

C167CR C167SR

16-Bit Single-Chip Microcontroller

16bit

Microcontrollers



Never stop thinking.

Edition 2005-02

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|-------------------|---|
| Previous Version: | V3.2, 2001-07 V3.1, 2000-04 V3.0, 2000-02 1999-10 (Introduction of clock-related timing) 1999-06 1999-03 (Summarizes and replaces all older docs) 1998-03 (C167SR/CR, 25 MHz Addendum) 07.97 / 12.96 (C167CR-4RM) 12.96 (C167CR-16RM) 06.95 (C167CR, C167SR) 06.94 / 05.93 (C167) |
|-------------------|---|

| Page | Subjects (major changes since last revision) |
|------------------|---|
| all | The layout of several graphics and text structures has been adapted to company documentation rules, obvious typographical errors have been corrected. |
| all | The contents of this document have been re-arranged into numbered sections and a table of contents has been added. |
| 6 | BGA-type added to product list |
| 8 | Pin designation corrected (pin 78) |
| 9 | Input threshold control added to Port 6 |
| 17 ... 25 | Pin diagram and pin description for BGA package added |
| 45 | Port 6 added to input-threshold controlled ports |
| 85 | Mechanical package drawing corrected (P-MQFP-144-8) |
| 86 | Mechanical package drawing added (P-BGA-176-2) |

We Listen to Your Comments

Any information within this document that you feel is wrong, unclear or missing at all? Your feedback will help us to continuously improve the quality of this document. Please send your proposal (including a reference to this document) to:

mcdocu.comments@infineon.com



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1 Summary of Features

- High Performance 16-bit CPU with 4-Stage Pipeline
 - 80/60 ns Instruction Cycle Time at 25/33 MHz CPU Clock
 - 400/303 ns Multiplication (16×16 bits), 800/606 ns Division ($32 / 16$ bits)
 - 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 56 Sources, Sample-Rate down to 40/30 ns
- 8-Channel Interrupt-Driven Single-Cycle Data Transfer Facilities via Peripheral Event Controller (PEC)
- Clock Generation via on-chip PLL (factors 1:1.5/2/2.5/3/4/5), via prescaler or via direct clock input
- On-Chip Memory Modules
 - 2 Kbytes On-Chip Internal RAM (IRAM)
 - 2 Kbytes On-Chip Extension RAM (XRAM)
 - 128/32 Kbytes On-Chip Mask ROM
- On-Chip Peripheral Modules
 - 16-Channel 10-bit A/D Converter with Programmable Conversion Time down to 7.8 μ s
 - Two 16-Channel Capture/Compare Units
 - 4-Channel PWM Unit
 - Two Multi-Functional General Purpose Timer Units with 5 Timers
 - Two Serial Channels (Synchronous/Asynchronous and High-Speed-Synchronous)
 - On-Chip CAN Interface (Rev. 2.0B active) with 15 Message Objects (Full CAN / Basic CAN)
- Up to 16 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
 - Five Programmable Chip-Select Signals
 - Hold- and Hold-Acknowledge Bus Arbitration Support
- Idle and Power Down Modes
- Programmable Watchdog Timer and Oscillator Watchdog

Summary of Features

- Up to 111 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
- 144-Pin MQFP Package
- 176-Pin BGA Package¹⁾

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 temperature range, and the supply voltage
- the package and the type of delivery.

For the available ordering codes for the C167CR 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.

This document describes several derivatives of the C167 group. **Table 1** 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.

For simplicity all versions are referred to by the term **C167CR** throughout this document.

1) The external connections of the C167CR in P-BGA-176-2 are referred to as pins throughout this document, although they are mechanically realized as solder balls.

Summary of Features
Table 1 C167CR Derivative Synopsis

| Derivative¹⁾ | Program ROM Size | XRAM Size | Operating Frequency | Package |
|---|-------------------------|------------------|----------------------------|----------------|
| SAK-C167SR-LM SAB-C167SR-LM | – | 2 Kbytes | 25 MHz | P-MQFP-144-8 |
| SAK-C167SR-L33M SAB-C167SR-L33M | – | 2 Kbytes | 33 MHz | P-MQFP-144-8 |
| SAK-C167CR-LM SAF-C167CR-LM SAB-C167CR-LM | – | 2 Kbytes | 25 MHz | P-MQFP-144-8 |
| SAK-C167CR-L33M SAB-C167CR-L33M | – | 2 Kbytes | 33 MHz | P-MQFP-144-8 |
| SAK-C167CR-4RM SAB-C167CR-4RM | 32 Kbytes | 2 Kbytes | 25 MHz | P-MQFP-144-8 |
| SAK-C167CR-4R33M SAB-C167CR-4R33M | 32 Kbytes | 2 Kbytes | 33 MHz | P-MQFP-144-8 |
| SAK-C167CR-16RM | 128 Kbytes | 2 Kbytes | 25 MHz | P-MQFP-144-8 |
| SAK-C167CR-16R33M | 128 Kbytes | 2 Kbytes | 33 MHz | P-MQFP-144-8 |
| SAK-C167CR-LE | – | 2 Kbytes | 25 MHz | P-BGA-176-2 |

1) This Data Sheet is valid for devices manufactured in 0.5 μm technology, i.e. devices starting with and including design step GA(-T)6.

2 General Device Information

2.1 Introduction

The C167CR derivatives are high performance derivatives of the Infineon C166 Family of full featured single-chip CMOS microcontrollers. They combine high CPU performance (up to 16.5 million instructions per second) with high peripheral functionality and enhanced IO-capabilities. They also provide clock generation via PLL and various on-chip memory modules such as program ROM, internal RAM, and extension RAM.

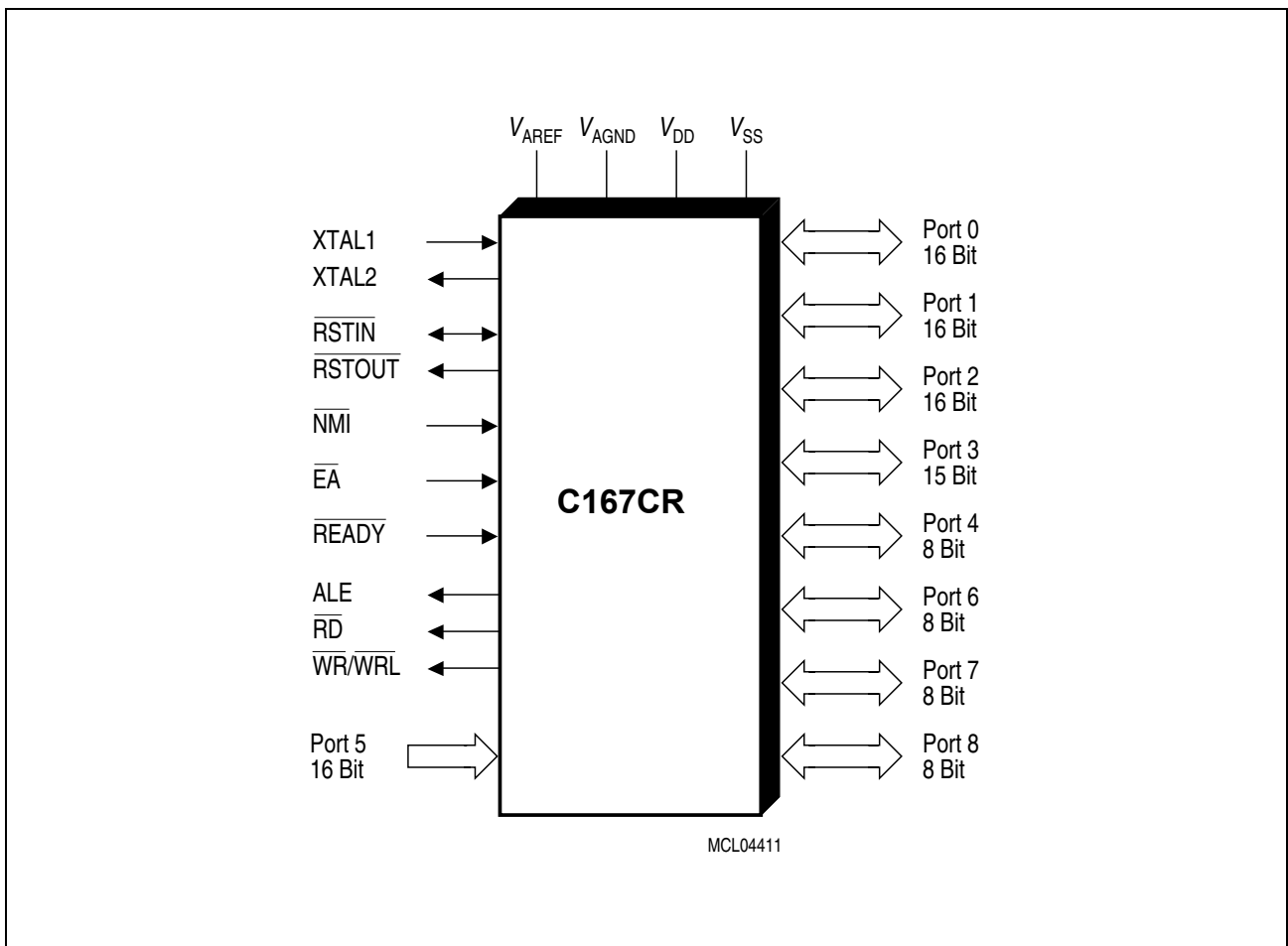


Figure 1 **Logic Symbol**

2.2 Pin Configuration and Definition for P-MQFP-144-8

The pins of the C167CR are described in detail in [Table 2](#), including all their alternate functions. [Figure 2](#) summarizes all pins in a condensed way, showing their location on the 4 sides of the package.

Note: The P-BGA-176-2 is described in [Table 3](#) and [Figure 3](#).

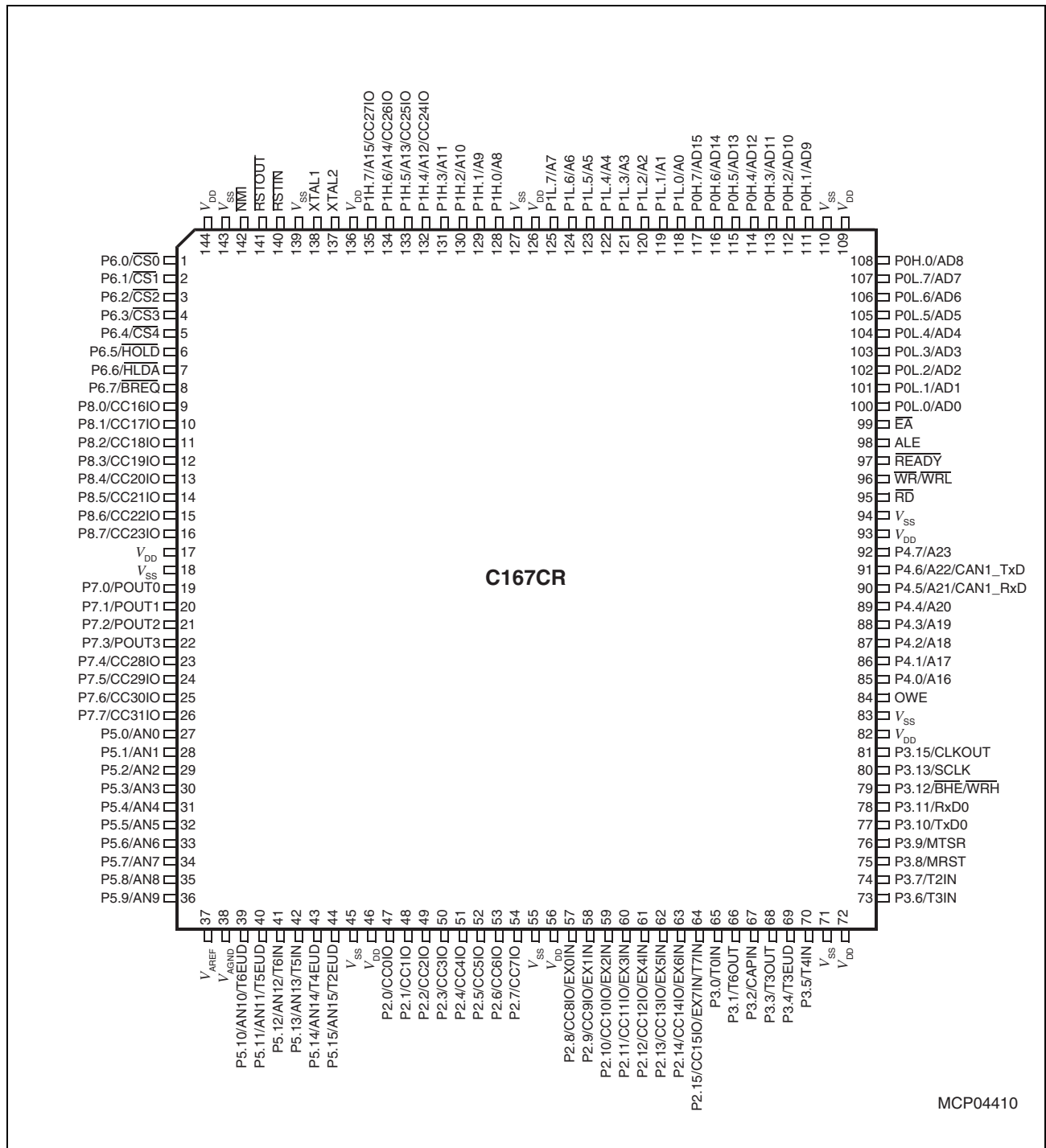


Figure 2 Pin Configuration P-MQFP-144-8 (top view)

Table 2 Pin Definitions and Functions P-MQFP-144-8

| Symbol | Pin No. | Input Outp. | Function |
|-----------|---------|-------------|---|
| P6 | | IO | Port 6 is an 8-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 6 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 6 is selectable (TTL or special). The Port 6 pins also serve for alternate functions: |
| P6.0 | 1 | O | $\overline{\text{CS0}}$ Chip Select 0 Output |
| P6.1 | 2 | O | $\overline{\text{CS1}}$ Chip Select 1 Output |
| P6.2 | 3 | O | $\overline{\text{CS2}}$ Chip Select 2 Output |
| P6.3 | 4 | O | $\overline{\text{CS3}}$ Chip Select 3 Output |
| P6.4 | 5 | O | $\overline{\text{CS4}}$ Chip Select 4 Output |
| P6.5 | 6 | I | $\overline{\text{HOLD}}$ External Master Hold Request Input |
| P6.6 | 7 | I/O | $\overline{\text{HLDA}}$ Hold Acknowledge Output (master mode) or Input (slave mode) |
| P6.7 | 8 | O | $\overline{\text{BREQ}}$ Bus Request Output |
| P8 | | IO | Port 8 is an 8-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). The following Port 8 pins also serve for alternate functions: |
| P8.0 | 9 | I/O | CC16IO CAPCOM2: CC16 Capture Inp./Compare Outp. |
| P8.1 | 10 | I/O | CC17IO CAPCOM2: CC17 Capture Inp./Compare Outp. |
| P8.2 | 11 | I/O | CC18IO CAPCOM2: CC18 Capture Inp./Compare Outp. |
| P8.3 | 12 | I/O | CC19IO CAPCOM2: CC19 Capture Inp./Compare Outp. |
| P8.4 | 13 | I/O | CC20IO CAPCOM2: CC20 Capture Inp./Compare Outp. |
| P8.5 | 14 | I/O | CC21IO CAPCOM2: CC21 Capture Inp./Compare Outp. |
| P8.6 | 15 | I/O | CC22IO CAPCOM2: CC22 Capture Inp./Compare Outp. |
| P8.7 | 16 | I/O | CC23IO CAPCOM2: CC23 Capture Inp./Compare Outp. |

General Device Information
Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|-----------|---------|----------------|---|
| P7 | | IO | Port 7 is an 8-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 7 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 7 is selectable (TTL or special). The following Port 7 pins also serve for alternate functions: |
| P7.0 | 19 | O | POUT0 PWM Channel 0 Output |
| P7.1 | 20 | O | POUT1 PWM Channel 1 Output |
| P7.2 | 21 | O | POUT2 PWM Channel 2 Output |
| P7.3 | 22 | O | POUT3 PWM Channel 3 Output |
| P7.4 | 23 | I/O | CC28IO CAPCOM2: CC28 Capture Inp./Compare Outp. |
| P7.5 | 24 | I/O | CC29IO CAPCOM2: CC29 Capture Inp./Compare Outp. |
| P7.6 | 25 | I/O | CC30IO CAPCOM2: CC30 Capture Inp./Compare Outp. |
| P7.7 | 26 | I/O | CC31IO CAPCOM2: CC31 Capture Inp./Compare Outp. |
| P5 | | I | Port 5 is a 16-bit input-only port with Schmitt-Trigger characteristic. The pins of Port 5 also serve as analog input channels for the A/D converter, or they serve as timer inputs: |
| P5.0 | 27 | I | AN0 |
| P5.1 | 28 | I | AN1 |
| P5.2 | 29 | I | AN2 |
| P5.3 | 30 | I | AN3 |
| P5.4 | 31 | I | AN4 |
| P5.5 | 32 | I | AN5 |
| P5.6 | 33 | I | AN6 |
| P5.7 | 34 | I | AN7 |
| P5.8 | 35 | I | AN8 |
| P5.9 | 36 | I | AN9 |
| P5.10 | 39 | I | AN10, T6EUD GPT2 Timer T6 Ext. Up/Down Ctrl. Inp. |
| P5.11 | 40 | I | AN11, T5EUD GPT2 Timer T5 Ext. Up/Down Ctrl. Inp. |
| P5.12 | 41 | I | AN12, T6IN GPT2 Timer T6 Count Inp. |
| P5.13 | 42 | I | AN13, T5IN GPT2 Timer T5 Count Inp. |
| P5.14 | 43 | I | AN14, T4EUD GPT1 Timer T4 Ext. Up/Down Ctrl. Inp. |
| P5.15 | 44 | I | AN15, T2EUD GPT1 Timer T5 Ext. Up/Down Ctrl. Inp. |

General Device Information
Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|-----------|---------|----------------|---|
| P2 | | I/O | Port 2 is a 16-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 2 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 2 is selectable (TTL or special). The following Port 2 pins also serve for alternate functions: |
| P2.0 | 47 | I/O | CC0IO CAPCOM1: CC0 Capture Inp./Compare Output |
| P2.1 | 48 | I/O | CC1IO CAPCOM1: CC1 Capture Inp./Compare Output |
| P2.2 | 49 | I/O | CC2IO CAPCOM1: CC2 Capture Inp./Compare Output |
| P2.3 | 50 | I/O | CC3IO CAPCOM1: CC3 Capture Inp./Compare Output |
| P2.4 | 51 | I/O | CC4IO CAPCOM1: CC4 Capture Inp./Compare Output |
| P2.5 | 52 | I/O | CC5IO CAPCOM1: CC5 Capture Inp./Compare Output |
| P2.6 | 53 | I/O | CC6IO CAPCOM1: CC6 Capture Inp./Compare Output |
| P2.7 | 54 | I/O | CC7IO CAPCOM1: CC7 Capture Inp./Compare Output |
| P2.8 | 57 | I/O | CC8IO CAPCOM1: CC8 Capture Inp./Compare Output, I EX0IN Fast External Interrupt 0 Input |
| P2.9 | 58 | I/O | CC9IO CAPCOM1: CC9 Capture Inp./Compare Output, I EX1IN Fast External Interrupt 1 Input |
| P2.10 | 59 | I/O | CC10IO CAPCOM1: CC10 Capture Inp./Compare Outp., I EX2IN Fast External Interrupt 2 Input |
| P2.11 | 60 | I/O | CC11IO CAPCOM1: CC11 Capture Inp./Compare Outp., I EX3IN Fast External Interrupt 3 Input |
| P2.12 | 61 | I/O | CC12IO CAPCOM1: CC12 Capture Inp./Compare Outp., I EX4IN Fast External Interrupt 4 Input |
| P2.13 | 62 | I/O | CC13IO CAPCOM1: CC13 Capture Inp./Compare Outp., I EX5IN Fast External Interrupt 5 Input |
| P2.14 | 63 | I/O | CC14IO CAPCOM1: CC14 Capture Inp./Compare Outp., I EX6IN Fast External Interrupt 6 Input |
| P2.15 | 64 | I/O | CC15IO CAPCOM1: CC15 Capture Inp./Compare Outp., I EX7IN Fast External Interrupt 7 Input, I T7IN CAPCOM2: Timer T7 Count Input |

General Device Information
Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|---------------------|---------|----------------|---|
| P3 | | IO | Port 3 is a 15-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). The following Port 3 pins also serve for alternate functions: |
| P3.0 | 65 | I | T0IN CAPCOM1 Timer T0 Count Input |
| P3.1 | 66 | O | T6OUT GPT2 Timer T6 Toggle Latch Output |
| P3.2 | 67 | I | CAPIN GPT2 Register CAPREL Capture Input |
| P3.3 | 68 | O | T3OUT GPT1 Timer T3 Toggle Latch Output |
| P3.4 | 69 | I | T3EUD GPT1 Timer T3 External Up/Down Control Input |
| P3.5 | 70 | I | T4IN GPT1 Timer T4 Count/Gate/Reload/Capture Inp. |
| P3.6 | 73 | I | T3IN GPT1 Timer T3 Count/Gate Input |
| P3.7 | 74 | I | T2IN GPT1 Timer T2 Count/Gate/Reload/Capture Inp. |
| P3.8 | 75 | I/O | MRST SSC Master-Receive/Slave-Transmit Inp./Outp. |
| P3.9 | 76 | I/O | MTRSR SSC Master-Transmit/Slave-Receive Outp./Inp. |
| P3.10 | 77 | O | TxD0 ASC0 Clock/Data Output (Async./Sync.) |
| P3.11 | 78 | I/O | RxD0 ASC0 Data Input (Async.) or Inp./Outp. (Sync.) |
| P3.12 | 79 | O | <u>BHE</u> External Memory High Byte Enable Signal, |
| | | O | <u>WRH</u> External Memory High Byte Write Strobe |
| P3.13 | 80 | I/O | SCLK SSC Master Clock Output / Slave Clock Input. |
| P3.15 | 81 | O | CLKOUT System Clock Output (= CPU Clock) |
| OWE (V_{PP}) | 84 | I | Oscillator Watchdog Enable. This input enables the oscillator watchdog when high or disables it when low e.g. for testing purposes. An internal pull-up device holds this input high if nothing is driving it. For normal operation pin OWE should be high or not connected. In order to drive pin OWE low draw a current of at least 200 μ A. |

