} - 14 + t_C$                     | –                        | ns   |
| Data hold after $\overline{\text{RdCS}}$                            | $t_{51}$ | SR | 0                          | –          | 0  | –                        | ns   |
| Data float after $\overline{\text{RdCS}}$                           | $t_{52}$ | SR | –                          | $20 + t_F$ | –  | $2\text{TCL} - 20 + t_F$ | ns   |
| Address hold after $\overline{\text{RdCS}}, \overline{\text{WrCS}}$ | $t_{54}$ | CC | $20 + t_F$                 | –          | $2\text{TCL} - 20 + t_F$                     | –                        | ns   |
| Data hold after $\overline{\text{WrCS}}$                            | $t_{56}$ | CC | $20 + t_F$                 | –          | $2\text{TCL} - 20 + t_F$                     | –                        | ns   |

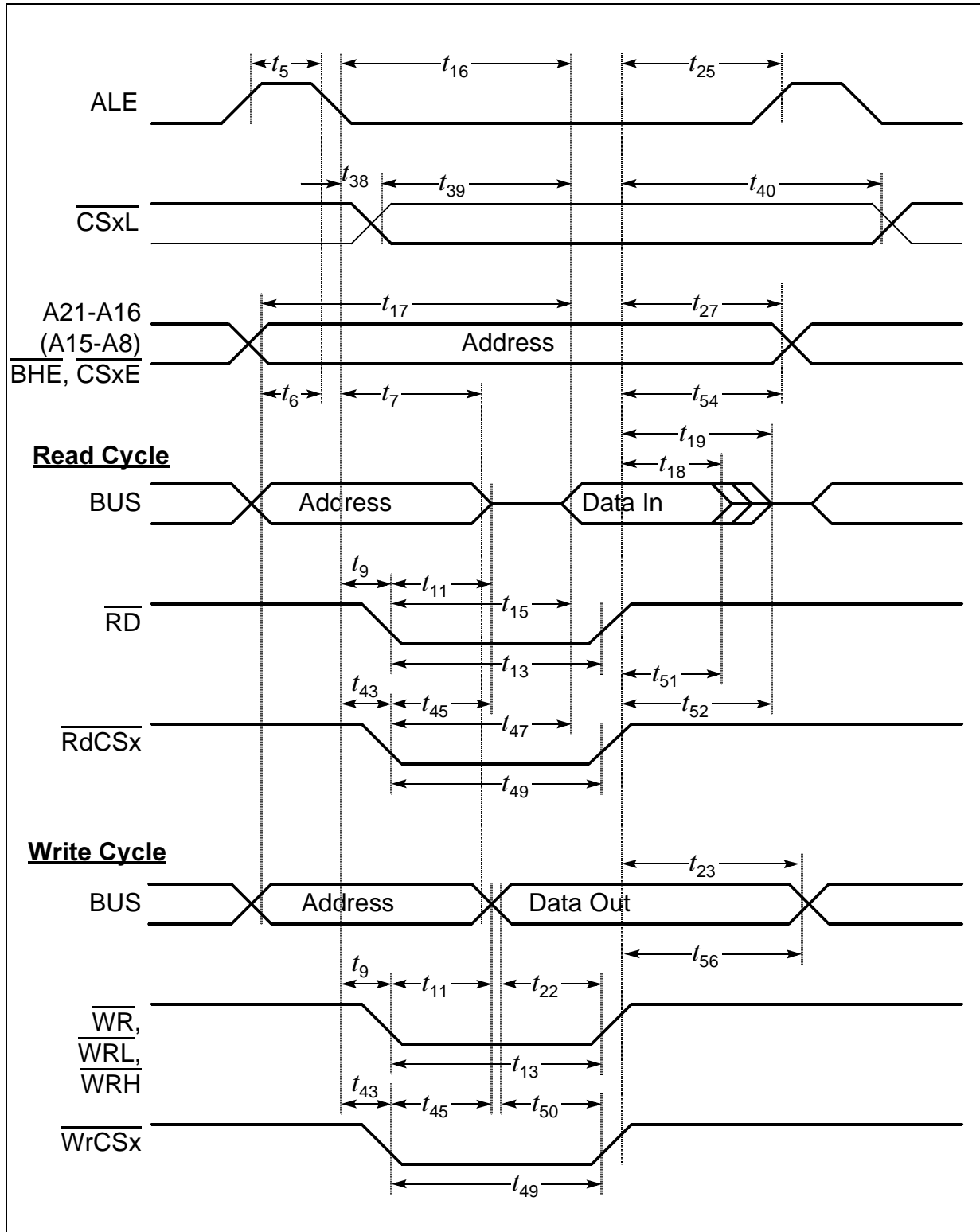
 1) These parameters refer to the latched chip select signals ( $\overline{\text{CSxL}}$ ). The early chip select signals ( $\overline{\text{CSxE}}$ ) are specified together with the address and signal BHE (see figures below).