General Device Information
Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|---|---------|----------------|--|
| P4 | | IO | Port 4 is an 8-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 can be used to output the segment address lines and for serial bus interfaces: |
| P4.0 | 85 | O | A16 Least Significant Segment Address Line |
| P4.1 | 86 | O | A17 Segment Address Line |
| P4.2 | 87 | O | A18 Segment Address Line |
| P4.3 | 88 | O | A19 Segment Address Line |
| P4.4 | 89 | O | A20 Segment Address Line |
| P4.5 | 90 | O | A21 Segment Address Line, |
| P4.6 | 91 | O | CAN1_RxD CAN 1 Receive Data Input |
| P4.7 | 92 | O | A22 Segment Address Line, CAN1_TxD CAN 1 Transmit Data Output |
| RD | 95 | O | A23 Most Significant Segment Address Line |
| $\overline{\text{WR}}$ / $\overline{\text{WRL}}$ | 96 | O | External Memory Read Strobe. $\overline{\text{RD}}$ is activated for every external instruction or data read access. |
| $\overline{\text{WR}}$ / $\overline{\text{WRL}}$ | 96 | O | External Memory Write Strobe. In $\overline{\text{WR}}$ -mode this pin is activated for every external data write access. In $\overline{\text{WRL}}$ -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. |
| $\overline{\text{READY}}$ | 97 | I | Ready Input. When the Ready function is enabled, a high level at this pin during an external memory access will force the insertion of memory cycle time waitstates until the pin returns to a low level. An internal pull-up device will hold this pin high when nothing is driving it. |
| ALE | 98 | O | Address Latch Enable Output. Can be used for latching the address into external memory or an address latch in the multiplexed bus modes. |
| $\overline{\text{EA}}$ | 99 | I | External Access Enable pin. A low level at this pin during and after Reset forces the C167CR to begin instruction execution out of external memory. A high level forces execution out of the internal program memory. "ROMless" versions must have this pin tied to '0'. |

General Device Information

Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|--|--|--------------------------------|---|
| PORT0 P0L.0-7 P0H.0-7 | 100-107 108, 111-117 | 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>Demultiplexed bus modes: 8-bit data bus: P0H = I/O, P0L = D7 - D0 16-bit data bus: P0H = D15 - D8, P0L = D7 - D0</p> <p>Multiplexed bus modes: 8-bit data bus: P0H = A15 - A8, P0L = AD7 - AD0 16-bit data bus: P0H = AD15 - AD8, P0L = AD7 - AD0</p> |
| PORT1 P1L.0-7 P1H.0-7 P1H.4 P1H.5 P1H.6 P1H.7 | 118-125 128-135 132 133 134 135 | IO I I I I | <p>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.</p> <p>The following PORT1 pins also serve for alternate functions:</p> <p>CC24IO CAPCOM2: CC24 Capture Input CC25IO CAPCOM2: CC25 Capture Input CC26IO CAPCOM2: CC26 Capture Input CC27IO CAPCOM2: CC27 Capture Input</p> |
| XTAL2 XTAL1 | 137 138 | O I | <p>XTAL2: Output of the oscillator amplifier circuit. 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> |

General Device Information

Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|----------------------------|---------|----------------|--|
| $\overline{\text{RSTIN}}$ | 140 | I/O | <p>Reset Input with Schmitt-Trigger characteristics. A low level at this pin while the oscillator is running resets the C167CR. An internal pull-up resistor permits power-on reset using only a capacitor connected to V_{SS}.</p> <p>A spike filter suppresses input pulses < 10 ns. Input pulses > 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 (<u>enabled</u> by setting bit BDRSTEN in register SYSCON) the $\overline{\text{RSTIN}}$ 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> <p><i>Note: To let the reset configuration of PORT0 settle and to let the PLL lock a reset duration of ca. 1 ms is recommended.</i></p> |
| $\overline{\text{RSTOUT}}$ | 141 | O | <p>Internal Reset Indication Output. This pin is set to a low level when the part is executing <u>either</u> a hardware-, a software- or a watchdog timer reset. $\overline{\text{RSTOUT}}$ remains low until the EINIT (end of initialization) instruction is executed.</p> |
| $\overline{\text{NMI}}$ | 142 | I | <p>Non-Maskable Interrupt Input. A high to low transition at this pin causes the CPU to vector to the NMI trap routine. <u>When</u> the PWRDN (power down) instruction is executed, the $\overline{\text{NMI}}$ pin must be <u>low in order</u> to force the C167CR to go into power down mode. If $\overline{\text{NMI}}$ is high, when PWRDN is executed, the part will <u>continue to run</u> in normal mode.</p> <p>If not used, pin $\overline{\text{NMI}}$ should be pulled high externally.</p> |
| V_{AREF} | 37 | – | Reference voltage for the A/D converter. |
| V_{AGND} | 38 | – | Reference ground for the A/D converter. |

General Device Information

Table 2 Pin Definitions and Functions P-MQFP-144-8 (cont'd)

| Symbol | Pin No. | Input Outp. | Function |
|----------|--|----------------|--|
| V_{DD} | 17, 46, 56, 72, 82, 93, 109, 126, 136, 144 | – | Digital Supply Voltage: + 5 V during normal operation and idle mode. ≥ 2.5 V during power down mode. |
| V_{SS} | 18, 45, 55, 71, 83, 94, 110, 127, 139, 143 | – | Digital Ground. |

Note: The following behavioural 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 as if it were a hardware reset. In particular, 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.

2.3 Pin Configuration and Definition for P-BGA-176-2

The pins¹⁾ of the C167CR are described in detail in **Table 3**, including all their alternate functions. **Figure 3** summarizes all pins in a condensed way, showing their location on the bottom of the package.

*Note: The P-MQFP-144-8 is described in **Table 2** and **Figure 2**.*

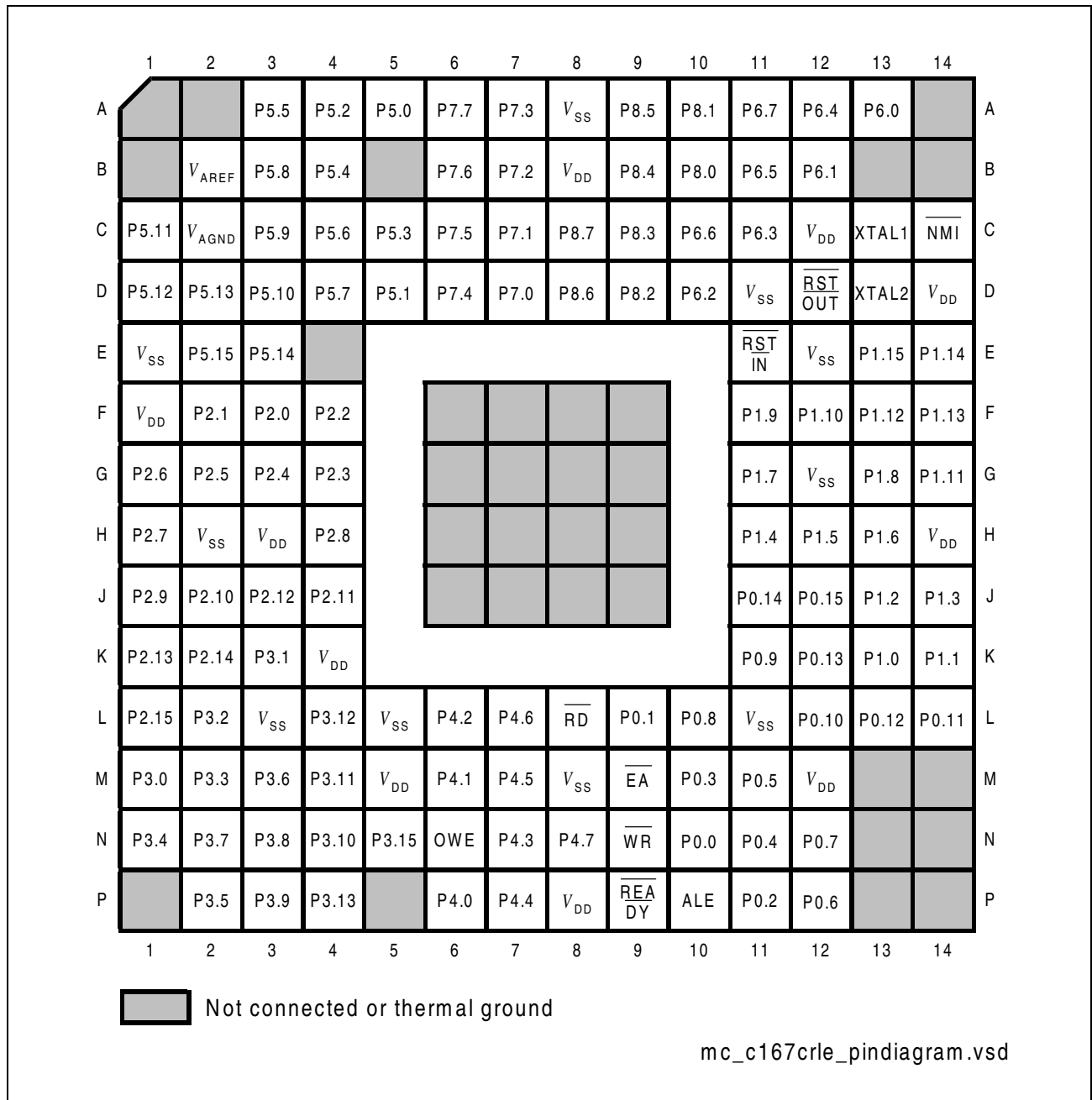


Figure 3 Pin Configuration P-BGA-176-2 (top view)

1) The external connections of the C167CR in P-BGA-176-2 are referred to as pins throughout this document, although they are mechanically realized as solder balls.

Table 3 Pin Definitions and Functions P-BGA-176-2

| Symbol | Pin Num. | Input Outp. | Function |
|-----------|----------|-------------|---|
| P5 | | I | Port 5 is a 16-bit input-only port with Schmitt-Trigger characteristic. The pins of Port 5 also serve as analog input channels for the A/D converter, or they serve as timer inputs: |
| P5.0 | A5 | I | AN0 |
| P5.1 | D5 | I | AN1 |
| P5.2 | A4 | I | AN2 |
| P5.3 | C5 | I | AN3 |
| P5.4 | B4 | I | AN4 |
| P5.5 | A3 | I | AN5 |
| P5.6 | C4 | I | AN6 |
| P5.7 | D4 | I | AN7 |
| P5.8 | B3 | I | AN8 |
| P5.9 | C3 | I | AN9 |
| P5.10 | D3 | I | AN10, T6EUD GPT2 Timer T6 Ext. Up/Down Ctrl. Inp. |
| P5.11 | C1 | I | AN11, T5EUD GPT2 Timer T5 Ext. Up/Down Ctrl. Inp. |
| P5.12 | D1 | I | AN12, T6IN GPT2 Timer T6 Count Inp. |
| P5.13 | D2 | I | AN13, T5IN GPT2 Timer T5 Count Inp. |
| P5.14 | E3 | I | AN14, T4EUD GPT1 Timer T4 Ext. Up/Down Ctrl. Inp. |
| P5.15 | E2 | I | AN15, T2EUD GPT1 Timer T5 Ext. Up/Down Ctrl. Inp. |
| P7 | | IO | Port 7 is an 8-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 7 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 7 is selectable (TTL or special). The following Port 7 pins also serve for alternate functions: |
| P7.0 | D7 | O | POUT0 PWM Channel 0 Output |
| P7.1 | C7 | O | POUT1 PWM Channel 1 Output |
| P7.2 | B7 | O | POUT2 PWM Channel 2 Output |
| P7.3 | A7 | O | POUT3 PWM Channel 3 Output |
| P7.4 | D6 | I/O | CC28IO CAPCOM2: CC28 Capture Inp./Compare Outp. |
| P7.5 | C6 | I/O | CC29IO CAPCOM2: CC29 Capture Inp./Compare Outp. |
| P7.6 | B6 | I/O | CC30IO CAPCOM2: CC30 Capture Inp./Compare Outp. |
| P7.7 | A6 | I/O | CC31IO CAPCOM2: CC31 Capture Inp./Compare Outp. |

General Device Information
Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|------------|----------|-------------|---|
| P8 | | IO | Port 8 is an 8-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). The following Port 8 pins also serve for alternate functions: |
| P8.0 | B10 | I/O | CC16IO CAPCOM2: CC16 Capture Inp./Compare Outp. |
| P8.1 | A10 | I/O | CC17IO CAPCOM2: CC17 Capture Inp./Compare Outp. |
| P8.2 | D9 | I/O | CC18IO CAPCOM2: CC18 Capture Inp./Compare Outp. |
| P8.3 | C9 | I/O | CC19IO CAPCOM2: CC19 Capture Inp./Compare Outp. |
| P8.4 | B9 | I/O | CC20IO CAPCOM2: CC20 Capture Inp./Compare Outp. |
| P8.5 | A9 | I/O | CC21IO CAPCOM2: CC21 Capture Inp./Compare Outp. |
| P8.6 | D8 | I/O | CC22IO CAPCOM2: CC22 Capture Inp./Compare Outp. |
| P8.7 | C8 | I/O | CC23IO CAPCOM2: CC23 Capture Inp./Compare Outp. |
| P6 | | IO | Port 6 is an 8-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 6 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 6 is selectable (TTL or special). The Port 6 pins also serve for alternate functions: |
| P6.0 | A13 | O | $\overline{CS0}$ Chip Select 0 Output |
| P6.1 | B12 | O | $\overline{CS1}$ Chip Select 1 Output |
| P6.2 | D10 | O | $\overline{CS2}$ Chip Select 2 Output |
| P6.3 | C11 | O | $\overline{CS3}$ Chip Select 3 Output |
| P6.4 | A12 | O | $\overline{CS4}$ Chip Select 4 Output |
| P6.5 | B11 | I | \overline{HOLD} External Master Hold Request Input |
| P6.6 | C10 | I/O | HLDA Hold Acknowledge Output (master mode) or Input (slave mode) |
| P6.7 | A11 | O | \overline{BREQ} Bus Request Output |
| NMI | C14 | I | 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 \overline{NMI} pin must be low in order to force the C167CR to go into power down mode. If \overline{NMI} is high, when PWRDN is executed, the part will continue to run in normal mode. If not used, pin \overline{NMI} should be pulled high externally. |

General Device Information

Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|--------------------------------|------------|----------------|---|
| XTAL2 XTAL1 | D13 C13 | O 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> |
| $\overline{\text{RST}}$ OUT | D12 | 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. $\overline{\text{RSTOUT}}$ remains low until the EINIT (end of initialization) instruction is executed.</p> |
| $\overline{\text{RSTIN}}$ | E11 | I/O | <p>Reset Input with Schmitt-Trigger characteristics. A low level at this pin while the oscillator is running resets the C167CR. An internal pull-up resistor permits power-on reset using only a capacitor connected to V_{SS}.</p> <p>A spike filter suppresses input pulses < 10 ns. Input pulses > 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 $\overline{\text{RSTIN}}$ 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> <p><i>Note: To let the reset configuration of PORT0 settle and to let the PLL lock a reset duration of ca. 1 ms is recommended.</i></p> |

General Device Information

Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|--|---|------------------------------------|---|
| PORT1 P1L.0-7 P1H.0-3 P1H.4 P1H.5 P1H.6 P1H.7 | K13, K14, J13, J14, H11, H12, H13, G11 G13, F11, F12, G14 F13 F14 E14 E13 | IO I I I I | <p>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.</p> <p>The following PORT1 pins also serve for alternate functions:</p> <p>CC24IO CAPCOM2: CC24 Capture Input CC25IO CAPCOM2: CC25 Capture Input CC26IO CAPCOM2: CC26 Capture Input CC27IO CAPCOM2: CC27 Capture Input</p> |
| PORT0 P0L.0-7 P0H.0-7 | N10, L9, P11, M10, N11, M11, P12, N12 L10, K11, L12, L14, L13, K12, J11, J12 | 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>Demultiplexed bus modes: 8-bit data bus: P0H = I/O, P0L = D7 - D0 16-bit data bus: P0H = D15 - D8, P0L = D7 - D0</p> <p>Multiplexed bus modes: 8-bit data bus: P0H = A15 - A8, P0L = AD7 - AD0 16-bit data bus: P0H = AD15 - AD8, P0L = AD7 - AD0</p> |
| $\overline{\text{RD}}$ | L8 | O | External Memory Read Strobe. $\overline{\text{RD}}$ is activated for every external instruction or data read access. |

General Device Information
Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|-------------------------|----------|-------------|--|
| \overline{EA} | M9 | I | External Access Enable pin. A low level at this pin during and after Reset forces the C167CR to begin instruction execution out of external memory. A high level forces execution out of the internal program memory. "ROMless" versions must have this pin tied to '0'. |
| $\overline{WR}/$ WRL | N9 | O | External Memory Write Strobe. In \overline{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. |
| \overline{READY} | P9 | I | Ready Input. When the Ready function is enabled, a high level at this pin during an external memory access will force the insertion of memory cycle time waitstates until the pin returns to a low level. An internal pull-up device will hold this pin high when nothing is driving it. |
| ALE | P10 | O | Address Latch Enable Output. Can be used for latching the address into external memory or an address latch in the multiplexed bus modes. |
| P4 | | IO | Port 4 is an 8-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 can be used to output the segment address lines and for serial bus interfaces: |
| P4.0 | P6 | O | A16 Least Significant Segment Address Line |
| P4.1 | M6 | O | A17 Segment Address Line |
| P4.2 | L6 | O | A18 Segment Address Line |
| P4.3 | N7 | O | A19 Segment Address Line |
| P4.4 | P7 | O | A20 Segment Address Line |
| P4.5 | M7 | O | A21 Segment Address Line, |
| | | I | CAN1_RxD CAN 1 Receive Data Input |
| P4.6 | L7 | O | A22 Segment Address Line, |
| | | O | CAN1_TxD CAN 1 Transmit Data Output |
| P4.7 | N8 | O | A23 Most Significant Segment Address Line |

General Device Information
Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|---------------------|----------|-------------|---|
| OWE (V_{PP}) | N6 | I | Oscillator Watchdog Enable. This input enables the oscillator watchdog when high or disables it when low e.g. for testing purposes. An internal pull-up device holds this input high if nothing is driving it. For normal operation pin OWE should be high or not connected. In order to drive pin OWE low draw a current of at least 200 μ A. |
| P3 | | IO | Port 3 is a 15-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). The following Port 3 pins also serve for alternate functions: |
| P3.0 | M1 | I | T0IN CAPCOM1 Timer T0 Count Input |
| P3.1 | K3 | O | T6OUT GPT2 Timer T6 Toggle Latch Output |
| P3.2 | L2 | I | CAPIN GPT2 Register CAPREL Capture Input |
| P3.3 | M2 | O | T3OUT GPT1 Timer T3 Toggle Latch Output |
| P3.4 | N1 | I | T3EUD GPT1 Timer T3 External Up/Down Control Input |
| P3.5 | P2 | I | T4IN GPT1 Timer T4 Count/Gate/Reload/Capture Inp. |
| P3.6 | M3 | I | T3IN GPT1 Timer T3 Count/Gate Input |
| P3.7 | N2 | I | T2IN GPT1 Timer T2 Count/Gate/Reload/Capture Inp. |
| P3.8 | N3 | I/O | MRST SSC Master-Receive/Slave-Transmit Inp./Outp. |
| P3.9 | P3 | I/O | MTRSR SSC Master-Transmit/Slave-Receive Outp./Inp. |
| P3.10 | N4 | O | TxD0 ASC0 Clock/Data Output (Async./Sync.) |
| P3.11 | M4 | I/O | RxD0 ASC0 Data Input (Async.) or Inp./Outp. (Sync.) |
| P3.12 | L4 | O | $\overline{\text{BHE}}$ External Memory High Byte Enable Signal, |
| | | O | WRH External Memory High Byte Write Strobe |
| P3.13 | P4 | I/O | SCLK SSC Master Clock Output / Slave Clock Input. |
| P3.15 | N5 | O | CLKOUT System Clock Output (= CPU Clock) |

General Device Information
Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|------------|----------|-------------|---|
| P2 | | I/O | Port 2 is a 16-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 2 outputs can be configured as push/pull or open drain drivers. The input threshold of Port 2 is selectable (TTL or special). The following Port 2 pins also serve for alternate functions: |
| P2.0 | F3 | I/O | CC0IO CAPCOM1: CC0 Capture Inp./Compare Output |
| P2.1 | F2 | I/O | CC1IO CAPCOM1: CC1 Capture Inp./Compare Output |
| P2.2 | F4 | I/O | CC2IO CAPCOM1: CC2 Capture Inp./Compare Output |
| P2.3 | G4 | I/O | CC3IO CAPCOM1: CC3 Capture Inp./Compare Output |
| P2.4 | G3 | I/O | CC4IO CAPCOM1: CC4 Capture Inp./Compare Output |
| P2.5 | G2 | I/O | CC5IO CAPCOM1: CC5 Capture Inp./Compare Output |
| P2.6 | G1 | I/O | CC6IO CAPCOM1: CC6 Capture Inp./Compare Output |
| P2.7 | H1 | I/O | CC7IO CAPCOM1: CC7 Capture Inp./Compare Output |
| P2.8 | H4 | I/O | CC8IO CAPCOM1: CC8 Capture Inp./Compare Output, I EX0IN Fast External Interrupt 0 Input |
| P2.9 | J1 | I/O | CC9IO CAPCOM1: CC9 Capture Inp./Compare Output, I EX1IN Fast External Interrupt 1 Input |
| P2.10 | J2 | I/O | CC10IO CAPCOM1: CC10 Capture Inp./Compare Outp., I EX2IN Fast External Interrupt 2 Input |
| P2.11 | J4 | I/O | CC11IO CAPCOM1: CC11 Capture Inp./Compare Outp., I EX3IN Fast External Interrupt 3 Input |
| P2.12 | J3 | I/O | CC12IO CAPCOM1: CC12 Capture Inp./Compare Outp., I EX4IN Fast External Interrupt 4 Input |
| P2.13 | K1 | I/O | CC13IO CAPCOM1: CC13 Capture Inp./Compare Outp., I EX5IN Fast External Interrupt 5 Input |
| P2.14 | K2 | I/O | CC14IO CAPCOM1: CC14 Capture Inp./Compare Outp., I EX6IN Fast External Interrupt 6 Input |
| P2.15 | L1 | I/O | CC15IO CAPCOM1: CC15 Capture Inp./Compare Outp., I EX7IN Fast External Interrupt 7 Input, I T7IN CAPCOM2: Timer T7 Count Input |
| V_{AREF} | B2 | – | Reference voltage for the A/D converter. |
| V_{AGND} | C2 | – | Reference ground for the A/D converter. |

General Device Information

Table 3 Pin Definitions and Functions P-BGA-176-2 (cont'd)

| Symbol | Pin Num. | Input Outp. | Function |
|----------|---|----------------|--|
| V_{DD} | B8, C12, D14, F1, H3, H14, K4, M5, M12, P8 | – | Digital Supply Voltage: + 5 V during normal operation and idle mode. ≥ 2.5 V during power down mode. |
| V_{SS} | A8, D11, E1, E12, G12, H2, L3, L5, L11, M8 | – | Digital Ground. |

Note: The following behavioural 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 as if it were a hardware reset. In particular, 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.

3 Functional Description

The architecture of the C167CR combines advantages of both RISC and CISC processors and of advanced peripheral subsystems in a very well-balanced way. In addition the on-chip memory blocks allow the design of compact systems with maximum performance.

The following block diagram gives an overview of the different on-chip components and of the advanced, high bandwidth internal bus structure of the C167CR.

*Note: All time specifications refer to a CPU clock of 33 MHz
(see definition in the AC Characteristics section).*

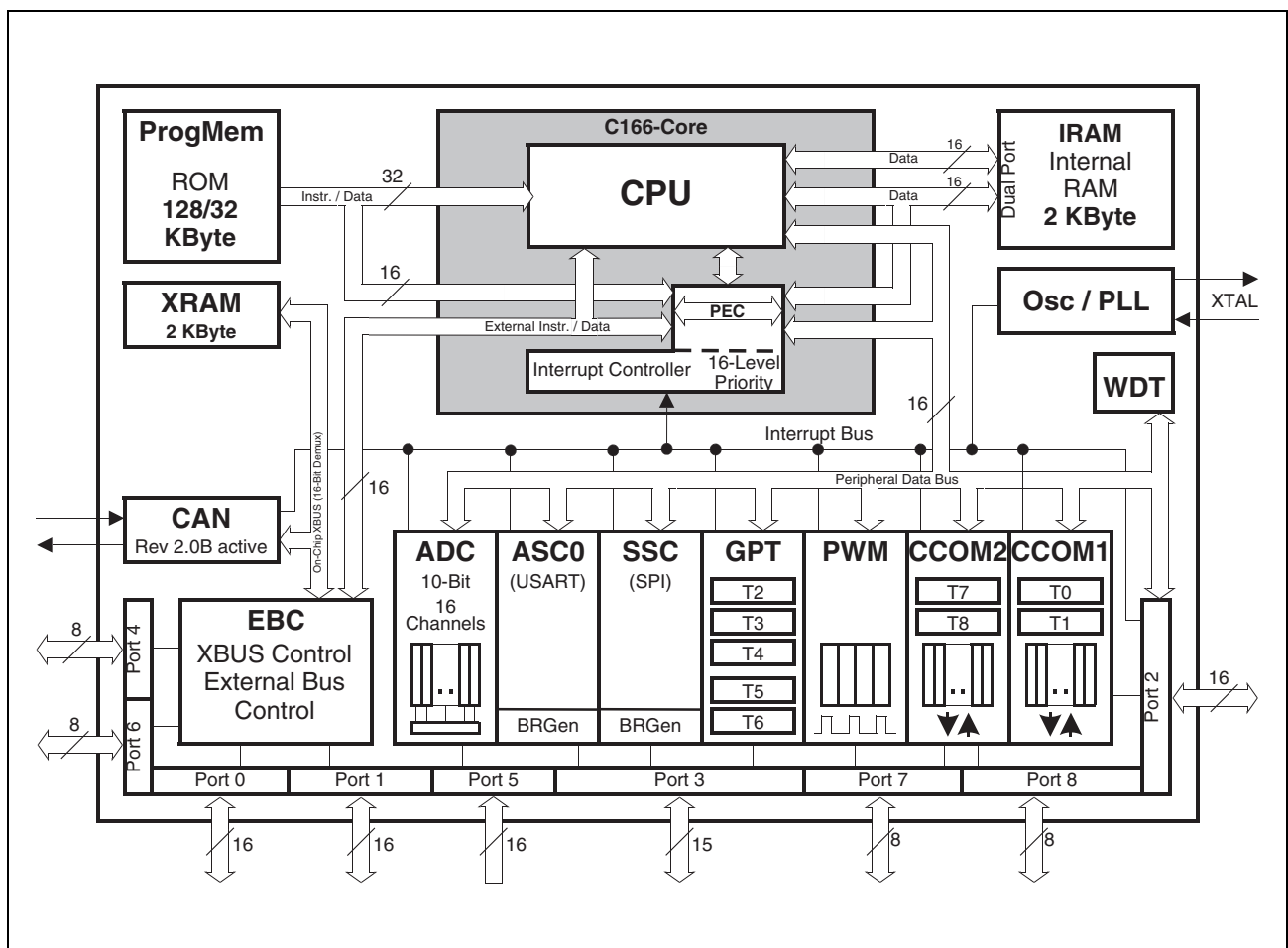


Figure 4 Block Diagram

The program memory, the internal RAM (IRAM) and the set of generic peripherals are connected to the CPU via separate buses. A fourth bus, the XBUS, connects external resources as well as additional on-chip resources, the X-Peripherals (see [Figure 4](#)).

3.1 Memory Organization

The memory space of the C167CR 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 C167CR incorporates 128/32 Kbytes (depending on the derivative) of on-chip mask-programmable ROM for code or constant data. The lower 32 Kbytes of the on-chip ROM 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.

In order to meet the needs of designs where more memory is required than is provided on chip, up to 16 Mbytes of external RAM and/or ROM can be connected to the microcontroller.

3.2 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-/24-bit Addresses, 16-bit Data, Demultiplexed
- 16-/18-/20-/24-bit Addresses, 16-bit Data, Multiplexed
- 16-/18-/20-/24-bit Addresses, 8-bit Data, Multiplexed
- 16-/18-/20-/24-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 control the access to 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 5 external \overline{CS} signals (4 windows plus default) can be generated in order to save external glue logic. The C167CR 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).

Access to very slow memories or memories with varying access times is supported via a particular 'Ready' function.

A $\overline{HOLD}/\overline{HLDA}$ protocol is available for bus arbitration and allows to share external resources with other bus masters. The bus arbitration is enabled by setting bit HLDEN in register PSW. After setting HLDEN once, pins P6.7 ... P6.5 (BREQ, HLDA, HOLD) are automatically controlled by the EBC. In Master Mode (default after reset) the HLDA pin is an output. By setting bit DP6.7 to '1' the Slave Mode is selected where pin HLDA is switched to input. This allows to directly connect the slave controller to another master controller without glue logic.

For applications which require less than 16 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 8 address lines, if an address space of 16 Mbytes is used.

Functional Description

Note: When the on-chip CAN Module is to be used the segment address output on Port 4 must be limited to 4 bits (i.e. A19 ... A16) in order to enable the alternate function of the CAN interface pins. \overline{CS} lines can be used to increase the total amount of addressable external memory.

3.3 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 C167CR's instructions can be executed in just one machine cycle which requires 60 ns at 33 MHz CPU clock. 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 16×16 bit multiplication in 5 cycles and a 32-/16-bit division in 10 cycles. Another pipeline optimization, the so-called 'Jump Cache', allows reducing the execution time of repeatedly performed jumps in a loop from 2 cycles to 1 cycle.

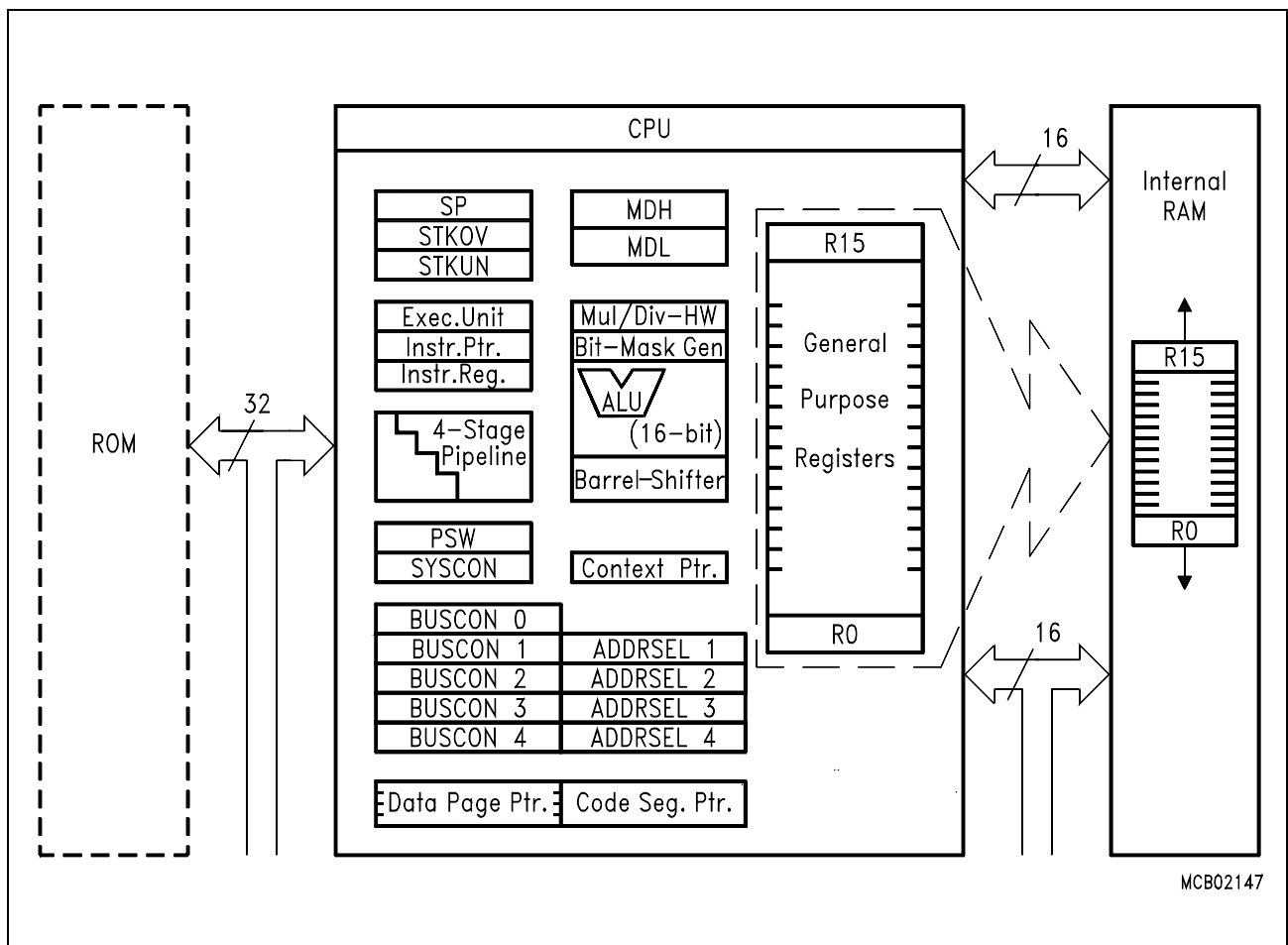


Figure 5 CPU Block Diagram

Functional Description

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 1024 words 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 C167CR 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.

3.4 Interrupt System

With an interrupt response time within a range from just 5 to 12 CPU clocks (in case of internal program execution), the C167CR is capable of reacting very fast to the occurrence of non-deterministic events.

The architecture of the C167CR 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 C167CR 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.

Table 4 shows all of the possible C167CR 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).

Functional Description
Table 4 C167CR Interrupt Nodes

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location | Trap Number |
|--|--------------|-------------|------------------|----------------------|-----------------|
| CAPCOM Register 0 | CC0IR | CC0IE | CC0INT | 00'0040 _H | 10 _H |
| CAPCOM Register 1 | CC1IR | CC1IE | CC1INT | 00'0044 _H | 11 _H |
| CAPCOM Register 2 | CC2IR | CC2IE | CC2INT | 00'0048 _H | 12 _H |
| CAPCOM Register 3 | CC3IR | CC3IE | CC3INT | 00'004C _H | 13 _H |
| CAPCOM Register 4 | CC4IR | CC4IE | CC4INT | 00'0050 _H | 14 _H |
| CAPCOM Register 5 | CC5IR | CC5IE | CC5INT | 00'0054 _H | 15 _H |
| CAPCOM Register 6 | CC6IR | CC6IE | CC6INT | 00'0058 _H | 16 _H |
| CAPCOM Register 7 | CC7IR | CC7IE | CC7INT | 00'005C _H | 17 _H |
| CAPCOM Register 8 | CC8IR | CC8IE | CC8INT | 00'0060 _H | 18 _H |
| CAPCOM Register 9 | CC9IR | CC9IE | CC9INT | 00'0064 _H | 19 _H |
| CAPCOM Register 10 | CC10IR | CC10IE | CC10INT | 00'0068 _H | 1A _H |
| CAPCOM Register 11 | CC11IR | CC11IE | CC11INT | 00'006C _H | 1B _H |
| CAPCOM Register 12 | CC12IR | CC12IE | CC12INT | 00'0070 _H | 1C _H |
| CAPCOM Register 13 | CC13IR | CC13IE | CC13INT | 00'0074 _H | 1D _H |
| CAPCOM Register 14 | CC14IR | CC14IE | CC14INT | 00'0078 _H | 1E _H |
| CAPCOM Register 15 | CC15IR | CC15IE | CC15INT | 00'007C _H | 1F _H |
| CAPCOM Register 16 | CC16IR | CC16IE | CC16INT | 00'00C0 _H | 30 _H |
| CAPCOM Register 17 | CC17IR | CC17IE | CC17INT | 00'00C4 _H | 31 _H |
| CAPCOM Register 18 | CC18IR | CC18IE | CC18INT | 00'00C8 _H | 32 _H |
| CAPCOM Register 19 | CC19IR | CC19IE | CC19INT | 00'00CC _H | 33 _H |
| CAPCOM Register 20 | CC20IR | CC20IE | CC20INT | 00'00D0 _H | 34 _H |
| CAPCOM Register 21 | CC21IR | CC21IE | CC21INT | 00'00D4 _H | 35 _H |
| CAPCOM Register 22 | CC22IR | CC22IE | CC22INT | 00'00D8 _H | 36 _H |
| CAPCOM Register 23 | CC23IR | CC23IE | CC23INT | 00'00DC _H | 37 _H |
| CAPCOM Register 24 | CC24IR | CC24IE | CC24INT | 00'00E0 _H | 38 _H |
| CAPCOM Register 25 | CC25IR | CC25IE | CC25INT | 00'00E4 _H | 39 _H |
| CAPCOM Register 26 | CC26IR | CC26IE | CC26INT | 00'00E8 _H | 3A _H |
| CAPCOM Register 27 | CC27IR | CC27IE | CC27INT | 00'00EC _H | 3B _H |
| CAPCOM Register 28 | CC28IR | CC28IE | CC28INT | 00'00E0 _H | 3C _H |
| CAPCOM Register 29 | CC29IR | CC29IE | CC29INT | 00'0110 _H | 44 _H |

Functional Description
Table 4 C167CR Interrupt Nodes (cont'd)

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location | Trap Number |
|--|--------------|-------------|------------------|----------------------|-----------------|
| CAPCOM Register 30 | CC30IR | CC30IE | CC30INT | 00'0114 _H | 45 _H |
| CAPCOM Register 31 | CC31IR | CC31IE | CC31INT | 00'0118 _H | 46 _H |
| CAPCOM Timer 0 | T0IR | T0IE | T0INT | 00'0080 _H | 20 _H |
| CAPCOM Timer 1 | T1IR | T1IE | T1INT | 00'0084 _H | 21 _H |
| CAPCOM Timer 7 | T7IR | T7IE | T7INT | 00'00F4 _H | 3D _H |
| CAPCOM Timer 8 | T8IR | T8IE | T8INT | 00'00F8 _H | 3E _H |
| GPT1 Timer 2 | T2IR | T2IE | T2INT | 00'0088 _H | 22 _H |
| GPT1 Timer 3 | T3IR | T3IE | T3INT | 00'008C _H | 23 _H |
| GPT1 Timer 4 | T4IR | T4IE | T4INT | 00'0090 _H | 24 _H |
| GPT2 Timer 5 | T5IR | T5IE | T5INT | 00'0094 _H | 25 _H |
| GPT2 Timer 6 | T6IR | T6IE | T6INT | 00'0098 _H | 26 _H |
| GPT2 CAPREL Reg. | CRIR | CRIE | CRINT | 00'009C _H | 27 _H |
| A/D Conversion Complete | ADCIR | ADCIE | ADCINT | 00'00A0 _H | 28 _H |
| A/D Overrun Error | ADEIR | ADEIE | ADEINT | 00'00A4 _H | 29 _H |
| ASC0 Transmit | S0TIR | S0TIE | S0TINT | 00'00A8 _H | 2A _H |
| ASC0 Transmit Buffer | S0TBIR | S0TBIE | S0TBINT | 00'011C _H | 47 _H |
| ASC0 Receive | S0RIR | S0RIE | S0RINT | 00'00AC _H | 2B _H |
| ASC0 Error | S0EIR | S0EIE | S0EINT | 00'00B0 _H | 2C _H |
| SSC Transmit | SCTIR | SCTIE | SCTINT | 00'00B4 _H | 2D _H |
| SSC Receive | SCRIR | SCRIE | SCRINT | 00'00B8 _H | 2E _H |
| SSC Error | SCEIR | SCEIE | SCEINT | 00'00BC _H | 2F _H |
| PWM Channel 0 ... 3 | PWMIR | PWMIE | PWMINT | 00'00FC _H | 3F _H |
| CAN Interface 1 | XP0IR | XP0IE | XP0INT | 00'0100 _H | 40 _H |
| Unassigned node | XP1IR | XP1IE | XP1INT | 00'0104 _H | 41 _H |
| Unassigned node | XP2IR | XP2IE | XP2INT | 00'0108 _H | 42 _H |
| PLL/OWD | XP3IR | XP3IE | XP3INT | 00'010C _H | 43 _H |

Functional Description

The C167CR 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.

Table 5 shows all of the possible exceptions or error conditions that can arise during run-time:

Table 5 Hardware Trap Summary

| Exception Condition | Trap Flag | Trap Vector | Vector Location | Trap Number | Trap Priority |
|--|--|---|--|---|----------------------------|
| Reset Functions: <ul style="list-style-type: none"> • Hardware Reset • Software Reset • W-dog Timer Overflow | – | RESET RESET RESET | 00'0000 _H 00'0000 _H 00'0000 _H | 00 _H 00 _H 00 _H | III III III |
| Class A Hardware Traps: <ul style="list-style-type: none"> • Non-Maskable Interrupt • Stack Overflow • Stack Underflow | NMI STKOF STKUF | NMITRAP STOTRAP STUTRAP | 00'0008 _H 00'0010 _H 00'0018 _H | 02 _H 04 _H 06 _H | II II II |
| Class B Hardware Traps: <ul style="list-style-type: none"> • Undefined Opcode • Protected Instruction Fault • Illegal Word Operand Access • Illegal Instruction Access • Illegal External Bus Access | UNDOPC PRTFLT ILLOPA ILLINA ILLBUS | BTRAP BTRAP BTRAP BTRAP BTRAP | 00'0028 _H 00'0028 _H 00'0028 _H 00'0028 _H 00'0028 _H | 0A _H 0A _H 0A _H 0A _H 0A _H | I I I I I |
| Reserved | – | – | [2C _H - 3C _H] | [0B _H - 0F _H] | – |
| Software Traps <ul style="list-style-type: none"> • TRAP Instruction | – | – | Any [00'0000 _H - 00'01FC _H] in steps of 4 _H | Any [00 _H - 7F _H] | Current CPU Priority |

3.5 Capture/Compare (CAPCOM) Units

The CAPCOM units support generation and control of timing sequences on up to 32 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.

Four 16-bit timers (T0/T1, T7/T8) with reload registers provide two independent time bases for the capture/compare register array.

The input clock for the timers is programmable to several prescaled values of the internal system clock, or may be derived from an overflow/underflow of timer T6 in module GPT2. This provides a wide range of variation for the timer period and resolution and allows precise adjustments to the application specific requirements. In addition, external count inputs for CAPCOM timers T0 and T7 allow event scheduling for the capture/compare registers relative to external events.

Both of the two capture/compare register arrays contain 16 dual purpose capture/compare registers, each of which may be individually allocated to either CAPCOM timer T0 or T1 (T7 or T8, respectively), and programmed for capture or compare function. Each register has one port pin associated with it which serves as an input pin for triggering the capture function, or as an output pin (except for CC24 ... CC27) 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 ('captured') 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.

Functional Description

Table 6 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. |

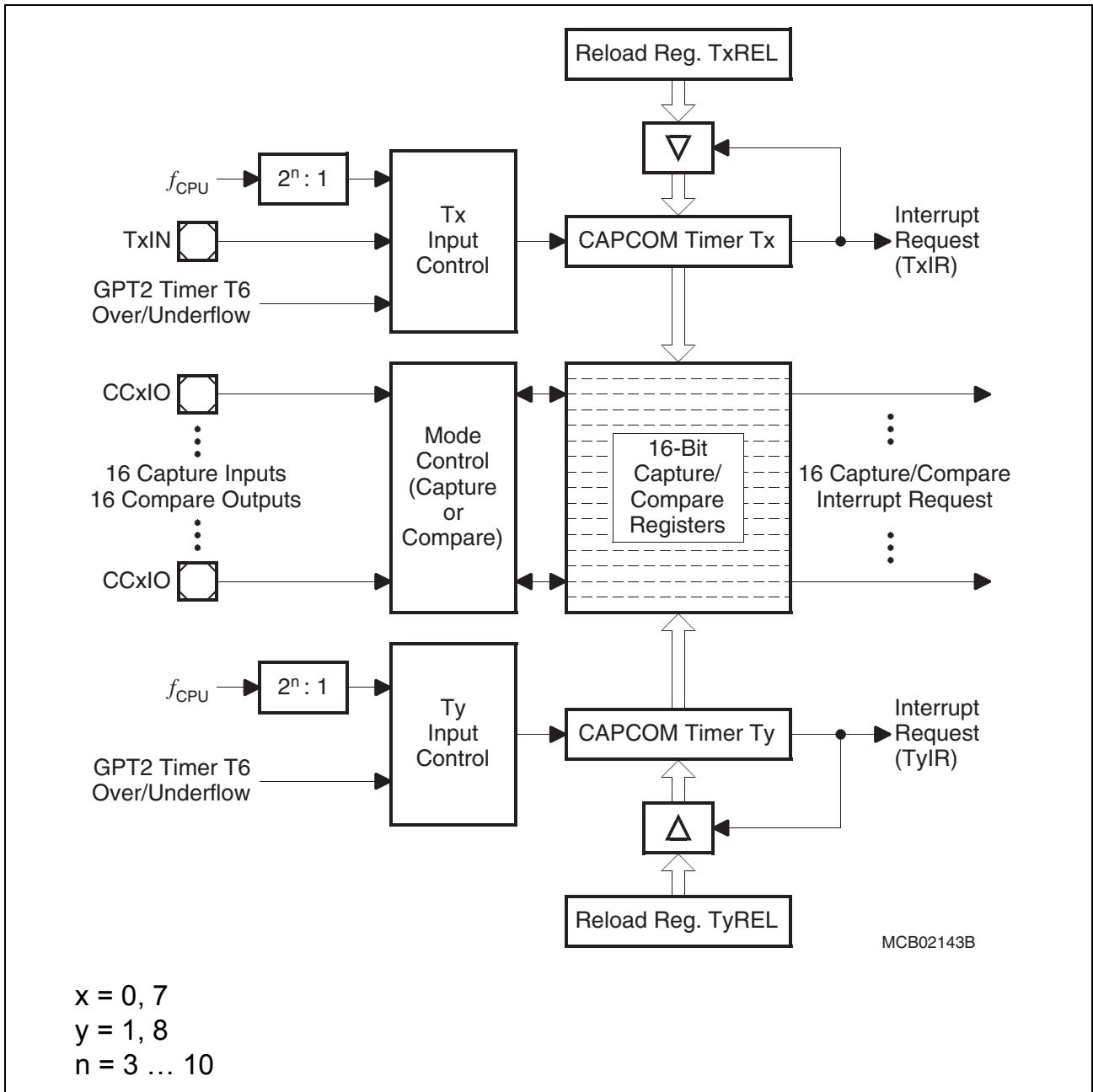


Figure 6 CAPCOM Unit Block Diagram

3.6 PWM Module

The Pulse Width Modulation Module can generate up to four PWM output signals using edge-aligned or center-aligned PWM. In addition the PWM module can generate PWM burst signals and single shot outputs. The frequency range of the PWM signals covers 4 Hz to 16.5 MHz (referred to a CPU clock of 33 MHz), depending on the resolution of the PWM output signal. The level of the output signals is selectable and the PWM module can generate interrupt requests.