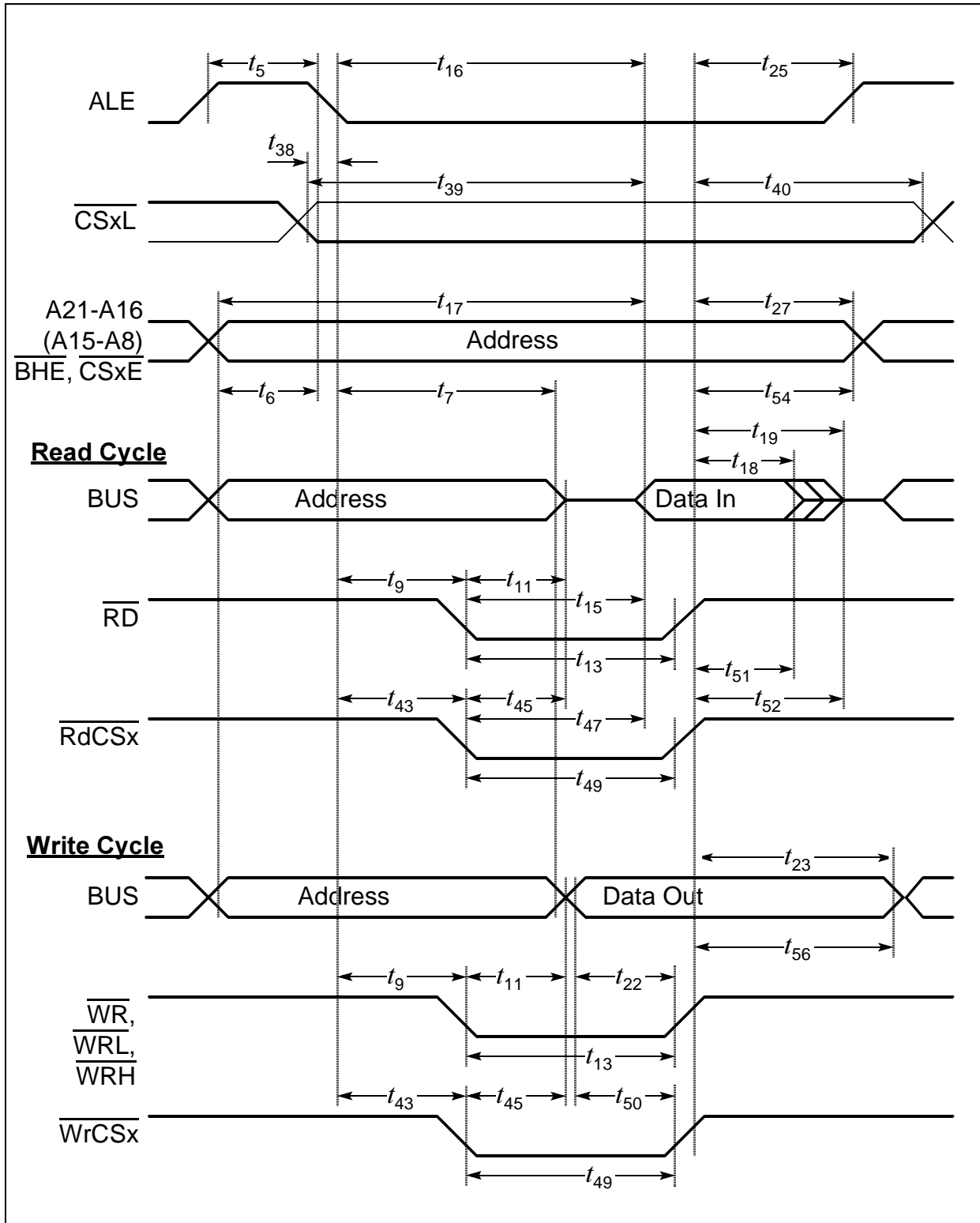
**Figure 15 External Memory Cycle: Multiplexed Bus, With Read/Write Delay, Normal ALE**



**Figure 16 External Memory Cycle: Multiplexed Bus, With Read/Write Delay, Extended ALE**



**Figure 17 External Memory Cycle: Multiplexed Bus, No Read/Write Delay, Normal ALE**



**Figure 18 External Memory Cycle: Multiplexed Bus, No Read/Write Delay, Extended ALE**

**AC Characteristics**
**Demultiplexed Bus**

(Operating Conditions apply)