3.7 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 five 16-bit timers which are organized in two separate modules, GPT1 and GPT2. 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 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 is 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.

Functional Description

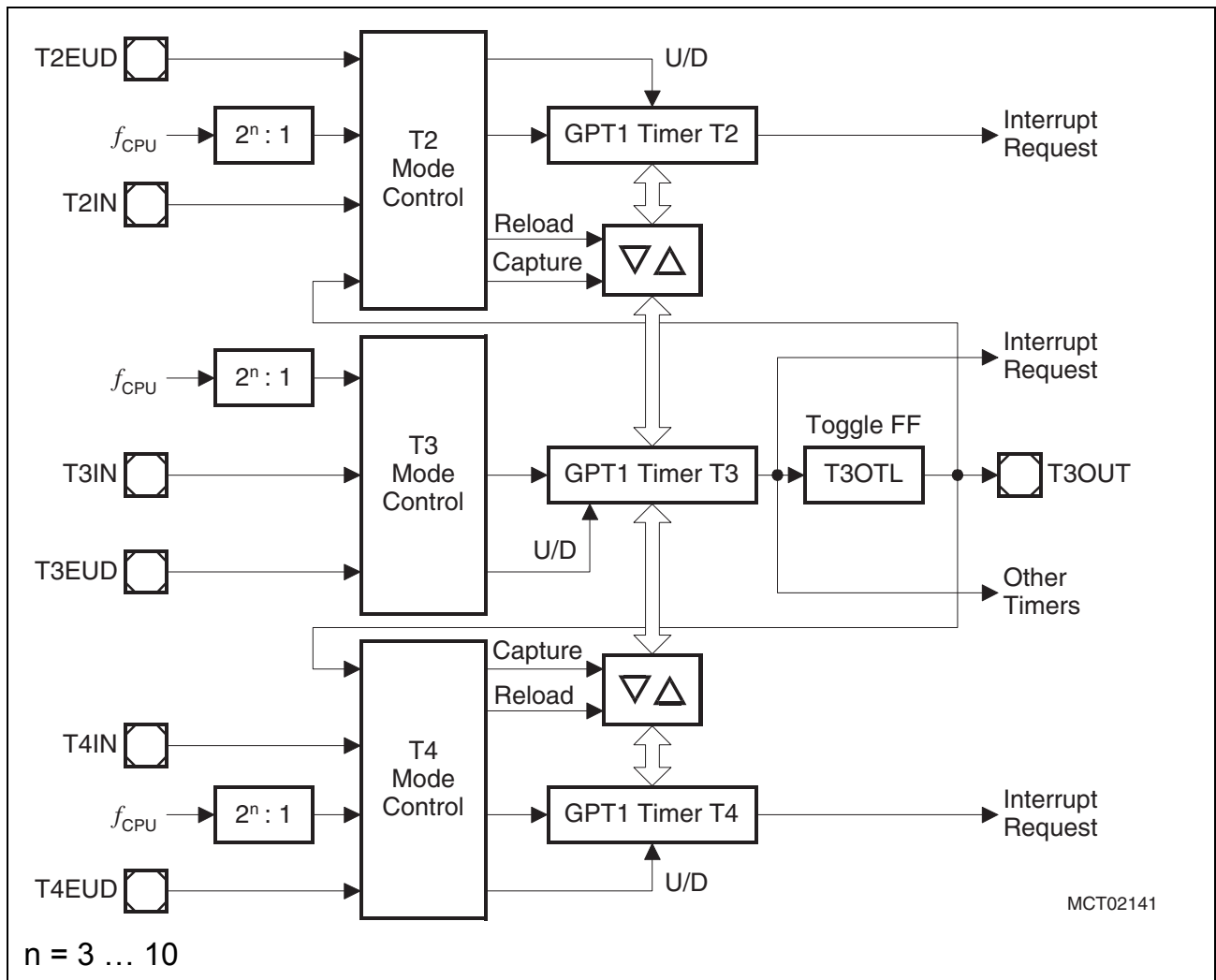


Figure 7 Block Diagram of GPT1

With its maximum resolution of 8 TCL, the **GPT2 module** provides precise event control and time measurement. It includes two timers (T5, T6) and a capture/reload register (CAPREL). Both timers can be clocked with an input clock which is derived from the CPU clock via a programmable prescaler or with external signals. 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). Concatenation of the timers is supported via the output toggle latch (T6OTL) of timer T6, which changes its state on each timer overflow/underflow.

The state of this latch may be used to clock timer T5, and/or it may be output on pin T6OUT. The overflows/underflows of timer T6 can additionally be used to clock the CAPCOM timers T0 or T1, and to cause a reload from the CAPREL register. The CAPREL register may capture the contents of timer T5 based on an external signal transition on the corresponding port pin (CAPIN), and timer T5 may optionally be cleared after the capture procedure. This allows the C167CR to measure absolute time differences or to perform pulse multiplication without software overhead.

Functional Description

The capture trigger (timer T5 to CAPREL) may also be generated upon transitions of GPT1 timer T3's inputs T3IN and/or T3EUD. This is especially advantageous when T3 operates in Incremental Interface Mode.

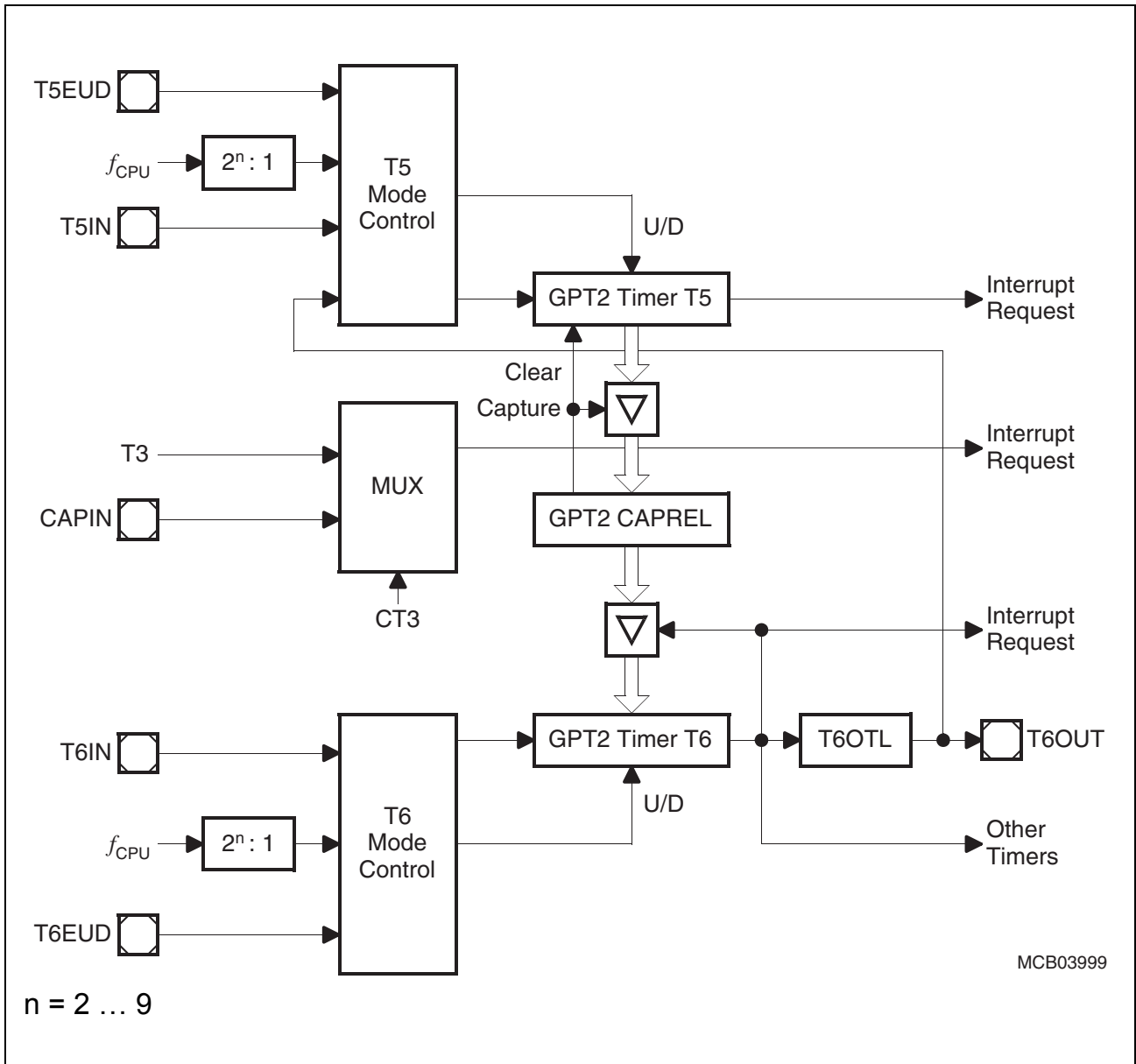


Figure 8 Block Diagram of GPT2

3.8 A/D Converter

For analog signal measurement, a 10-bit A/D converter with 16 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.

Overrun 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 16 analog input channels, the remaining channel inputs can be used as digital input port pins.

The A/D converter of the C167CR 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 register P5DIDIS (Port 5 Digital Input Disable).

3.9 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 781 kbit/s/1.03 Mbit/s and half-duplex synchronous communication at up to 3.1/4.1 Mbit/s (@ 25/33 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 6.25/8.25 Mbit/s (@ 25/33 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 three 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.

3.10 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 XCLK and is programmable up to a data rate of 1 Mbit/s. The CAN-Module uses two pins of Port 4 to interface to an external bus transceiver.

Note: When the CAN interface is to be used the segment address output on Port 4 must be limited to 4 bits, i.e. A19 ... A16. This is necessary to enable the alternate function of the CAN interface pins.

3.11 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 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 or by 128. 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 15.5 μ s and 254 ms can be monitored (@ 33 MHz).

The default Watchdog Timer interval after reset is 3.97 ms (@ 33 MHz).

3.12 Parallel Ports

The C167CR provides up to 111 I/O lines which are organized into eight 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 five I/O ports can be configured (pin by pin) for push/pull operation or open-drain operation via control registers. During the internal reset, all port pins are configured as inputs.

The input threshold of Port 2, Port 3, Port 6, Port 7, and Port 8 is selectable (TTL or CMOS like), where the special CMOS like input threshold reduces noise sensitivity due to the input hysteresis. The input threshold may be selected individually for each byte of the respective ports.

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 A23/19/17 ... A16 in systems where segmentation is enabled to access more than 64 Kbytes of memory.

Port 2, Port 8 and Port 7 (and parts of PORT1) are associated with the capture inputs or compare outputs of the CAPCOM units and/or with the outputs of the PWM module.

Port 6 provides optional bus arbitration signals ($\overline{\text{BREQ}}$, $\overline{\text{HLDA}}$, $\overline{\text{HOLD}}$) and chip select signals.

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

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

The edge characteristics (transition time) of the C167CR's port drivers can be selected via the Port Driver Control Register (PDCR). Two bits select fast edges ('0') or reduced edges ('1') for bus interface pins and non-bus pins separately.

PDCR.0 = BIPEC controls PORT0, PORT1, Port 4, $\overline{\text{RD}}$, $\overline{\text{WR}}$, ALE, CLKOUT, $\overline{\text{BHE/WRH}}$.

PDCR.4 = NBPEC controls Port 3, Port 8, $\overline{\text{RSTOUT}}$, $\overline{\text{RSTIN}}$ (bidir. reset mode).

3.13 Oscillator Watchdog

The Oscillator Watchdog (OWD) monitors the clock signal generated by the on-chip oscillator (either with a crystal or via external clock drive). For this operation the PLL provides a clock signal which is used to supervise transitions on the oscillator clock. This PLL clock is independent from the XTAL1 clock. When the expected oscillator clock transitions are missing the OWD activates the PLL Unlock / OWD interrupt node and supplies the CPU with the PLL clock signal. Under these circumstances the PLL will oscillate with its basic frequency.

In direct drive mode the PLL base frequency is used directly ($f_{\text{CPU}} = 2 \dots 5 \text{ MHz}$).

In prescaler mode the PLL base frequency is divided by 2 ($f_{\text{CPU}} = 1 \dots 2.5 \text{ MHz}$).

Note: The CPU clock source is only switched back to the oscillator clock after a hardware reset.

The oscillator watchdog can be disabled via hardware by (externally) pulling low pin OWE (internal pull-up provides high level if not connected). In this case (OWE = '0') the PLL remains idle and provides no clock signal, while the CPU clock signal is derived directly from the oscillator clock or via prescaler. Also no interrupt request will be generated in case of a missing oscillator clock.

3.14 Instruction Set Summary

Table 7 lists the instructions of the C167CR 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 7 Instruction Set Summary

| Mnemonic | Description | Bytes |
|--------------------|--|--------------|
| 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 bits) | 2 |
| DIV(U) | (Un)Signed divide register MDL by direct GPR (16 / 16 bits) | 2 |
| DIVL(U) | (Un)Signed long divide reg. MD by direct GPR (32 / 16 bits) | 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, 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 |

Functional Description
Table 7 Instruction Set Summary (cont'd)

| Mnemonic | Description | Bytes |
|------------------------|---|--------------|
| 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 |
| 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, 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, 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 and 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 |

Functional Description

Table 7 Instruction Set Summary (cont'd)

| Mnemonic | Description | Bytes |
|-----------------|--|--------------|
| DISWDT | Disable Watchdog Timer | 4 |
| EINIT | Signify End-of-Initialization on $\overline{\text{RSTOUT}}$ -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 |

Functional Description
3.15 Special Function Registers Overview

The following table lists all SFRs which are implemented in the C167CR 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).

Note: Registers within device specific interface modules (CAN) are only present in the corresponding device, of course.