 ALE cycle time =  $4 \text{ TCL} + 2t_A + t_C + t_F$  (80 ns at 25 MHz CPU clock without waitstates)

| Parameter  | Symbol   |    | Max. CPU Clock<br>= 25 MHz |                                    | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |   | Unit |
|--|----------|----|----------------------------|------------------------------------|--|---|------|
|  |          |    | min.                       | max.                               | min.   | max.  |      |
| ALE high time  | $t_5$    | CC | $10 + t_A$                 | –                                  | TCL - 10<br>+ $t_A$                          | –   | ns   |
| Address setup to ALE   | $t_6$    | CC | $4 + t_A$                  | –                                  | TCL - 16<br>+ $t_A$                          | –   | ns   |
| ALE falling edge to $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (with RW-delay) | $t_8$    | CC | $10 + t_A$                 | –                                  | TCL - 10<br>+ $t_A$                          | –   | ns   |
| ALE falling edge to $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$ (no RW-delay)   | $t_9$    | CC | $-10 + t_A$                | –                                  | -10<br>+ $t_A$                               | –   | ns   |
| $\overline{\text{RD}}$ , $\overline{\text{WR}}$ low time<br>(with RW-delay)            | $t_{12}$ | CC | $30 + t_C$                 | –                                  | 2TCL - 10<br>+ $t_C$                         | –   | ns   |
| $\overline{\text{RD}}$ , $\overline{\text{WR}}$ low time<br>(no RW-delay)              | $t_{13}$ | CC | $50 + t_C$                 | –                                  | 3TCL - 10<br>+ $t_C$                         | –   | ns   |
| $\overline{\text{RD}}$ to valid data in<br>(with RW-delay)                             | $t_{14}$ | SR | –                          | $20 + t_C$                         | –  | 2TCL - 20<br>+ $t_C$                          | ns   |
| $\overline{\text{RD}}$ to valid data in<br>(no RW-delay)                               | $t_{15}$ | SR | –                          | $40 + t_C$                         | –  | 3TCL - 20<br>+ $t_C$                          | ns   |
| ALE low to valid data in   | $t_{16}$ | SR | –                          | $40 + t_A + t_C$                   | –  | 3TCL - 20<br>+ $t_A + t_C$                    | ns   |
| Address to valid data in   | $t_{17}$ | SR | –                          | $50 + 2t_A + t_C$                  | –  | 4TCL - 30<br>+ $2t_A + t_C$                   | ns   |
| Data hold after $\overline{\text{RD}}$<br>rising edge                                  | $t_{18}$ | SR | 0                          | –                                  | 0  | –   | ns   |
| Data float after $\overline{\text{RD}}$ rising<br>edge (with RW-delay <sup>1)</sup> )  | $t_{20}$ | SR | –                          | $26 + 2t_A + t_F$<br><sup>1)</sup> | –  | 2TCL - 14<br>+ $22t_A + t_F$<br><sup>1)</sup> | ns   |
| Data float after $\overline{\text{RD}}$ rising<br>edge (no RW-delay <sup>1)</sup> )    | $t_{21}$ | SR | –                          | $10 + 2t_A + t_F$<br><sup>1)</sup> | –  | TCL - 10<br>+ $22t_A + t_F$<br><sup>1)</sup>  | ns   |
| Data valid to $\overline{\text{WR}}$   | $t_{22}$ | CC | $20 + t_C$                 | –                                  | 2TCL - 20<br>+ $t_C$                         | –   | ns   |



**Demultiplexed Bus (continued)**

(Operating Conditions apply)

 ALE cycle time =  $4 \text{ TCL} + 2t_A + t_C + t_F$  (80 ns at 25 MHz CPU clock without waitstates)

| Parameter   | Symbol      | Max. CPU Clock<br>= 25 MHz |                   | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |   | Unit |
|---|-------------|----------------------------|-------------------|--|---|------|
|   |             | min.                       | max.              | min.   | max.  |      |
| Data hold after $\overline{\text{WR}}$  | $t_{24}$ CC | $10 + t_F$                 | –                 | $\text{TCL} - 10 + t_F$                      | –   | ns   |
| ALE rising edge after $\overline{\text{RD}}$ ,<br>$\overline{\text{WR}}$                        | $t_{26}$ CC | $-10 + t_F$                | –                 | $-10 + t_F$                                  | –   | ns   |
| Address hold after $\overline{\text{WR}}$ <sup>2)</sup>   | $t_{28}$ CC | $0 + t_F$                  | –                 | $0 + t_F$                                    | –   | ns   |
| ALE falling edge to $\overline{\text{CS}}$ <sup>3)</sup>  | $t_{38}$ CC | $-4 - t_A$                 | $10 - t_A$        | $-4 - t_A$                                   | $10 - t_A$                                    | ns   |
| $\overline{\text{CS}}$ low to Valid Data In <sup>3)</sup>                                       | $t_{39}$ SR | –                          | $40 + t_C + 2t_A$ | –  | $3\text{TCL} - 20 + t_C + 2t_A$               | ns   |
| $\overline{\text{CS}}$ hold after $\overline{\text{RD}}$ , $\overline{\text{WR}}$ <sup>3)</sup> | $t_{41}$ CC | $6 + t_F$                  | –                 | $\text{TCL} - 14 + t_F$                      | –   | ns   |
| ALE falling edge to<br>$\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ (with RW-<br>delay)  | $t_{42}$ CC | $16 + t_A$                 | –                 | $\text{TCL} - 4 + t_A$                       | –   | ns   |
| ALE falling edge to<br>$\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ (no RW-<br>delay)    | $t_{43}$ CC | $-4 + t_A$                 | –                 | $-4 + t_A$                                   | –   | ns   |
| $\overline{\text{RdCS}}$ to Valid Data In<br>(with RW-delay)                                    | $t_{46}$ SR | –                          | $16 + t_C$        | –  | $2\text{TCL} - 24 + t_C$                      | ns   |
| $\overline{\text{RdCS}}$ to Valid Data In<br>(no RW-delay)                                      | $t_{47}$ SR | –                          | $36 + t_C$        | –  | $3\text{TCL} - 24 + t_C$                      | ns   |
| $\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ Low Time<br>(with RW-delay)                 | $t_{48}$ CC | $30 + t_C$                 | –                 | $2\text{TCL} - 10 + t_C$                     | –   | ns   |
| $\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ Low Time<br>(no RW-delay)                   | $t_{49}$ CC | $50 + t_C$                 | –                 | $3\text{TCL} - 10 + t_C$                     | –   | ns   |
| Data valid to $\overline{\text{WrCS}}$  | $t_{50}$ CC | $26 + t_C$                 | –                 | $2\text{TCL} - 14 + t_C$                     | –   | ns   |
| Data hold after $\overline{\text{RdCS}}$  | $t_{51}$ SR | 0                          | –                 | 0  | –   | ns   |
| Data float after $\overline{\text{RdCS}}$<br>(with RW-delay) <sup>1)</sup>                      | $t_{53}$ SR | –                          | $20 + t_F$        | –  | $2\text{TCL} - 20 + 2t_A + t_F$ <sup>1)</sup> | ns   |
| Data float after $\overline{\text{RdCS}}$<br>(no RW-delay) <sup>1)</sup>                        | $t_{68}$ SR | –                          | $0 + t_F$         | –  | $\text{TCL} - 20 + 2t_A + t_F$ <sup>1)</sup>  | ns   |

**Demultiplexed Bus (continued)**

(Operating Conditions apply)

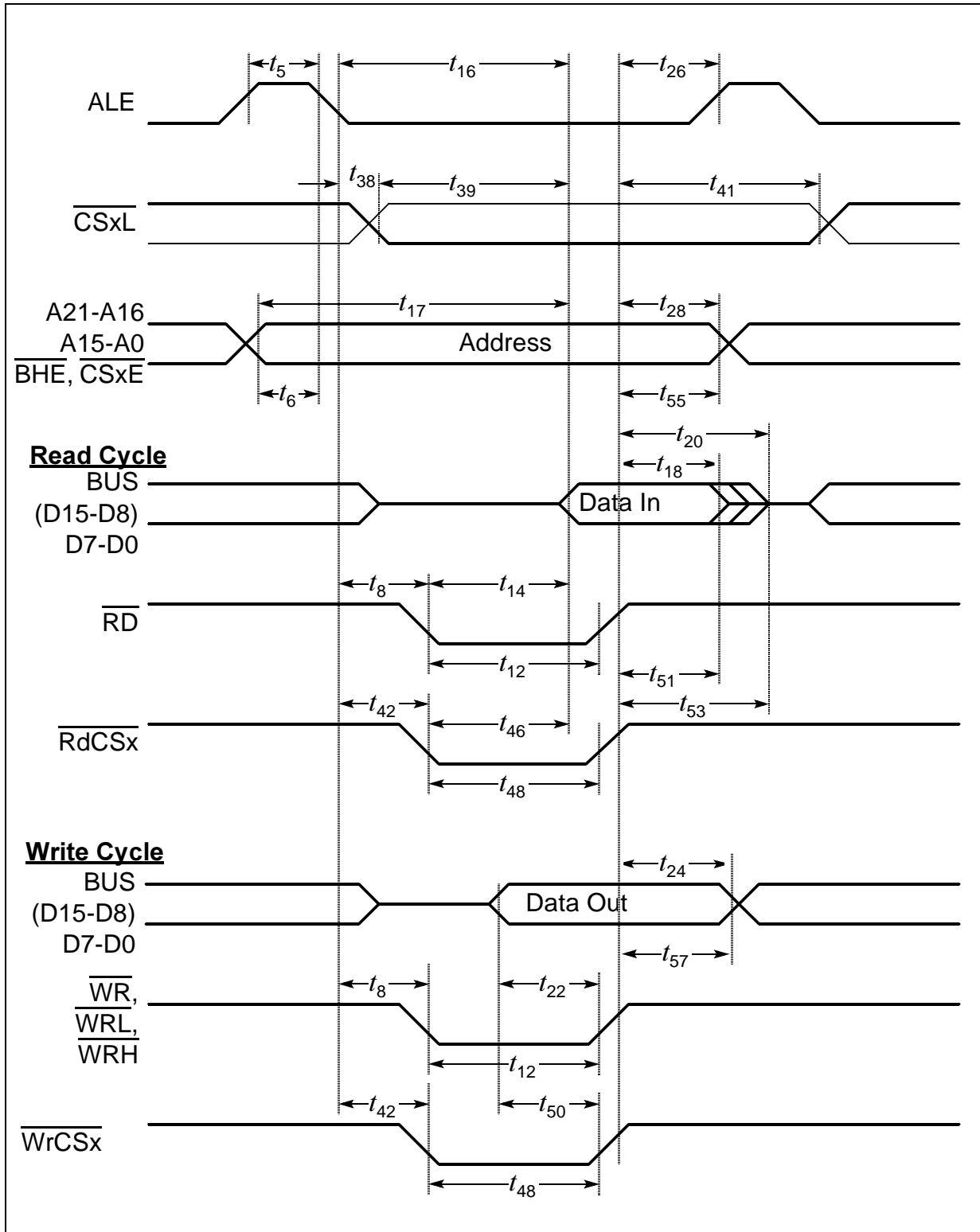
ALE cycle time =  $4 \text{ TCL} + 2t_A + t_C + t_F$  (80 ns at 25 MHz CPU clock without waitstates)