Table 8 C167CR Registers, Ordered by Name

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|-----------------|----------------------------|--------------------------|--|-------------------|
| ADCIC | b FF98 _H | CC _H | A/D Converter End of Conversion Interrupt Control Register | 0000 _H |
| ADCON | b FFA0 _H | D0 _H | A/D Converter Control Register | 0000 _H |
| ADDAT | FEA0 _H | 50 _H | A/D Converter Result Register | 0000 _H |
| ADDAT2 | F0A0 _H | E 50 _H | A/D Converter 2 Result Register | 0000 _H |
| ADDRSEL1 | FE18 _H | 0C _H | Address Select Register 1 | 0000 _H |
| ADDRSEL2 | FE1A _H | 0D _H | Address Select Register 2 | 0000 _H |
| ADDRSEL3 | FE1C _H | 0E _H | Address Select Register 3 | 0000 _H |
| ADDRSEL4 | FE1E _H | 0F _H | Address Select Register 4 | 0000 _H |
| ADEIC | b FF9A _H | CD _H | A/D Converter Overrun Error Interrupt Control Register | 0000 _H |
| BUSCON0 | b FF0C _H | 86 _H | Bus Configuration Register 0 | 0XX0 _H |
| BUSCON1 | b FF14 _H | 8A _H | Bus Configuration Register 1 | 0000 _H |
| BUSCON2 | b FF16 _H | 8B _H | Bus Configuration Register 2 | 0000 _H |
| BUSCON3 | b FF18 _H | 8C _H | Bus Configuration Register 3 | 0000 _H |
| BUSCON4 | b FF1A _H | 8D _H | Bus Configuration Register 4 | 0000 _H |
| C1BTR | EF04 _H | X – | CAN1 Bit Timing Register | UUUU _H |
| C1CSR | EF00 _H | X – | CAN1 Control / Status Register | XX01 _H |
| C1GMS | EF06 _H | X – | CAN1 Global Mask Short | UFUU _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|---------------|-------------------------------------|-----------------|---|-------------------|
| C1IR | EF02 _H X | – | CAN1 Interrupt Register | XX _H |
| C1LGML | EF0A _H X | – | CAN1 Lower Global Mask Long | UUUU _H |
| C1LMLM | EF0E _H X | – | CAN1 Lower Mask of Last Message | UUUU _H |
| C1UAR | EFn2 _H X | – | CAN1 Upper Arbitration Register (message n) | UUUU _H |
| C1UGML | EF08 _H X | – | CAN1 Upper Global Mask Long | UUUU _H |
| C1UMLM | EF0C _H X | – | CAN1 Upper Mask of Last Message | UUUU _H |
| CAPREL | FE4A _H | 25 _H | GPT2 Capture/Reload Register | 0000 _H |
| CC0 | FE80 _H | 40 _H | CAPCOM Register 0 | 0000 _H |
| CC0IC | b FF78 _H | BC _H | CAPCOM Register 0 Interrupt Ctrl. Reg. | 0000 _H |
| CC1 | FE82 _H | 41 _H | CAPCOM Register 1 | 0000 _H |
| CC10 | FE94 _H | 4A _H | CAPCOM Register 10 | 0000 _H |
| CC10IC | b FF8C _H | C6 _H | CAPCOM Reg. 10 Interrupt Ctrl. Reg. | 0000 _H |
| CC11 | FE96 _H | 4B _H | CAPCOM Register 11 | 0000 _H |
| CC11IC | b FF8E _H | C7 _H | CAPCOM Reg. 11 Interrupt Ctrl. Reg. | 0000 _H |
| CC12 | FE98 _H | 4C _H | CAPCOM Register 12 | 0000 _H |
| CC12IC | b FF90 _H | C8 _H | CAPCOM Reg. 12 Interrupt Ctrl. Reg. | 0000 _H |
| CC13 | FE9A _H | 4D _H | CAPCOM Register 13 | 0000 _H |
| CC13IC | b FF92 _H | C9 _H | CAPCOM Reg. 13 Interrupt Ctrl. Reg. | 0000 _H |
| CC14 | FE9C _H | 4E _H | CAPCOM Register 14 | 0000 _H |
| CC14IC | b FF94 _H | CA _H | CAPCOM Reg. 14 Interrupt Ctrl. Reg. | 0000 _H |
| CC15 | FE9E _H | 4F _H | CAPCOM Register 15 | 0000 _H |
| CC15IC | b FF96 _H | CB _H | CAPCOM Reg. 15 Interrupt Ctrl. Reg. | 0000 _H |
| CC16 | FE60 _H | 30 _H | CAPCOM Register 16 | 0000 _H |
| CC16IC | b F160 _H E | B0 _H | CAPCOM Reg. 16 Interrupt Ctrl. Reg. | 0000 _H |
| CC17 | FE62 _H | 31 _H | CAPCOM Register 17 | 0000 _H |
| CC17IC | b F162 _H E | B1 _H | CAPCOM Reg. 17 Interrupt Ctrl. Reg. | 0000 _H |
| CC18 | FE64 _H | 32 _H | CAPCOM Register 18 | 0000 _H |
| CC18IC | b F164 _H E | B2 _H | CAPCOM Reg. 18 Interrupt Ctrl. Reg. | 0000 _H |
| CC19 | FE66 _H | 33 _H | CAPCOM Register 19 | 0000 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|---------------|-------------------------------------|-----------------|-------------------------------------|-------------------|
| CC19IC | b F166 _H E | B3 _H | CAPCOM Reg. 19 Interrupt Ctrl. Reg. | 0000 _H |
| CC1IC | b FF7A _H | BD _H | CAPCOM Reg. 1 Interrupt Ctrl. Reg. | 0000 _H |
| CC2 | FE84 _H | 42 _H | CAPCOM Register 2 | 0000 _H |
| CC20 | FE68 _H | 34 _H | CAPCOM Register 20 | 0000 _H |
| CC20IC | b F168 _H E | B4 _H | CAPCOM Reg. 20 Interrupt Ctrl. Reg. | 0000 _H |
| CC21 | FE6A _H | 35 _H | CAPCOM Register 21 | 0000 _H |
| CC21IC | b F16A _H E | B5 _H | CAPCOM Reg. 21 Interrupt Ctrl. Reg. | 0000 _H |
| CC22 | FE6C _H | 36 _H | CAPCOM Register 22 | 0000 _H |
| CC22IC | b F16C _H E | B6 _H | CAPCOM Reg. 22 Interrupt Ctrl. Reg. | 0000 _H |
| CC23 | FE6E _H | 37 _H | CAPCOM Register 23 | 0000 _H |
| CC23IC | b F16E _H E | B7 _H | CAPCOM Reg. 23 Interrupt Ctrl. Reg. | 0000 _H |
| CC24 | FE70 _H | 38 _H | CAPCOM Register 24 | 0000 _H |
| CC24IC | b F170 _H E | B8 _H | CAPCOM Reg. 24 Interrupt Ctrl. Reg. | 0000 _H |
| CC25 | FE72 _H | 39 _H | CAPCOM Register 25 | 0000 _H |
| CC25IC | b F172 _H E | B9 _H | CAPCOM Reg. 25 Interrupt Ctrl. Reg. | 0000 _H |
| CC26 | FE74 _H | 3A _H | CAPCOM Register 26 | 0000 _H |
| CC26IC | b F174 _H E | BA _H | CAPCOM Reg. 26 Interrupt Ctrl. Reg. | 0000 _H |
| CC27 | FE76 _H | 3B _H | CAPCOM Register 27 | 0000 _H |
| CC27IC | b F176 _H E | BB _H | CAPCOM Reg. 27 Interrupt Ctrl. Reg. | 0000 _H |
| CC28 | FE78 _H | 3C _H | CAPCOM Register 28 | 0000 _H |
| CC28IC | b F178 _H E | BC _H | CAPCOM Reg. 28 Interrupt Ctrl. Reg. | 0000 _H |
| CC29 | FE7A _H | 3D _H | CAPCOM Register 29 | 0000 _H |
| CC29IC | b F184 _H E | C2 _H | CAPCOM Reg. 29 Interrupt Ctrl. Reg. | 0000 _H |
| CC2IC | b FF7C _H | BE _H | CAPCOM Reg. 2 Interrupt Ctrl. Reg. | 0000 _H |
| CC3 | FE86 _H | 43 _H | CAPCOM Register 3 | 0000 _H |
| CC30 | FE7C _H | 3E _H | CAPCOM Register 30 | 0000 _H |
| CC30IC | b F18C _H E | C6 _H | CAPCOM Reg. 30 Interrupt Ctrl. Reg. | 0000 _H |
| CC31 | FE7E _H | 3F _H | CAPCOM Register 31 | 0000 _H |
| CC31IC | b F194 _H E | CA _H | CAPCOM Reg. 31 Interrupt Ctrl. Reg. | 0000 _H |
| CC3IC | b FF7E _H | BF _H | CAPCOM Reg. 3 Interrupt Ctrl. Reg. | 0000 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|--------------|----------------------------|--------------------------|--|-------------------|
| CC4 | FE88 _H | 44 _H | CAPCOM Register 4 | 0000 _H |
| CC4IC | b FF80 _H | C0 _H | CAPCOM Reg. 4 Interrupt Ctrl. Reg. | 0000 _H |
| CC5 | FE8A _H | 45 _H | CAPCOM Register 5 | 0000 _H |
| CC5IC | b FF82 _H | C1 _H | CAPCOM Register 5 Interrupt Ctrl. Reg. | 0000 _H |
| CC6 | FE8C _H | 46 _H | CAPCOM Register 6 | 0000 _H |
| CC6IC | b FF84 _H | C2 _H | CAPCOM Reg. 6 Interrupt Ctrl. Reg. | 0000 _H |
| CC7 | FE8E _H | 47 _H | CAPCOM Register 7 | 0000 _H |
| CC7IC | b FF86 _H | C3 _H | CAPCOM Reg. 7 Interrupt Ctrl. Reg. | 0000 _H |
| CC8 | FE90 _H | 48 _H | CAPCOM Register 8 | 0000 _H |
| CC8IC | b FF88 _H | C4 _H | CAPCOM Reg. 8 Interrupt Ctrl. Reg. | 0000 _H |
| CC9 | FE92 _H | 49 _H | CAPCOM Register 9 | 0000 _H |
| CC9IC | b FF8A _H | C5 _H | CAPCOM Reg. 9 Interrupt Ctrl. Reg. | 0000 _H |
| CCM0 | b FF52 _H | A9 _H | CAPCOM Mode Control Register 0 | 0000 _H |
| CCM1 | b FF54 _H | AA _H | CAPCOM Mode Control Register 1 | 0000 _H |
| CCM2 | b FF56 _H | AB _H | CAPCOM Mode Control Register 2 | 0000 _H |
| CCM3 | b FF58 _H | AC _H | CAPCOM Mode Control Register 3 | 0000 _H |
| CCM4 | b FF22 _H | 91 _H | CAPCOM Mode Control Register 4 | 0000 _H |
| CCM5 | b FF24 _H | 92 _H | CAPCOM Mode Control Register 5 | 0000 _H |
| CCM6 | b FF26 _H | 93 _H | CAPCOM Mode Control Register 6 | 0000 _H |
| CCM7 | b FF28 _H | 94 _H | CAPCOM Mode Control Register 7 | 0000 _H |
| CP | FE10 _H | 08 _H | CPU Context Pointer Register | FC00 _H |
| CRIC | b FF6A _H | B5 _H | GPT2 CAPREL Interrupt Ctrl. Register | 0000 _H |
| CSP | FE08 _H | 04 _H | CPU Code Segment Pointer Register (read only) | 0000 _H |
| DP0L | b F100 _H | E 80 _H | P0L Direction Control Register | 00 _H |
| DP0H | b F102 _H | E 81 _H | P0H Direction Control Register | 00 _H |
| DP1L | b F104 _H | E 82 _H | P1L Direction Control Register | 00 _H |
| DP1H | b F106 _H | E 83 _H | P1H Direction Control Register | 00 _H |
| DP2 | b FFC2 _H | E1 _H | Port 2 Direction Control Register | 0000 _H |
| DP3 | b FFC6 _H | E3 _H | Port 3 Direction Control Register | 0000 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | | Physical Address | 8-Bit Addr. | Description | Reset Value |
|----------------|----------|-------------------|--------------------------|---|-------------------|
| DP4 | b | FFCA _H | E5 _H | Port 4 Direction Control Register | 00 _H |
| DP6 | b | FFCE _H | E7 _H | Port 6 Direction Control Register | 00 _H |
| DP7 | b | FFD2 _H | E9 _H | Port 7 Direction Control Register | 00 _H |
| DP8 | b | FFD6 _H | EB _H | Port 8 Direction Control Register | 00 _H |
| DPP0 | | FE00 _H | 00 _H | CPU Data Page Pointer 0 Reg. (10 bits) | 0000 _H |
| DPP1 | | FE02 _H | 01 _H | CPU Data Page Pointer 1 Reg. (10 bits) | 0001 _H |
| DPP2 | | FE04 _H | 02 _H | CPU Data Page Pointer 2 Reg. (10 bits) | 0002 _H |
| DPP3 | | FE06 _H | 03 _H | CPU Data Page Pointer 3 Reg. (10 bits) | 0003 _H |
| EXICON | b | F1C0 _H | E E0 _H | External Interrupt Control Register | 0000 _H |
| MDC | b | FF0E _H | 87 _H | CPU Multiply Divide Control Register | 0000 _H |
| MDH | | FE0C _H | 06 _H | CPU Multiply Divide Reg. – High Word | 0000 _H |
| MDL | | FE0E _H | 07 _H | CPU Multiply Divide Reg. – Low Word | 0000 _H |
| ODP2 | b | F1C2 _H | E E1 _H | Port 2 Open Drain Control Register | 0000 _H |
| ODP3 | b | F1C6 _H | E E3 _H | Port 3 Open Drain Control Register | 0000 _H |
| ODP6 | b | F1CE _H | E E7 _H | Port 6 Open Drain Control Register | 00 _H |
| ODP7 | b | F1D2 _H | E E9 _H | Port 7 Open Drain Control Register | 00 _H |
| ODP8 | b | F1D6 _H | E EB _H | Port 8 Open Drain Control Register | 00 _H |
| ONES | | FF1E _H | 8F _H | Constant Value 1's Register (read only) | FFFF _H |
| P0H | b | FF02 _H | 81 _H | Port 0 High Reg. (Upper half of PORT0) | 00 _H |
| P0L | b | FF00 _H | 80 _H | Port 0 Low Reg. (Lower half of PORT0) | 00 _H |
| P1H | b | FF06 _H | 83 _H | Port 1 High Reg. (Upper half of PORT1) | 00 _H |
| P1L | b | FF04 _H | 82 _H | Port 1 Low Reg. (Lower half of PORT1) | 00 _H |
| P2 | b | FFC0 _H | E0 _H | Port 2 Register | 0000 _H |
| P3 | b | FFC4 _H | E2 _H | Port 3 Register | 0000 _H |
| P4 | b | FFC8 _H | E4 _H | Port 4 Register (8 bits) | 00 _H |
| P5 | b | FFA2 _H | D1 _H | Port 5 Register (read only) | XXXX _H |
| P5DIDIS | b | FFA4 _H | D2 _H | Port 5 Digital Input Disable Register | 0000 _H |
| P6 | b | FFCC _H | E6 _H | Port 6 Register (8 bits) | 00 _H |
| P7 | b | FFD0 _H | E8 _H | Port 7 Register (8 bits) | 00 _H |
| P8 | b | FFD4 _H | EA _H | Port 8 Register (8 bits) | 00 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|----------------|----------------------------|--------------------------|---|-------------------|
| PECC0 | FEC0 _H | 60 _H | PEC Channel 0 Control Register | 0000 _H |
| PECC1 | FEC2 _H | 61 _H | PEC Channel 1 Control Register | 0000 _H |
| PECC2 | FEC4 _H | 62 _H | PEC Channel 2 Control Register | 0000 _H |
| PECC3 | FEC6 _H | 63 _H | PEC Channel 3 Control Register | 0000 _H |
| PECC4 | FEC8 _H | 64 _H | PEC Channel 4 Control Register | 0000 _H |
| PECC5 | FECA _H | 65 _H | PEC Channel 5 Control Register | 0000 _H |
| PECC6 | FECC _H | 66 _H | PEC Channel 6 Control Register | 0000 _H |
| PECC7 | FECE _H | 67 _H | PEC Channel 7 Control Register | 0000 _H |
| PICON | b F1C4 _H | E E2 _H | Port Input Threshold Control Register | 0000 _H |
| PDCR | F0AA _H | E 55 _H | Pin Driver Control Register | 0000 _H |
| PP0 | F038 _H | E 1C _H | PWM Module Period Register 0 | 0000 _H |
| PP1 | F03A _H | E 1D _H | PWM Module Period Register 1 | 0000 _H |
| PP2 | F03C _H | E 1E _H | PWM Module Period Register 2 | 0000 _H |
| PP3 | F03E _H | E 1F _H | PWM Module Period Register 3 | 0000 _H |
| PSW | b FF10 _H | 88 _H | CPU Program Status Word | 0000 _H |
| PT0 | F030 _H | E 18 _H | PWM Module Up/Down Counter 0 | 0000 _H |
| PT1 | F032 _H | E 19 _H | PWM Module Up/Down Counter 1 | 0000 _H |
| PT2 | F034 _H | E 1A _H | PWM Module Up/Down Counter 2 | 0000 _H |
| PT3 | F036 _H | E 1B _H | PWM Module Up/Down Counter 3 | 0000 _H |
| PW0 | FE30 _H | 18 _H | PWM Module Pulse Width Register 0 | 0000 _H |
| PW1 | FE32 _H | 19 _H | PWM Module Pulse Width Register 1 | 0000 _H |
| PW2 | FE34 _H | 1A _H | PWM Module Pulse Width Register 2 | 0000 _H |
| PW3 | FE36 _H | 1B _H | PWM Module Pulse Width Register 3 | 0000 _H |
| PWMCON0 | b FF30 _H | 98 _H | PWM Module Control Register 0 | 0000 _H |
| PWMCON1 | b FF32 _H | 99 _H | PWM Module Control Register 1 | 0000 _H |
| PWMIC | b F17E _H | E BF _H | PWM Module Interrupt Control Register | 0000 _H |
| RP0H | b F108 _H | E 84 _H | System Start-up Config. Reg. (Rd. only) | XX _H |
| S0BG | FEB4 _H | 5A _H | Serial Channel 0 Baudrate Generator Reload Register | 0000 _H |
| S0CON | b FFB0 _H | D8 _H | Serial Channel 0 Control Register | 0000 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | | Physical Address | 8-Bit Addr. | Description | Reset Value |
|---------------|----------|-------------------|--------------------------|---|---------------------------------|
| S0EIC | b | FF70 _H | B8 _H | Serial Chan. 0 Error Interrupt Ctrl. Reg. | 0000 _H |
| S0RBUF | | FEB2 _H | 59 _H | Serial Channel 0 Receive Buffer Reg. (read only) | XX _H |
| S0RIC | b | FF6E _H | B7 _H | Serial Channel 0 Receive Interrupt Control Register | 0000 _H |
| S0TBIC | b | F19C _H | E CE _H | Serial Channel 0 Transmit Buffer Interrupt Control Register | 0000 _H |
| S0TBUF | | FEB0 _H | 58 _H | Serial Channel 0 Transmit Buffer Reg. (write only) | 00 _H |
| S0TIC | b | FF6C _H | B6 _H | Serial Channel 0 Transmit Interrupt Control Register | 0000 _H |
| SP | | FE12 _H | 09 _H | CPU System Stack Pointer Register | FC00 _H |
| SSCBR | | F0B4 _H | E 5A _H | SSC Baudrate Register | 0000 _H |
| SSCON | b | FFB2 _H | D9 _H | SSC Control Register | 0000 _H |
| SSCEIC | b | FF76 _H | BB _H | SSC Error Interrupt Control Register | 0000 _H |
| SSCRB | | F0B2 _H | E 59 _H | SSC Receive Buffer | XXXX _H |
| SSCRIC | b | FF74 _H | BA _H | SSC Receive Interrupt Control Register | 0000 _H |
| SSCTB | | F0B0 _H | E 58 _H | SSC Transmit Buffer | 0000 _H |
| SSCTIC | b | FF72 _H | B9 _H | SSC Transmit Interrupt Control Register | 0000 _H |
| STKOV | | FE14 _H | 0A _H | CPU Stack Overflow Pointer Register | FA00 _H |
| STKUN | | FE16 _H | 0B _H | CPU Stack Underflow Pointer Register | FC00 _H |
| SYSCON | b | FF12 _H | 89 _H | CPU System Configuration Register | ¹⁾ 0xx0 _H |
| T0 | | FE50 _H | 28 _H | CAPCOM Timer 0 Register | 0000 _H |
| T01CON | b | FF50 _H | A8 _H | CAPCOM Timer 0 and Timer 1 Ctrl. Reg. | 0000 _H |
| T0IC | b | FF9C _H | CE _H | CAPCOM Timer 0 Interrupt Ctrl. Reg. | 0000 _H |
| T0REL | | FE54 _H | 2A _H | CAPCOM Timer 0 Reload Register | 0000 _H |
| T1 | | FE52 _H | 29 _H | CAPCOM Timer 1 Register | 0000 _H |
| T1IC | b | FF9E _H | CF _H | CAPCOM Timer 1 Interrupt Ctrl. Reg. | 0000 _H |
| T1REL | | FE56 _H | 2B _H | CAPCOM Timer 1 Reload Register | 0000 _H |
| T2 | | FE40 _H | 20 _H | GPT1 Timer 2 Register | 0000 _H |
| T2CON | b | FF40 _H | A0 _H | GPT1 Timer 2 Control Register | 0000 _H |

Functional Description
Table 8 C167CR Registers, Ordered by Name (cont'd)

| Name | Physical Address | 8-Bit Addr. | Description | Reset Value |
|---------------|----------------------------|--------------------------|---|---------------------------------|
| T2IC | b FF60 _H | B0 _H | GPT1 Timer 2 Interrupt Control Register | 0000 _H |
| T3 | FE42 _H | 21 _H | GPT1 Timer 3 Register | 0000 _H |
| T3CON | b FF42 _H | A1 _H | GPT1 Timer 3 Control Register | 0000 _H |
| T3IC | b FF62 _H | B1 _H | GPT1 Timer 3 Interrupt Control Register | 0000 _H |
| T4 | FE44 _H | 22 _H | GPT1 Timer 4 Register | 0000 _H |
| T4CON | b FF44 _H | A2 _H | GPT1 Timer 4 Control Register | 0000 _H |
| T4IC | b FF64 _H | B2 _H | GPT1 Timer 4 Interrupt Control Register | 0000 _H |
| T5 | FE46 _H | 23 _H | GPT2 Timer 5 Register | 0000 _H |
| T5CON | b FF46 _H | A3 _H | GPT2 Timer 5 Control Register | 0000 _H |
| T5IC | b FF66 _H | B3 _H | GPT2 Timer 5 Interrupt Control Register | 0000 _H |
| T6 | FE48 _H | 24 _H | GPT2 Timer 6 Register | 0000 _H |
| T6CON | b FF48 _H | A4 _H | GPT2 Timer 6 Control Register | 0000 _H |
| T6IC | b FF68 _H | B4 _H | GPT2 Timer 6 Interrupt Control Register | 0000 _H |
| T7 | F050 _H | E 28 _H | CAPCOM Timer 7 Register | 0000 _H |
| T78CON | b FF20 _H | 90 _H | CAPCOM Timer 7 and 8 Ctrl. Reg. | 0000 _H |
| T7IC | b F17A _H | E BE _H | CAPCOM Timer 7 Interrupt Ctrl. Reg. | 0000 _H |
| T7REL | F054 _H | E 2A _H | CAPCOM Timer 7 Reload Register | 0000 _H |
| T8 | F052 _H | E 29 _H | CAPCOM Timer 8 Register | 0000 _H |
| T8IC | b F17C _H | E BF _H | CAPCOM Timer 8 Interrupt Ctrl. Reg. | 0000 _H |
| T8REL | F056 _H | E 2B _H | CAPCOM Timer 8 Reload Register | 0000 _H |
| TFR | b FFAC _H | D6 _H | Trap Flag Register | 0000 _H |
| WDT | FEAE _H | 57 _H | Watchdog Timer Register (read only) | 0000 _H |
| WDTCON | FFAE _H | D7 _H | Watchdog Timer Control Register | ²⁾ 00XX _H |
| XP0IC | b F186 _H | E C3 _H | CAN1 Module Interrupt Control Register | 0000 _H |
| XP1IC | b F18E _H | E C7 _H | Unassigned Interrupt Control Register | 0000 _H |
| XP2IC | b F196 _H | E CB _H | Unassigned Interrupt Control Register | 0000 _H |
| XP3IC | b F19E _H | E CF _H | PLL/OWD Interrupt Control Register | 0000 _H |
| ZEROS | b FF1C _H | 8E _H | Constant Value 0's Register (read only) | 0000 _H |

1) The system configuration is selected during reset.

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

4 Electrical Parameters

4.1 General Parameters

Table 9 Absolute Maximum Rating Parameters

| Parameter | Symbol | Limit Values | | Unit | Notes |
|--|------------|--------------|----------------|------|------------|
| | | Min. | Max. | | |
| Storage temperature | T_{ST} | -65 | 150 | °C | – |
| Junction temperature | T_J | -40 | 150 | °C | under bias |
| 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 C167CR. All parameters specified in the following sections refer to these operating conditions, unless otherwise noticed.

Table 10 Operating Condition Parameters

| Parameter | Symbol | Limit Values | | Unit | Notes |
|-----------------------------------|------------------|-------------------|------|------|---|
| | | Min. | Max. | | |
| Digital supply voltage | V_{DD} | 4.5 | 5.5 | V | Active mode, $f_{CPUmax} = 33$ MHz |
| | | 2.5 ¹⁾ | 5.5 | V | Power Down mode |
| Digital ground voltage | V_{SS} | 0 | | V | Reference voltage |
| Overload current | I_{OV} | – | ±5 | mA | Per pin ²⁾³⁾ |
| Absolute sum of overload currents | $\Sigma I_{OV} $ | – | 50 | mA | ³⁾ |
| External Load Capacitance | C_L | – | 50 | pF | Pin drivers in fast edge mode (PDCR.BIPEC = '0') |
| | | – | 30 | pF | Pin drivers in reduced edge mode (PDCR.BIPEC = '1') ³⁾ |
| | | – | 100 | pF | Pin drivers in fast edge mode, $f_{CPUmax} = 25$ MHz ⁴⁾ |
| Ambient temperature | T_A | 0 | 70 | °C | SAB-C167CR ... |
| | | -40 | 85 | °C | SAF-C167CR ... |
| | | -40 | 125 | °C | SAK-C167CR ... |

- 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. $V_{OV} > V_{DD} + 0.5$ V or $V_{OV} < V_{SS} - 0.5$ V). The absolute sum of input overload currents on all pins may not exceed **50 mA**. The supply voltage must remain within the specified limits. Proper operation is not guaranteed if overload conditions occur on functional pins like XTAL1, \overline{RD} , \overline{WR} , etc.
- 3) Not subject to production test - verified by design/characterization.
- 4) The increased capacitive load is valid for the 25 MHz-derivatives up to a CPU clock frequency of 25 MHz. Under these circumstances the timing parameters as specified in the "C167CR Data Sheet 1999-06" are valid.

Parameter Interpretation

The parameters listed in the following partly represent the characteristics of the C167CR 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 C167CR will provide signals with the respective timing characteristics.

SR (System Requirement):

The external system must provide signals with the respective timing characteristics to the C167CR.