| Parameter  | Symbol      | Max. CPU Clock<br>= 25 MHz |      | Variable CPU Clock<br>1 / 2TCL = 1 to 25 MHz |      | Unit |
|--|-------------|----------------------------|------|--|------|------|
|  |             | min.                       | max. | min.   | max. |      |
| Address hold after $\overline{\text{RdCS}}$ , $\overline{\text{WrCS}}$ | $t_{55}$ CC | $-6 + t_F$                 | –    | $-6 + t_F$                                   | –    | ns   |
| Data hold after $\overline{\text{WrCS}}$                               | $t_{57}$ CC | $6 + t_F$                  | –    | $\text{TCL} - 14 + t_F$                      | –    | ns   |

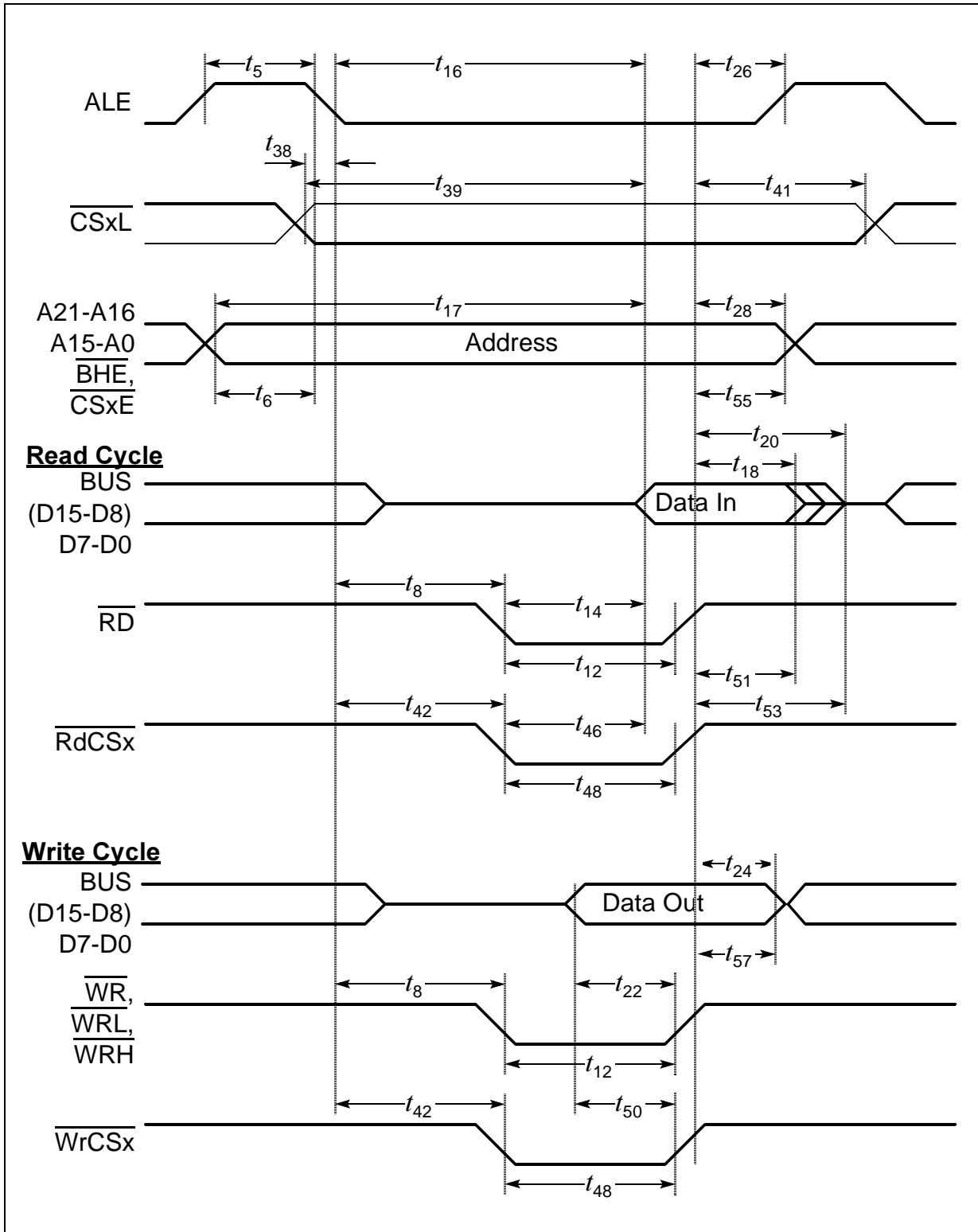
1) RW-delay and  $t_A$  refer to the next following bus cycle (including an access to an on-chip X-Peripheral).

2) Read data are latched with the same clock edge that triggers the address change and the rising  $\overline{\text{RD}}$  edge. Therefore address changes before the end of  $\overline{\text{RD}}$  have no impact on read cycles.

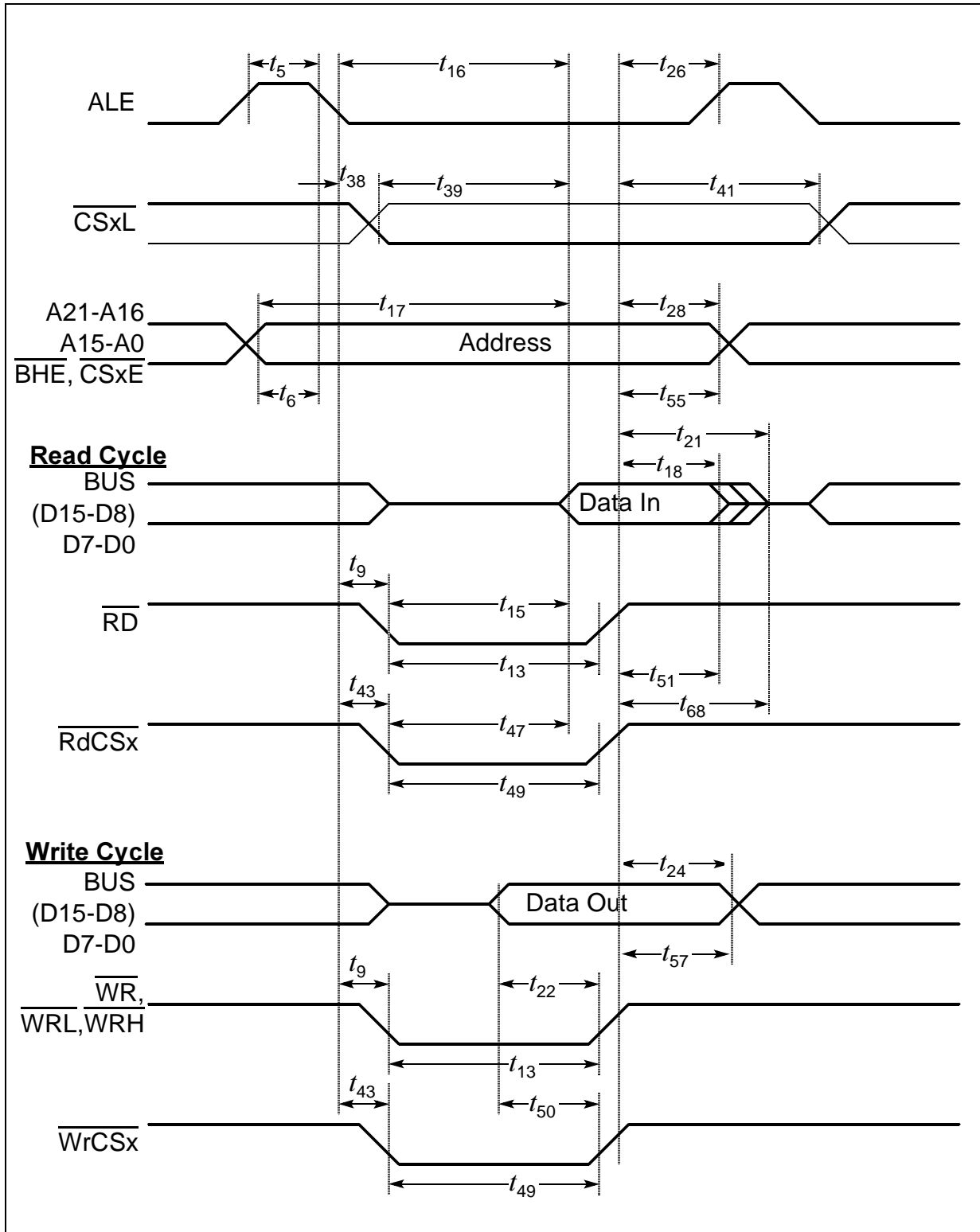
3) These parameters refer to the latched chip select signals ( $\overline{\text{CSxL}}$ ). The early chip select signals ( $\overline{\text{CSxE}}$ ) are specified together with the address and signal  $\overline{\text{BHE}}$  (see figures below).