4.2 DC Parameters

Table 11 DC Characteristics (Operating Conditions apply)¹⁾

| Parameter | Symbol | Limit Values | | Unit | Test Condition |
|---|--------------|--------------------|--------------------|------|--------------------------------|
| | | Min. | Max. | | |
| Input low voltage (TTL, all except XTAL1) | V_{IL} SR | -0.5 | $0.2 V_{DD} - 0.1$ | V | – |
| Input low voltage XTAL1 | V_{IL2} SR | -0.5 | $0.3 V_{DD}$ | V | – |
| Input low voltage (Special Threshold) | V_{ILS} SR | -0.5 | 2.0 | V | – |
| Input high voltage (TTL, all except \overline{RSTIN} and XTAL1) | V_{IH} SR | $0.2 V_{DD} + 0.9$ | $V_{DD} + 0.5$ | V | – |
| Input high voltage \overline{RSTIN} (when operated as input) | V_{IH1} SR | $0.6 V_{DD}$ | $V_{DD} + 0.5$ | V | – |
| Input high voltage XTAL1 | V_{IH2} SR | $0.7 V_{DD}$ | $V_{DD} + 0.5$ | V | – |
| Input high voltage (Special Threshold) | V_{IHS} SR | $0.8 V_{DD} - 0.2$ | $V_{DD} + 0.5$ | V | – |
| Input Hysteresis (Special Threshold) | HYS | 400 | – | mV | Series resistance = 0 Ω |
| Output low voltage ($\overline{PORT0}$, $\overline{PORT1}$, Port 4, ALE, \overline{RD} , \overline{WR} , \overline{BHE} , CLKOUT, \overline{RSTOUT} , \overline{RSTIN} ²⁾) | V_{OL} CC | – | 0.45 | V | $I_{OL} = 2.4 \text{ mA}$ |
| Output low voltage (all other outputs) | V_{OL1} CC | – | 0.45 | V | $I_{OL} = 1.6 \text{ mA}$ |

Electrical Parameters
Table 11 DC Characteristics (Operating Conditions apply)¹⁾ (cont'd)

| Parameter | Symbol | Limit Values | | Unit | Test Condition |
|---|--------------------------|--------------|-----------|---------|-----------------------------------|
| | | Min. | Max. | | |
| Output high voltage ³⁾ (PORT0, PORT1, Port 4, ALE, RD, WR, BHE, CLKOUT, RSTOUT) | V_{OH} CC | 2.4 | – | V | $I_{OH} = -2.4$ mA |
| | | $0.9 V_{DD}$ | – | V | $I_{OH} = -0.5$ mA |
| Output high voltage ³⁾ (all other outputs) | V_{OH1} CC | 2.4 | – | V | $I_{OH} = -1.6$ mA |
| | | $0.9 V_{DD}$ | – | V | $I_{OH} = -0.5$ mA |
| Input leakage current (Port 5) | I_{OZ1} CC | – | ± 200 | nA | $0\text{ V} < V_{IN} < V_{DD}$ |
| Input leakage current (all other) ⁴⁾ | I_{OZ2} CC | – | ± 500 | nA | $0.45\text{ V} < V_{IN} < V_{DD}$ |
| RSTIN inactive current ⁵⁾ | I_{RSTH} ⁶⁾ | – | -10 | μ A | $V_{IN} = V_{IH1}$ |
| RSTIN active current ⁵⁾ | I_{RSTL} ⁷⁾ | -100 | – | μ A | $V_{IN} = V_{IL}$ |
| READY/RD/WR inact. current ⁸⁾ | I_{RWH} ⁶⁾ | – | -40 | μ A | $V_{OUT} = 2.4$ V |
| READY/RD/WR active current ⁸⁾ | I_{RWL} ⁷⁾ | -500 | – | μ A | $V_{OUT} = V_{OLmax}$ |
| ALE inactive current ⁸⁾ | I_{ALEL} ⁶⁾ | – | 40 | μ A | $V_{OUT} = V_{OLmax}$ |
| ALE active current ⁸⁾ | I_{ALEH} ⁷⁾ | 500 | – | μ A | $V_{OUT} = 2.4$ V |
| Port 6 inactive current ⁸⁾ | I_{P6H} ⁶⁾ | – | -40 | μ A | $V_{OUT} = 2.4$ V |
| Port 6 active current ⁸⁾ | I_{P6L} ⁷⁾ | -500 | – | μ A | $V_{OUT} = V_{OL1max}$ |
| PORT0 configuration current ⁹⁾ | I_{P0H} ⁶⁾ | – | -10 | μ A | $V_{IN} = V_{IHmin}$ |
| | I_{P0L} ⁷⁾ | -100 | – | μ A | $V_{IN} = V_{ILmax}$ |
| XTAL1 input current | I_{IL} CC | – | ± 20 | μ A | $0\text{ V} < V_{IN} < V_{DD}$ |
| Pin capacitance ¹⁰⁾ (digital inputs/outputs) | C_{IO} CC | – | 10 | pF | $f = 1$ MHz; $T_A = 25$ °C |

- 1) Keeping signal levels within the levels specified in this table, ensures operation without overload conditions. For signal levels outside these specifications also refer to the specification of the overload current I_{OV} .
- 2) Valid in bidirectional reset mode only.
- 3) 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.
- 4) This parameter is not valid for pins $\overline{\text{READY}}$, $\overline{\text{ALE}}$, $\overline{\text{RD}}$, and $\overline{\text{WR}}$ while the respective pull device is on.
- 5) These parameters describe the $\overline{\text{RSTIN}}$ pull-up, which equals a resistance of ca. 50 to 250 k Ω .
- 6) The maximum current may be drawn while the respective signal line remains inactive.
- 7) The minimum current must be drawn in order to drive the respective signal line active.
- 8) This specification is valid during Reset and during Hold-mode or Adapt-mode. During Hold-mode Port 6 pins are only affected, if they are used (configured) for CS output and the open drain function is not enabled. The $\overline{\text{READY}}$ -pull-up is always active, except for Power-down mode.

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- 9) This specification is valid during Reset and during Adapt-mode.
 10) Not subject to production test - verified by design/characterization.

Table 12 Power Consumption C167CR (Operating Conditions apply)

| Parameter | Symbol | Limit Values | | Unit | Test Condition |
|---|----------|--------------|---------------------------|------|--|
| | | Min. | Max. | | |
| Power supply current (active) with all peripherals active | I_{DD} | – | $15 + 2.5 \times f_{CPU}$ | mA | $\overline{RSTIN} = V_{IL}$ f_{CPU} in [MHz] ¹⁾ |
| Idle mode supply current | I_{ID} | – | $10 + 1.0 \times f_{CPU}$ | mA | $\overline{RSTIN} = V_{IH1}$ f_{CPU} in [MHz] ¹⁾ |
| Power-down mode supply current | I_{PD} | – | 50 | μA | $V_{DD} = V_{DDmax}$ ²⁾ |

- 1) The supply current is a function of the operating frequency. This dependency is illustrated in [Figure 9](#). These parameters are tested at V_{DDmax} and maximum CPU clock with all outputs disconnected and all inputs at V_{IL} or V_{IH} .
- 2) 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} , all outputs (including pins configured as outputs) disconnected.

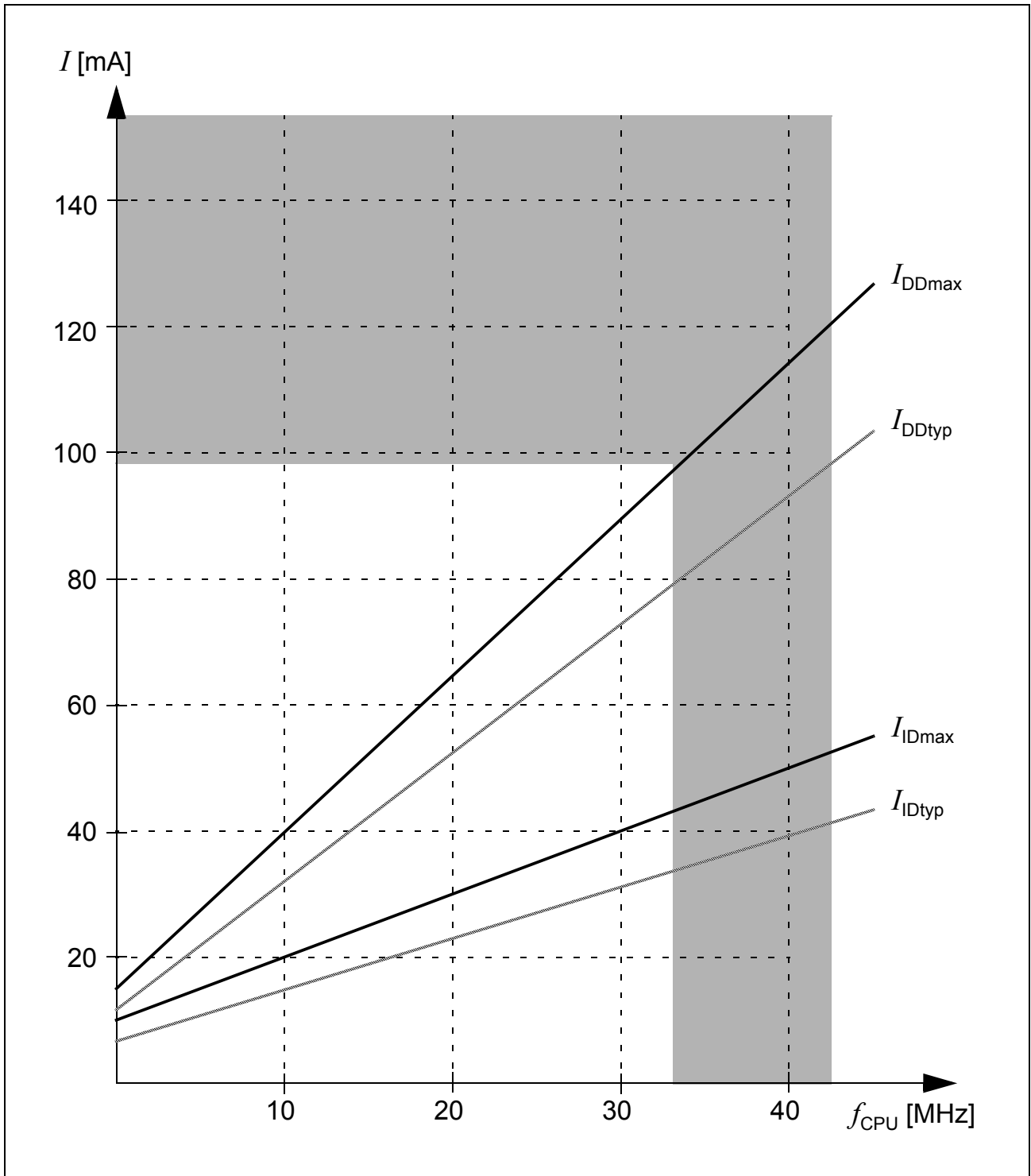


Figure 9 Supply/Idle Current as a Function of Operating Frequency

4.3 Analog/Digital Converter Parameters

Table 13 A/D Converter Characteristics (Operating Conditions apply)

| Parameter | Symbol | Limit Values | | Unit | Test Condition |
|---|---------------|----------------|------------------------------------|------------|----------------------------------|
| | | Min. | Max. | | |
| Analog reference supply | V_{AREF} SR | 4.0 | $V_{DD} + 0.1$ | V | 1) |
| Analog reference ground | V_{AGND} SR | $V_{SS} - 0.1$ | $V_{SS} + 0.2$ | V | – |
| Analog input voltage range | V_{AIN} SR | V_{AGND} | V_{AREF} | V | 2) |
| Basic clock frequency | f_{BC} | 0.5 | 6.25 | MHz | 3) |
| Conversion time | t_C CC | – | $40 t_{BC} + t_S$ $+ 2 t_{CPU}$ | – | 4) $t_{CPU} = 1/f_{CPU}$ |
| Calibration time after reset | t_{CAL} CC | – | $3328 t_{BC}$ | – | 5) |
| Total unadjusted error | TUE CC | – | ± 2 | LSB | 1) |
| Internal resistance of reference voltage source | R_{AREF} SR | – | $t_{BC} / 60$ $- 0.25$ | k Ω | t_{BC} in [ns] ⁶⁾⁷⁾ |
| Internal resistance of analog source | R_{ASRC} SR | – | $t_S / 450$ $- 0.25$ | k Ω | t_S in [ns] ⁷⁾⁸⁾ |
| ADC input capacitance | C_{AIN} CC | – | 33 | pF | 7) |

- 1) TUE is tested at $V_{AREF} = 5.0$ V, $V_{AGND} = 0$ V, $V_{DD} = 4.9$ V. It is guaranteed by design for all other voltages within the defined voltage range.
If the analog reference supply voltage exceeds the power supply voltage by up to 0.2 V (i.e. $V_{AREF} = V_{DD} + 0.2$ V) the maximum TUE is increased to ± 3 LSB. This range is not 100% tested.
The specified TUE is guaranteed only if the absolute sum of input overload currents on Port 5 pins (see I_{OV} specification) does not exceed 10 mA.
During the reset calibration sequence the maximum TUE may be ± 4 LSB.
- 2) V_{AIN} may exceed V_{AGND} or V_{AREF} up to the absolute maximum ratings. However, the conversion result in these cases will be X000_H or X3FF_H, respectively.
- 3) The limit values for f_{BC} must not be exceeded when selecting the CPU frequency and the ADCTC setting.
- 4) This parameter includes the sample time t_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_{BC} depend on programming and can be taken from [Table 14](#).
This parameter depends on the ADC control logic. It is not a real maximum value, but rather a fixum.
- 5) During the reset calibration conversions can be executed (with the current accuracy). The time required for these conversions is added to the total reset calibration time.
- 6) 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.
- 7) Not subject to production test - verified by design/characterization.

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8) During the sample time the input capacitance C_{AIN} 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_S . After the end of the sample time t_S , changes of the analog input voltage have no effect on the conversion result.

Values for the sample time t_S depend on programming and can be taken from [Table 14](#).

Sample time and conversion time of the C167CR's A/D Converter are programmable. [Table 14](#) should be used to calculate the above timings.

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

Table 14 A/D Converter Computation Table

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

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 $t_S = t_{BC} \times 8 = 1280$ ns

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

4.4 AC Parameters

4.4.1 Definition of Internal Timing

The internal operation of the C167CR 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 10](#)).

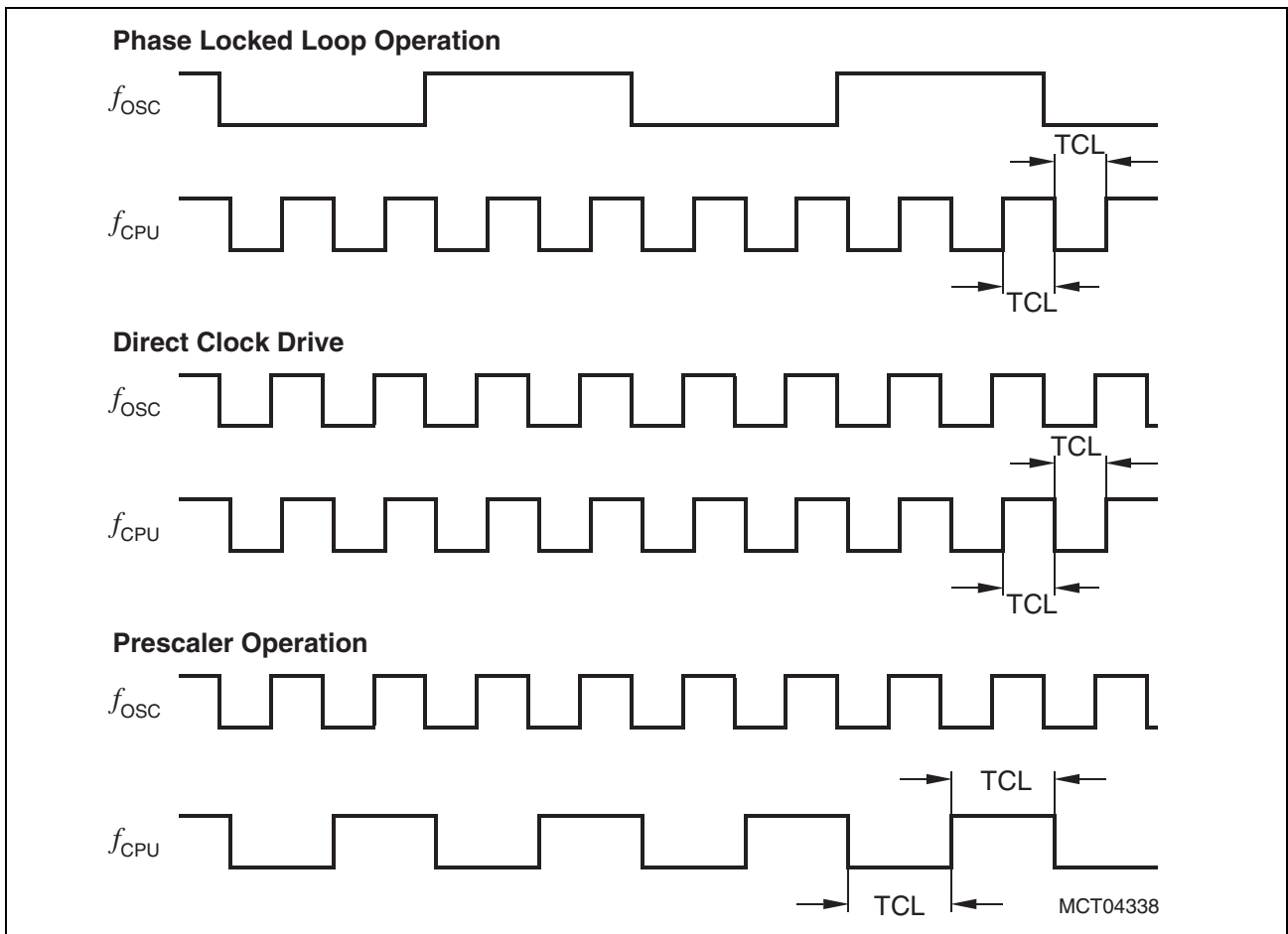


Figure 10 Generation Mechanisms for the CPU Clock

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 C167CR.

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

The used mechanism to generate the basic CPU clock is selected by bitfield CLKCFG in register RP0H.7-5.

Upon a long hardware reset register RP0H is loaded with the logic levels present on the

Electrical Parameters

upper half of PORT0 (P0H), i.e. bitfield CLKCFG represents the logic levels on pins P0.15-13 (P0H.7-5).

Table 15 associates the combinations of these three bits with the respective clock generation mode.

Table 15 C167CR Clock Generation Modes

| CLKCFG (P0H.7-5) | CPU Frequency $f_{\text{CPU}} = f_{\text{OSC}} \times F$ | External Clock Input Range¹⁾ | Notes |
|-------------------------|--|--|----------------------------|
| 1 1 1 | $f_{\text{OSC}} \times 4$ | 2.5 to 8.25 MHz | Default configuration |
| 1 1 0 | $f_{\text{OSC}} \times 3$ | 3.33 to 11 MHz | – |
| 1 0 1 | $f_{\text{OSC}} \times 2$ | 5 to 16.5 MHz | – |
| 1 0 0 | $f_{\text{OSC}} \times 5$ | 2 to 6.6 MHz | – |
| 0 1 1 | $f_{\text{OSC}} \times 1$ | 1 to 33 MHz | Direct drive ²⁾ |
| 0 1 0 | $f_{\text{OSC}} \times 1.5$ | 6.66 to 22 MHz | – |
| 0 0 1 | $f_{\text{OSC}} / 2$ | 2 to 66 MHz | CPU clock via prescaler |
| 0 0 0 | $f_{\text{OSC}} \times 2.5$ | 4 to 13.2 MHz | – |

1) The external clock input range refers to a CPU clock range of 10 ... 33 MHz (PLL operation).

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

Prescaler Operation

When prescaler operation is configured (CLKCFG = 001_B) 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

When PLL operation is configured (via CLKCFG) 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. $f_{\text{CPU}} = f_{\text{OSC}} \times F$). 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.

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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 11](#)).

For a period of $N \times \text{TCL}$ the minimum value is computed using the corresponding deviation D_N :

$$(N \times \text{TCL})_{\min} = N \times \text{TCL}_{\text{NOM}} - D_N, D_N [\text{ns}] = \pm(13.3 + N \times 6.3) / f_{\text{CPU}} [\text{MHz}], \quad (1)$$

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

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

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 negligible.

Note: For all periods longer than 40 TCL the $N = 40$ value can be used (see [Figure 11](#)).

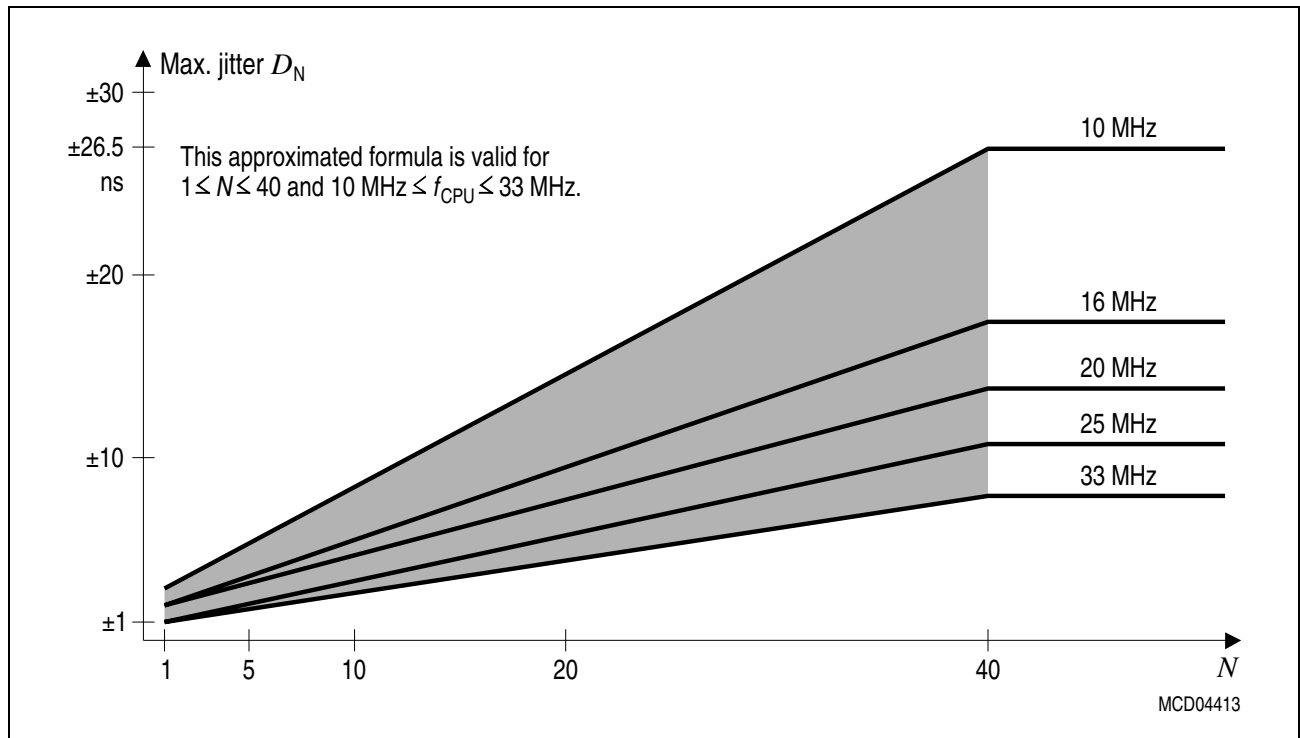


Figure 11 **Approximated Maximum Accumulated PLL Jitter**

Direct Drive

When direct drive is configured (CLKCFG = 011_B) 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_{CPU} directly follows the frequency of f_{OSC} so the high and low time of f_{CPU} (i.e. the duration of an individual TCL) is defined by the duty cycle of the input clock f_{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:

$$\text{TCL}_{\text{min}} = 1/f_{\text{OSC}} \times \text{DC}_{\text{min}} \quad (\text{DC} = \text{duty cycle}) \quad (2)$$

For two consecutive TCLs the deviation caused by the duty cycle of f_{OSC} is compensated so the duration of 2TCL is always $1/f_{\text{OSC}}$. The minimum value 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 $2\text{TCL} = 1/f_{\text{OSC}}$.

4.4.2 External Clock Drive XTAL1

Table 16 External Clock Drive Characteristics (Operating Conditions apply)

| Parameter | Symbol | SR | Direct Drive 1:1 | | Prescaler 2:1 | | PLL 1:N | | Unit |
|-------------------------|-----------|----|---------------------|------|------------------|------|------------------|-------------------|------|
| | | | Min. | Max. | Min. | Max. | Min. | Max. | |
| Oscillator period | t_{OSC} | SR | 30 | – | 15 | – | 45 ¹⁾ | 500 ¹⁾ | ns |
| High time ²⁾ | t_1 | SR | 15 ³⁾ | – | 5 | – | 10 | – | ns |
| Low time ²⁾ | t_2 | SR | 15 ³⁾ | – | 5 | – | 10 | – | ns |
| Rise time ²⁾ | t_3 | SR | – | 8 | – | 5 | – | 10 | ns |
| Fall time ²⁾ | t_4 | SR | – | 8 | – | 5 | – | 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_{IL2} 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.

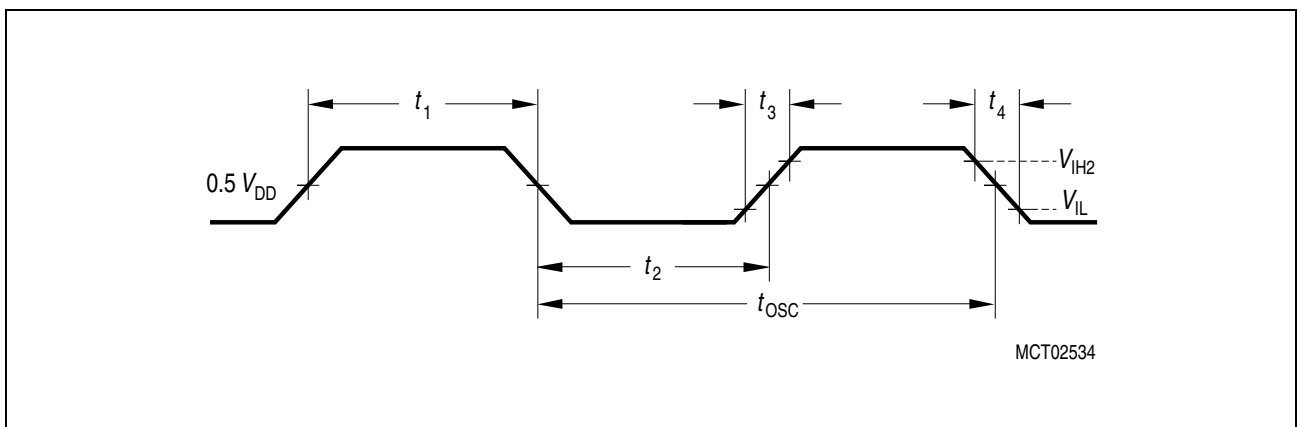


Figure 12 External Clock Drive XTAL1

Note: If the on-chip oscillator is used together with a crystal, the oscillator frequency is limited to a range of 4 MHz to 40 MHz.

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. Please refer to the limits specified by the crystal supplier.

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).

4.4.3 Testing Waveforms

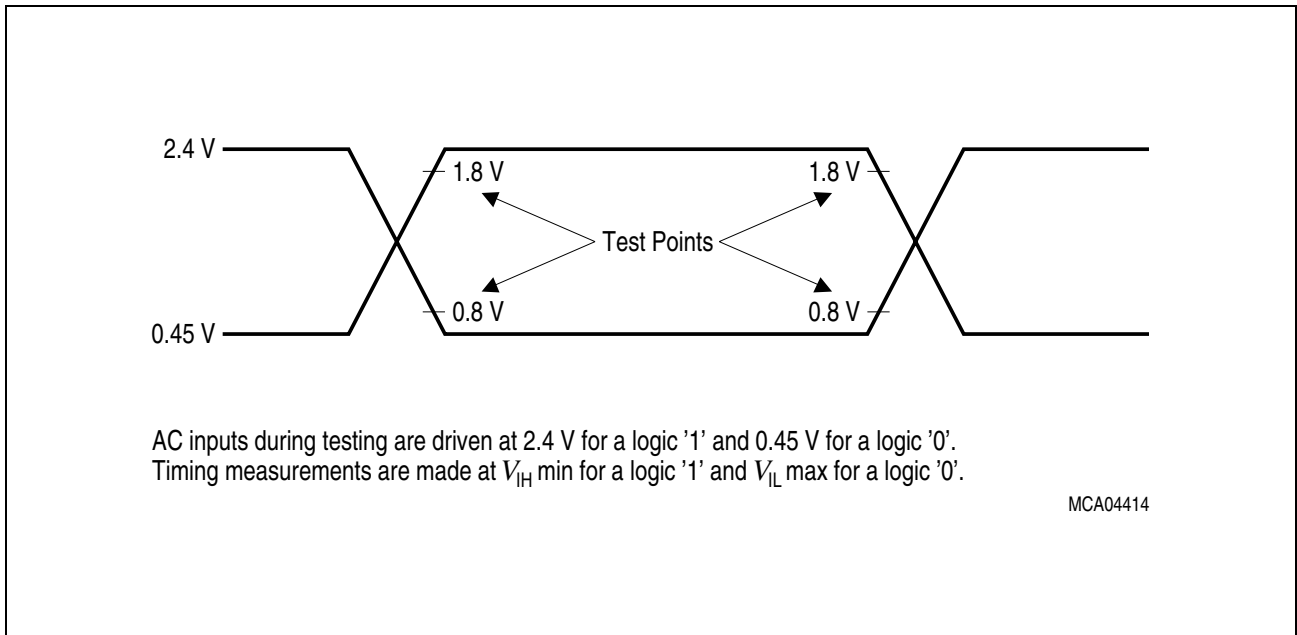


Figure 13 Input Output Waveforms

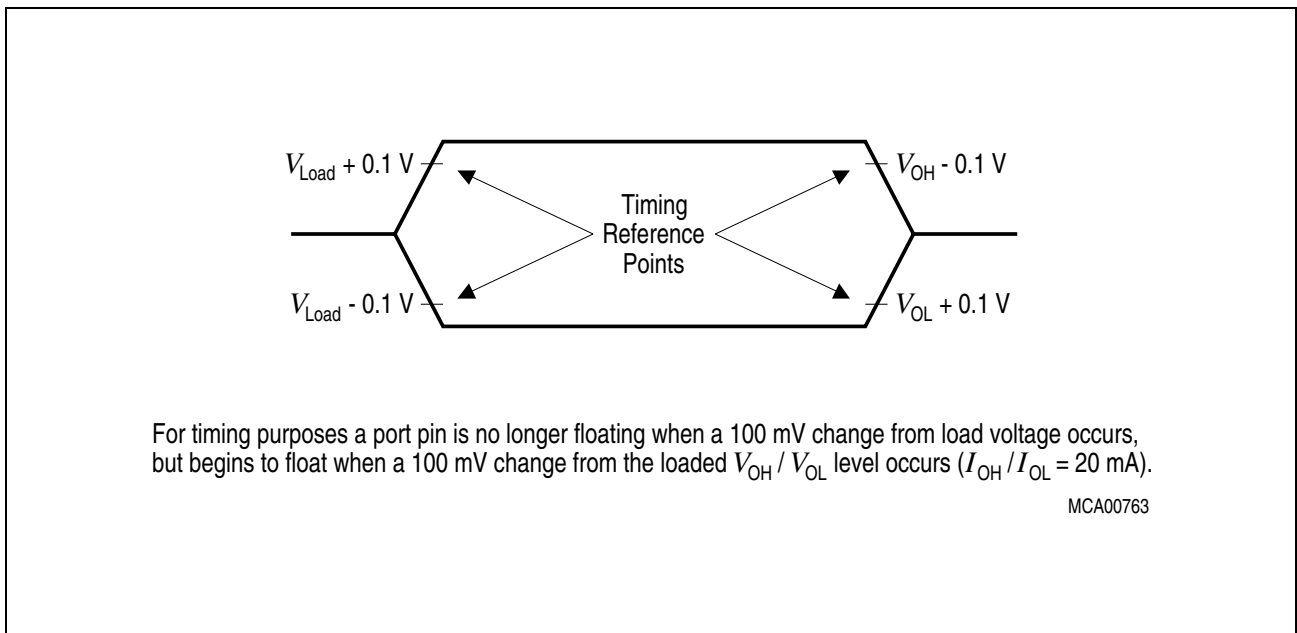


Figure 14 Float Waveforms

4.4.4 External Bus Timing

Table 17 CLKOUT Reference Signal

| Parameter | Symbol | Limits | | Unit |
|-------------------|-------------|------------------|------|------|
| | | Min. | Max. | |
| CLKOUT cycle time | t_{c5} CC | 30 ¹⁾ | | ns |
| CLKOUT high time | t_{c6} CC | 8 | – | ns |
| CLKOUT low time | t_{c7} CC | 6 | – | ns |
| CLKOUT rise time | t_{c8} CC | – | 4 | ns |
| CLKOUT fall time | t_{c9} CC | – | 4 | ns |

- 1) The CLKOUT cycle time is influenced by the PLL jitter.
 For a single CLKOUT cycle (2 TCL) the deviation caused by the PLL jitter is below 1 ns (for $f_{CPU} > 25$ MHz).
 For longer periods the relative deviation decreases (see PLL deviation formula).

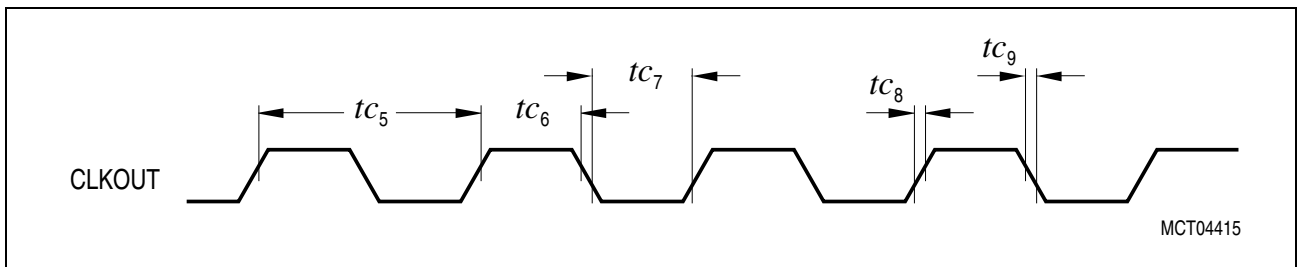


Figure 15 CLKOUT Signal Timing

Variable Memory Cycles

The bus timing shown below is programmable via the BUSCONx registers. The duration of ALE and two types of waitstates can be selected. This table summarizes the possible bus cycle durations.

Table 18 Variable Memory Cycles

| Bus Cycle Type | Bus Cycle Duration | Unit | 25/33 MHz, 0 Waitstates |
|---|--|------|-------------------------|
| Demultiplexed bus cycle with normal ALE | $4 + 2 \times (15 - \langle MCTC \rangle) + 2 \times (1 - \langle MTTC \rangle)$ | TCL | 80 ns/60.6 ns |
| Demultiplexed bus cycle with extended ALE | $6 + 2 \times (15 - \langle MCTC \rangle) + 2 \times (1 - \langle MTTC \rangle)$ | TCL | 120 ns/90.9 ns |
| Multiplexed bus cycle with normal ALE | $6 + 2 \times (15 - \langle MCTC \rangle) + 2 \times (1 - \langle MTTC \rangle)$ | TCL | 120 ns/90.9 ns |
| Multiplexed bus cycle with extended ALE | $8 + 2 \times (15 - \langle MCTC \rangle) + 2 \times (1 - \langle MTTC \rangle)$ | TCL | 160 ns/121.2 ns |

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Table 19 External Bus Cycle Timing (Operating Conditions apply)

| Parameter | Symbol | Limits | | Unit |
|--|--------------|--------|------|------|
| | | Min. | Max. | |
| Output delay from $\overline{\text{CLKOUT}}$ falling edge Valid for: address, $\overline{\text{BHE}}$, early $\overline{\text{CS}}$, write data out, ALE | t_{c10} CC | -2 | 11 | ns |
| Output delay from $\overline{\text{CLKOUT}}$ rising edge Valid for: latched $\overline{\text{CS}}$, ALE low | t_{c11} CC | -2 | 6 | ns |
| Output delay from $\overline{\text{CLKOUT}}$ rising edge Valid for: $\overline{\text{WR}}$ low (no RW delay), $\overline{\text{RD}}$ low (no RW delay) | t_{c12} CC | -2 | 8 | ns |
| Output delay from $\overline{\text{CLKOUT}}$ falling edge Valid for: $\overline{\text{RD}}/\overline{\text{WR}}$ low (with RW delay), $\overline{\text{RD}}$ high (with RW delay) | t_{c13} CC | -2 | 6 | ns |
| Input setup time to $\overline{\text{CLKOUT}}$ falling edge Valid for: read data in | t_{c14} SR | 14 | – | ns |
| Input hold time after $\overline{\text{CLKOUT}}$ falling edge Valid for: read data in ¹⁾ | t_{c15} SR | 0 | – | ns |
| Output hold time after $\overline{\text{CLKOUT}}$ falling edge Valid for: address, $\overline{\text{BHE}}$, early $\overline{\text{CS}}$ ²⁾ | t_{c17} CC | -2 | 6 | ns |
| Output hold time after $\overline{\text{CLKOUT}}$ edge ³⁾ Valid for: write data out | t_{c18} CC | -2 | – | ns |
| Output delay from $\overline{\text{CLKOUT}}$ falling edge Valid for: $\overline{\text{WR}}$ high | t_{c19} CC | -2 | 4 | ns |
| Turn off delay after $\overline{\text{CLKOUT}}$ edge ³⁾ Valid for: write data out | t_{c20} CC | – | 7 | ns |
| Turn on delay after $\overline{\text{CLKOUT}}$ falling edge ³⁾ Valid for: write data out | t_{c21} CC | -5 | – | ns |

1) Read data are latched with the same (internal) clock edge that triggers the address change and the rising edge of $\overline{\text{RD}}$. Therefore the read data may be removed immediately after the rising edge of $\overline{\text{RD}}$. Address changes before the end of $\overline{\text{RD}}$ have also no impact on (demultiplexed) read cycles.

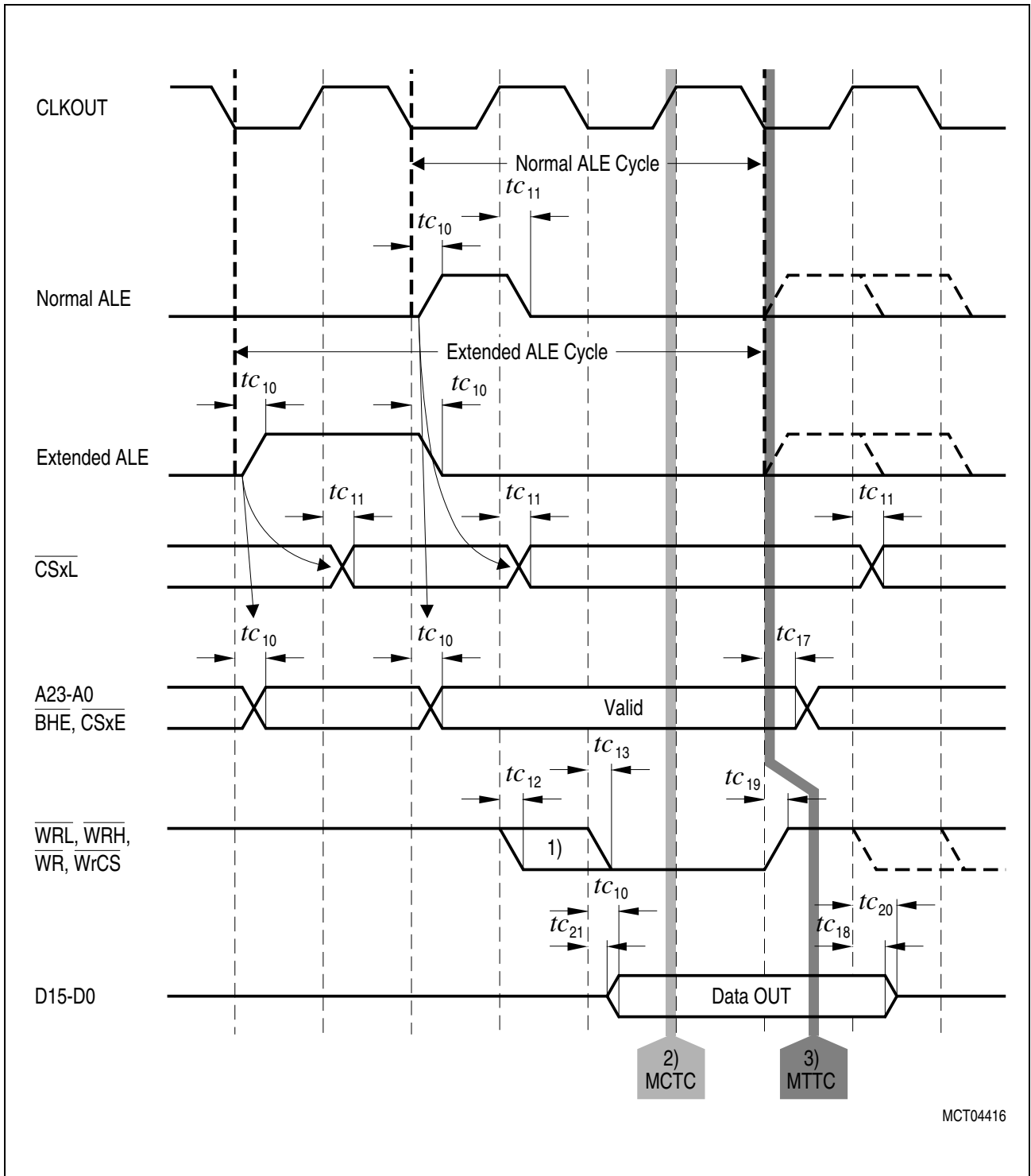
2) Due to comparable propagation delays (at comparable capacitive loads) the address does not change before $\overline{\text{WR}}$ goes high. The minimum output delay ($t_{c17\text{min}}$) is therefore the actual value of t_{c19} .

3) Not subject to production test - verified by design/characterization.

General Notes for the Following Timing Figures

These standard notes apply to all subsequent timing figures. Additional individual notes are placed at the respective figure.

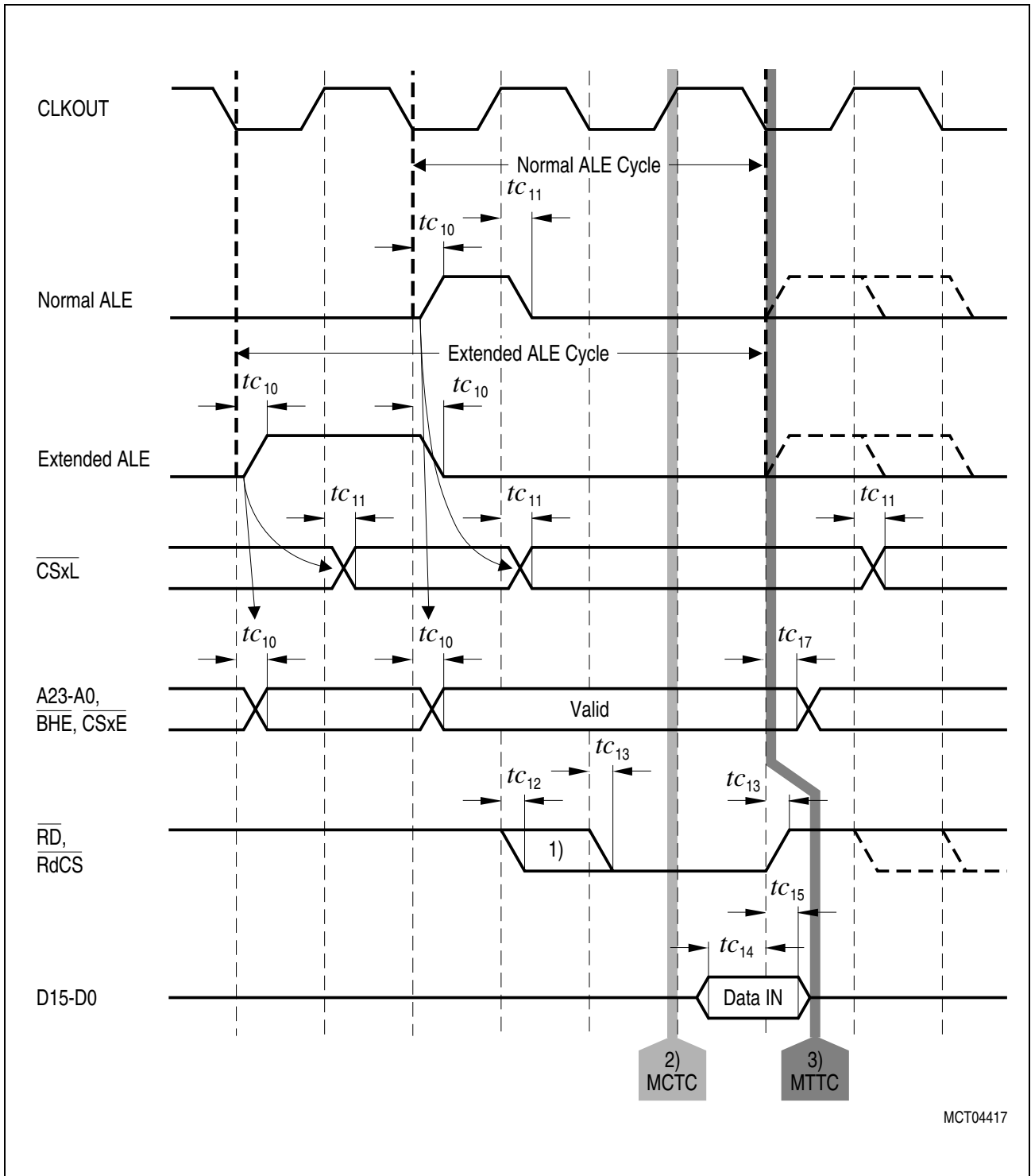
1. *The falling edge of signals \overline{RD} and $\overline{WR/WRH/WRL/WrCS}$ is controlled by the Read/Write delay feature (bit $BUSCON.RWDCx$).*
2. *A bus cycle is extended here, if MCTC waitstates are selected or if the \overline{READY} input is sampled inactive.*
3. *A bus cycle is extended here, if an MTTC waitstate is selected.*