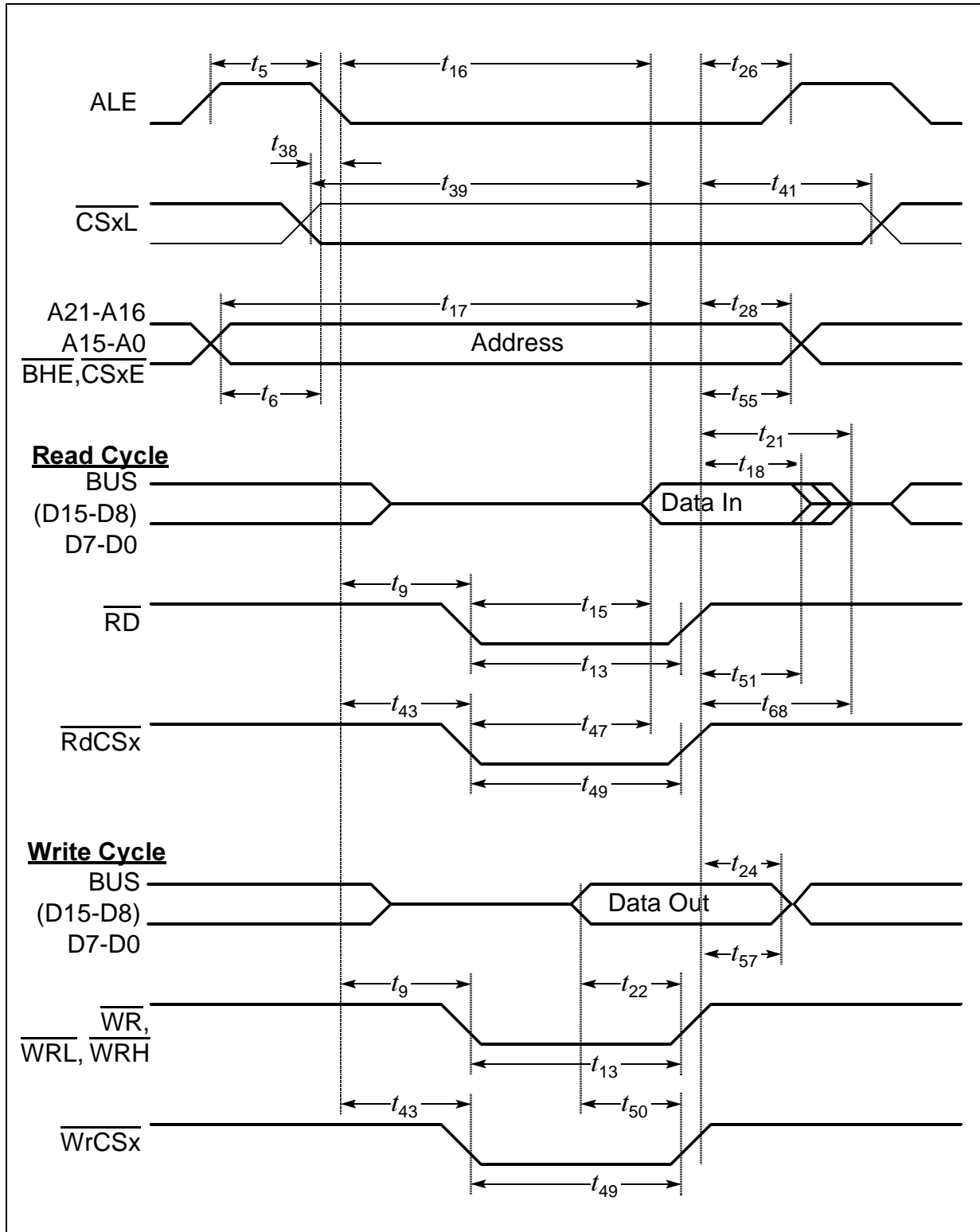
**Figure 19 External Memory Cycle: Demultiplexed Bus, With Read/Write Delay, Normal ALE**



**Figure 20 External Memory Cycle: Demultiplexed Bus, With Read/Write Delay, Extended ALE**



**Figure 21 External Memory Cycle: Demultiplexed Bus, No Read/Write Delay, Normal ALE**



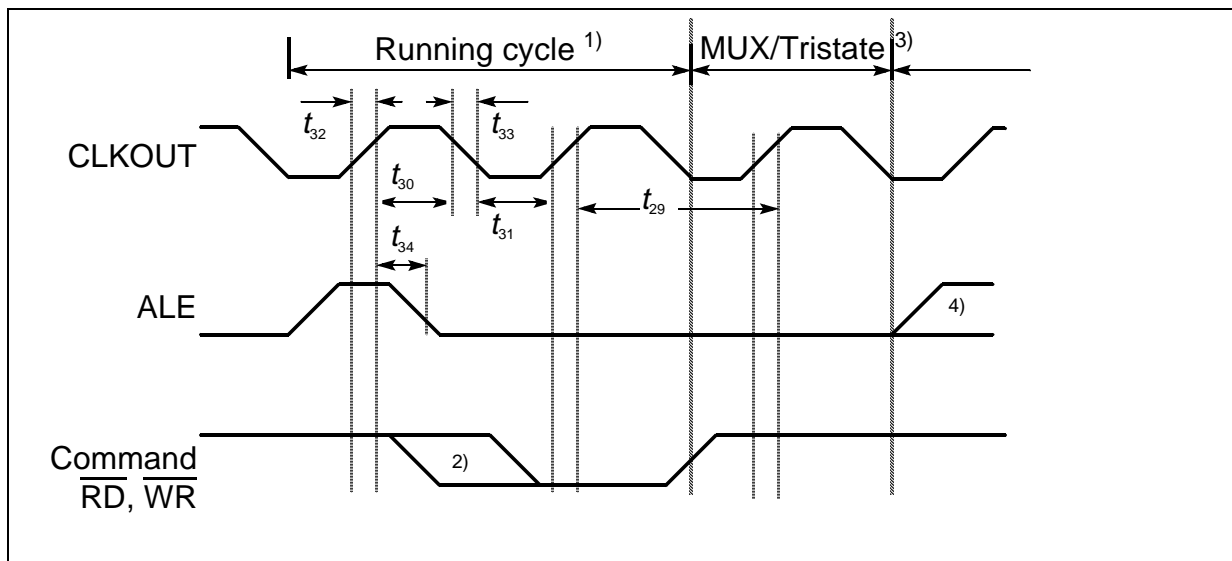
**Figure 22 External Memory Cycle: Demultiplexed Bus, No Read/Write Delay, Extended ALE**

### AC Characteristics

#### CLKOUT

(Operating Conditions apply)

| Parameter                              | Symbol      | Max. CPU Clock = 25 MHz |            | Variable CPU Clock 1 / 2TCL = 1 to 25 MHz |            | Unit |
|--|-------------|-------------------------|------------|---|------------|------|
|  |             | min.                    | max.       | min.                                      | max.       |      |
| CLKOUT cycle time                      | $t_{29}$ CC | 40                      | 40         | 2TCL                                      | 2TCL       | ns   |
| CLKOUT high time                       | $t_{30}$ CC | 14                      | –          | TCL – 6                                   | –          | ns   |
| CLKOUT low time                        | $t_{31}$ CC | 10                      | –          | TCL – 10                                  | –          | ns   |
| CLKOUT rise time                       | $t_{32}$ CC | –                       | 4          | –   | 4          | ns   |
| CLKOUT fall time                       | $t_{33}$ CC | –                       | 4          | –   | 4          | ns   |
| CLKOUT rising edge to ALE falling edge | $t_{34}$ CC | $0 + t_A$               | $10 + t_A$ | $0 + t_A$                                 | $10 + t_A$ | ns   |



**Figure 23 CLKOUT Timing**

**Notes**

- 1) Cycle as programmed, including MCTC waitstates (Example shows 0 MCTC WS).
- 2) The leading edge of the respective command depends on RW-delay.
- 3) Multiplexed bus modes have a MUX waitstate added after a bus cycle, and an additional MTTC waitstate may be inserted here.  
For a multiplexed bus with MTTC waitstate this delay is 2 CLKOUT cycles, for a demultiplexed bus without MTTC waitstate this delay is zero.
- 4) The next external bus cycle may start here.