MCT04416

Figure 16 Demultiplexed Bus, Write Access

Electrical Parameters



MCT04417

Figure 17 Demultiplexed Bus, Read Access

Electrical Parameters

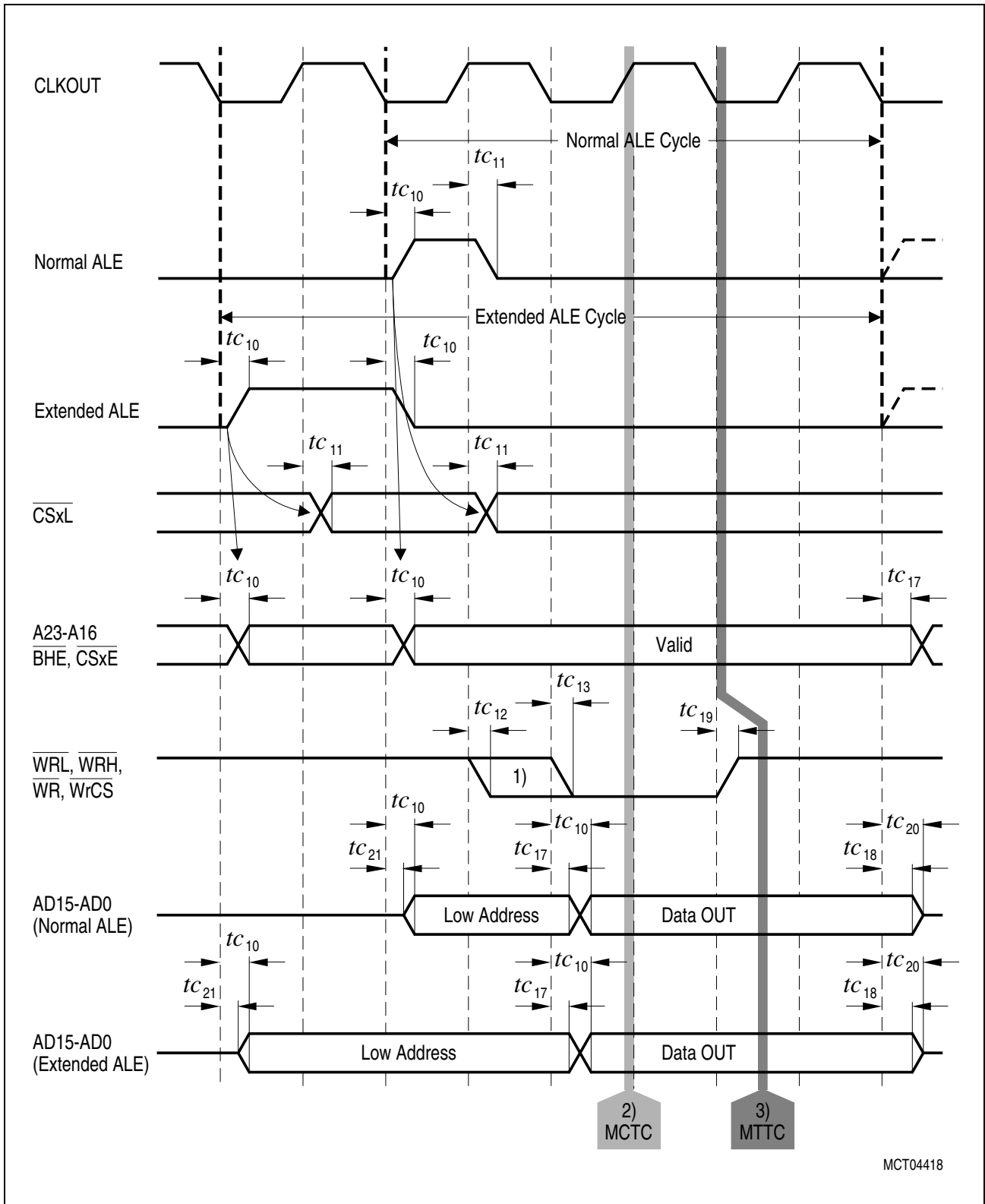
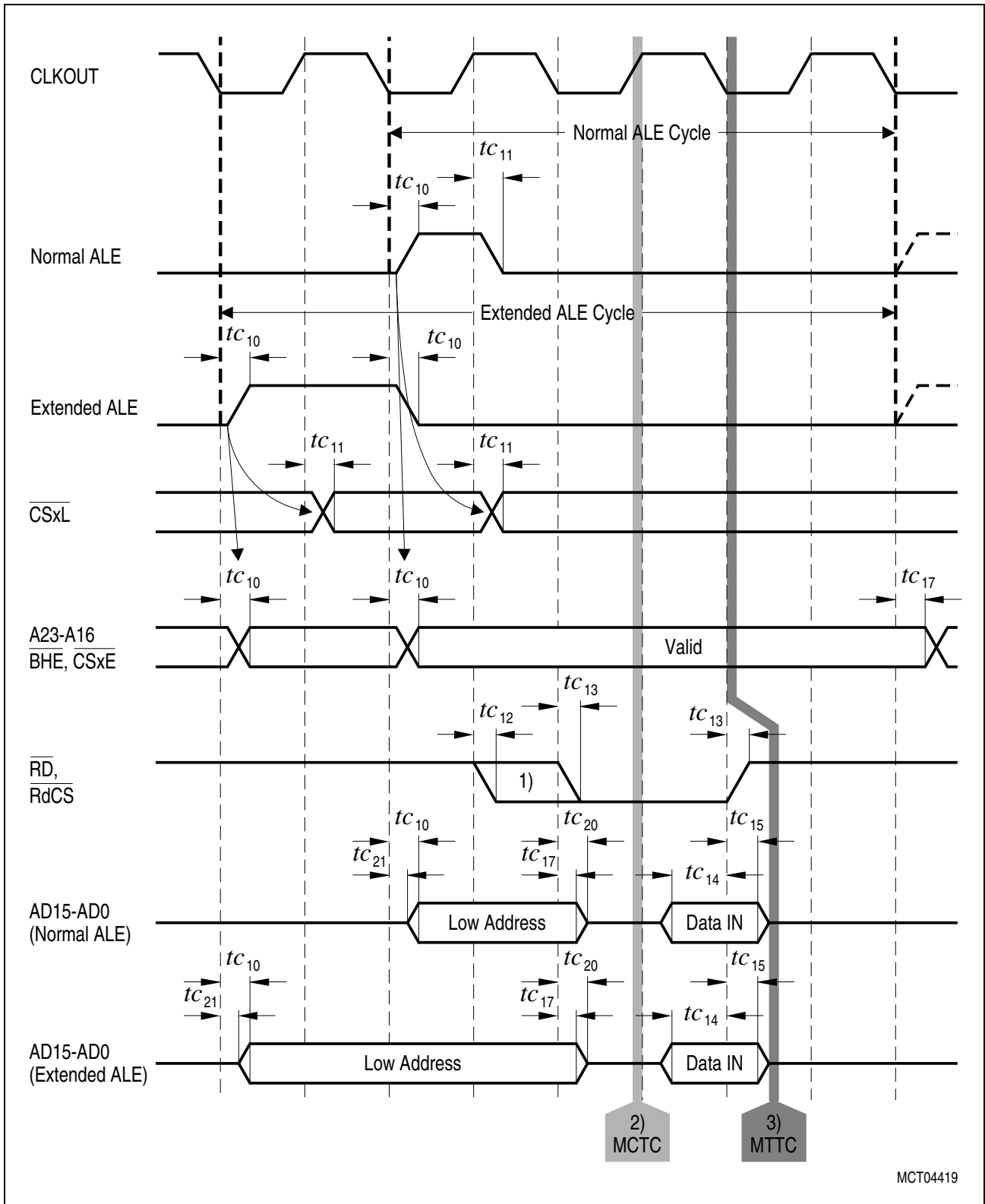


Figure 18 Multiplexed Bus, Write Access

Electrical Parameters



MCT04419

Figure 19 Multiplexed Bus, Read Access

Bus Cycle Control via $\overline{\text{READY}}$ Input

The duration of an external bus cycle can be controlled by the external circuitry via the $\overline{\text{READY}}$ input signal.

Synchronous $\overline{\text{READY}}$ permits the shortest possible bus cycle but requires the input signal to be synchronous to the reference signal CLKOUT.

Asynchronous $\overline{\text{READY}}$ puts no timing constraints on the input signal but incurs one waitstate minimum due to the additional synchronization stage.

Table 20 $\overline{\text{READY}}$ Timing (Operating Conditions apply)

| Parameter | Symbol | Limits | | Unit |
|--|--------------|--------------------|------|------|
| | | Min. | Max. | |
| Input setup time to CLKOUT rising edge Valid for: $\overline{\text{READY}}$ input | t_{c25} CC | 12 | – | ns |
| Input hold time after CLKOUT rising edge Valid for: $\overline{\text{READY}}$ input | t_{c26} CC | 0 | – | ns |
| Asynchronous $\overline{\text{READY}}$ input low time ⁶⁾ | t_{c27} CC | $t_{c5} + t_{c25}$ | – | ns |

Notes (Valid also for [Figure 20](#))

4. *Cycle as programmed, including MCTC waitstates (Example shows 0 MCTC WS).*
5. *$\overline{\text{READY}}$ sampled HIGH at this sampling point generates a $\overline{\text{READY}}$ controlled waitstate, $\overline{\text{READY}}$ sampled LOW at this sampling point terminates the currently running bus cycle.*
6. *These timings are given for test purposes only, in order to assure recognition at a specific clock edge. If the Asynchronous $\overline{\text{READY}}$ signal does not fulfill the indicated setup and hold times with respect to CLKOUT, it must fulfill t_{c27} in order to be safely synchronized. Proper deactivation of $\overline{\text{READY}}$ is guaranteed if $\overline{\text{READY}}$ is deactivated in response to the trailing (rising) edge of the corresponding command ($\overline{\text{RD}}$ or $\overline{\text{WR}}$).*
7. *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.*
8. *If the next following bus cycle is $\overline{\text{READY}}$ controlled, an active $\overline{\text{READY}}$ signal must be disabled before the first valid sample point for the next bus cycle. This sample point depends on the MTTC waitstate of the current cycle, and on the MCTC waitstates and the ALE mode of the next following cycle. If the current cycle uses a multiplexed bus the intrinsic MUX waitstate adds another CLKOUT cycle to the $\overline{\text{READY}}$ deactivation time.*

Electrical Parameters

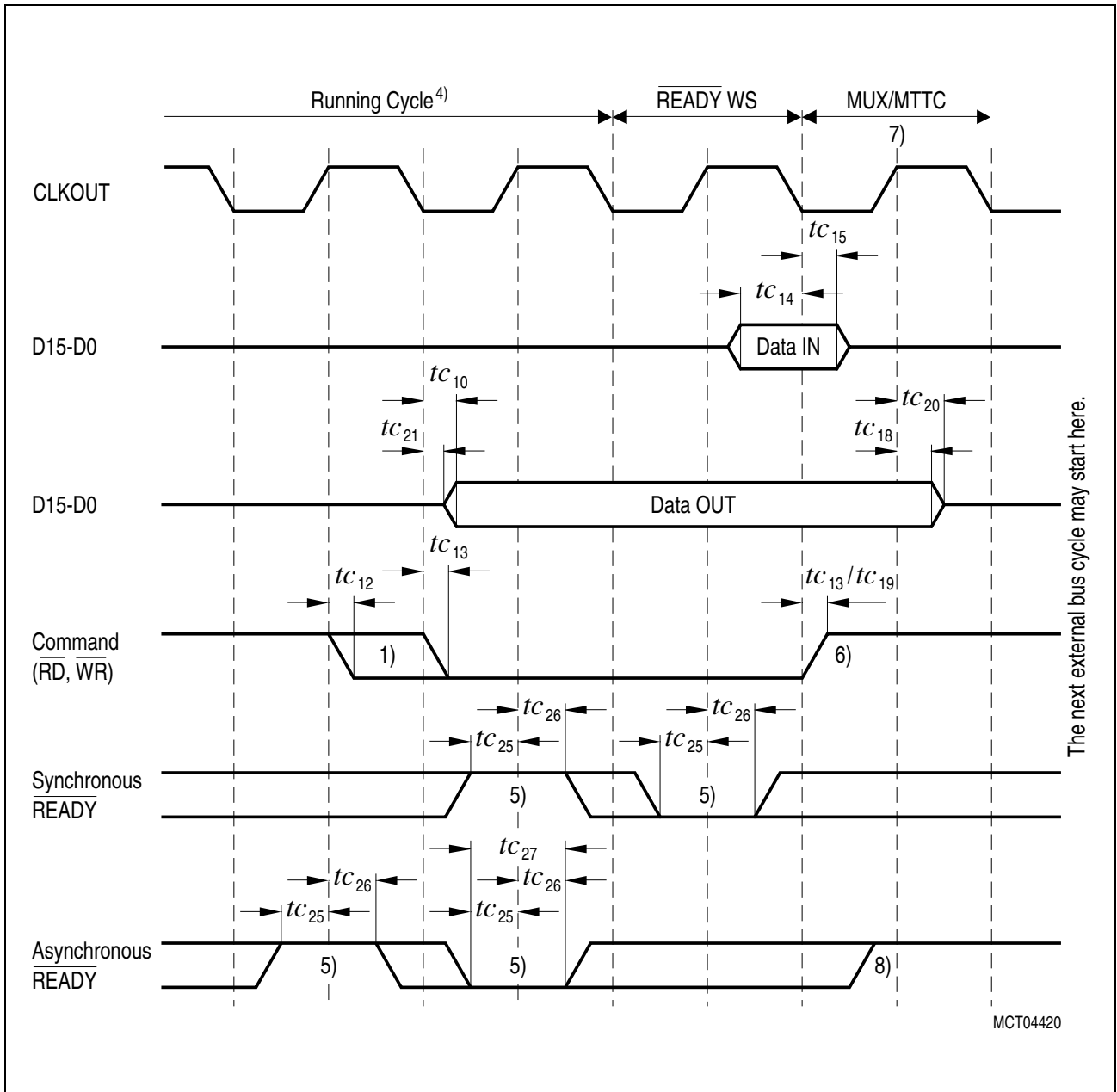


Figure 20 **READY** Timings

External Bus Arbitration

Table 21 Bus Arbitration Timing (Operating Conditions apply)

| Parameter | Symbol | | Limits | | Unit |
|--|-----------|----|--------|------|------|
| | | | Min. | Max. | |
| $\overline{\text{HOLD}}$ input setup time to CLKOUT falling edge | t_{c28} | SR | 18 | – | ns |
| CLKOUT to $\overline{\text{BREQ}}$ delay | t_{c29} | CC | -4 | 6 | ns |
| CLKOUT to $\overline{\text{HLDA}}$ delay | t_{c30} | CC | -4 | 6 | ns |
| $\overline{\text{CSx}}$ release ¹⁾ | t_{c31} | CC | 0 | 10 | ns |
| $\overline{\text{CSx}}$ drive | t_{c32} | CC | -2 | 6 | ns |
| Other signals release ¹⁾ | t_{c33} | CC | 0 | 10 | ns |
| Other signals drive ¹⁾ | t_{c34} | CC | 0 | 6 | ns |

1) Not subject to production test - verified by design/characterization.

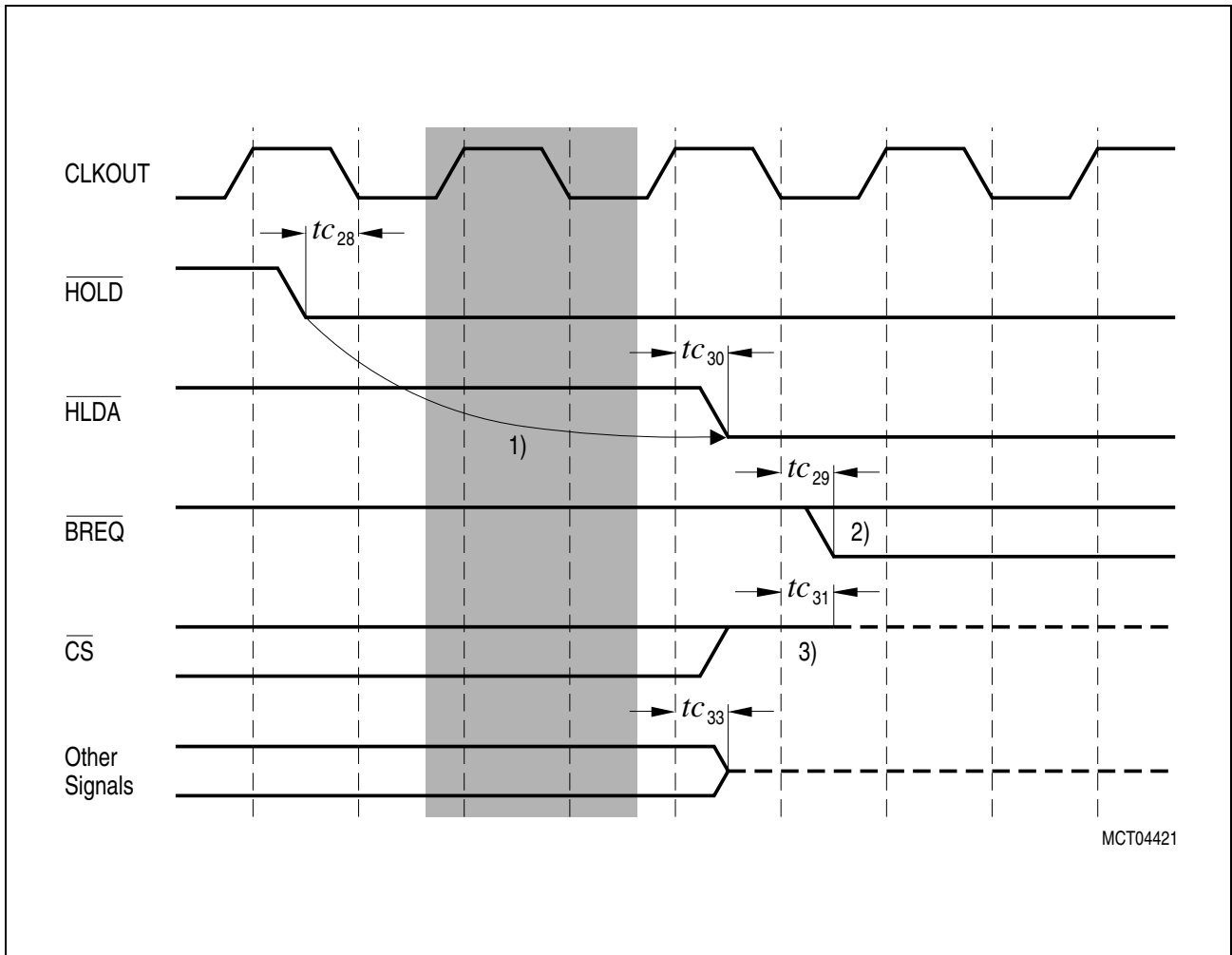
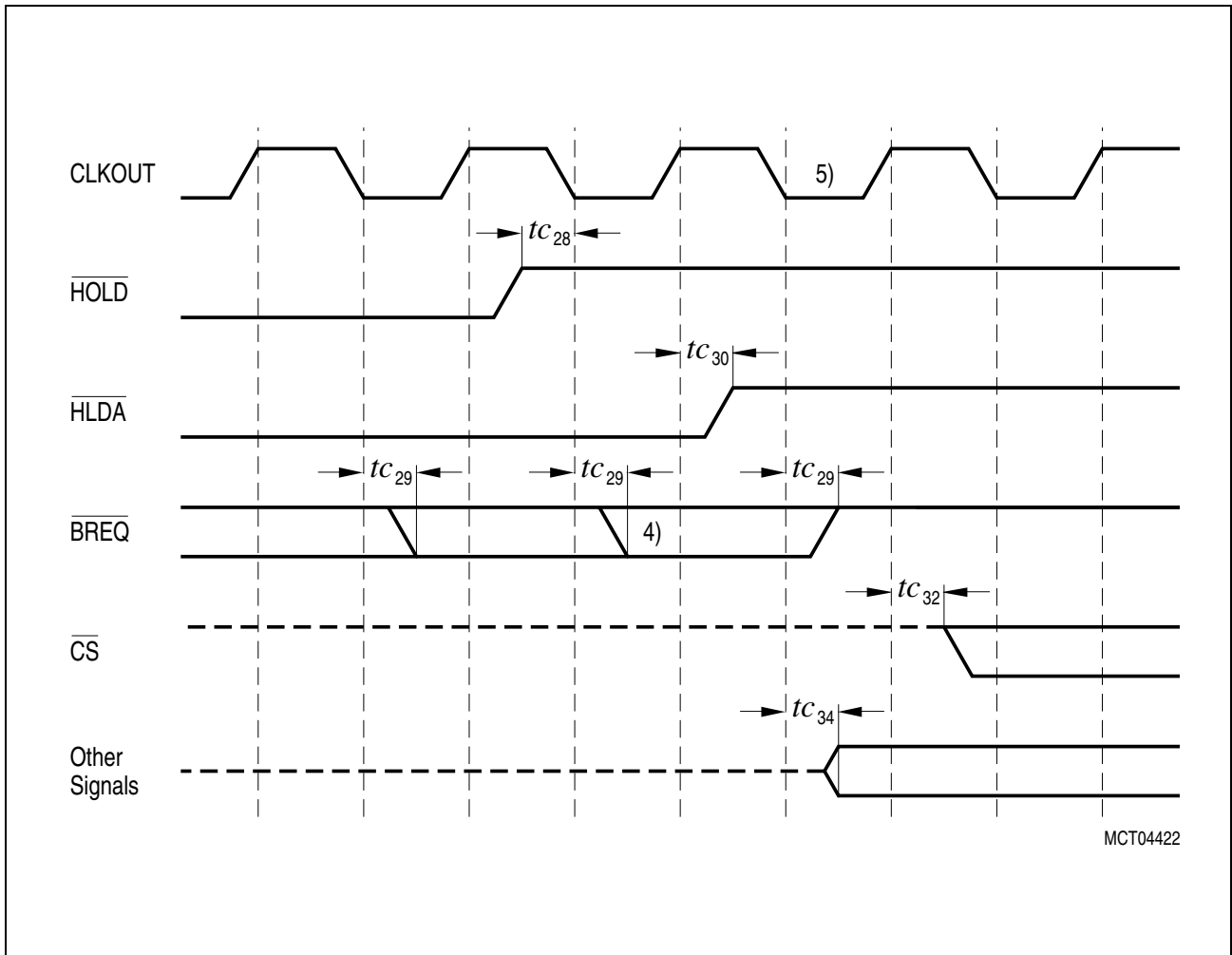


Figure 21 External Bus Arbitration, Releasing the Bus

Notes

1. The C167CR will complete the currently running bus cycle before granting bus access.
2. This is the first possibility for \overline{BREQ} to get active.
3. The \overline{CS} outputs will be resistive high (pull-up) after t_{33} . Latched \overline{CS} outputs are driven high for 1 TCL before the output drivers are switched off.



MCT04422

Figure 22 External Bus Arbitration, Regaining the Bus

Notes

4. This is the last chance for \overline{BREQ} to trigger the indicated regain-sequence. Even if \overline{BREQ} is activated earlier, the regain-sequence is initiated by \overline{HOLD} going high. Please note that \overline{HOLD} may also be deactivated without the C167CR requesting the bus.
5. The next C167CR driven bus cycle may start here.

External XRAM Access

If XPER-Share mode is enabled the on-chip XRAM of the C167CR can be accessed (during hold states) by an external master like an asynchronous SRAM.

Table 22 XRAM Access Timing (Operating Conditions apply)¹⁾

| Parameter | Symbol | | Limits | | Unit | |
|--|----------|----------|--------|----------|------|----|
| | | | Min. | Max. | | |
| Address setup time before $\overline{RD}/\overline{WR}$ falling edge | t_{40} | SR | 4 | – | ns | |
| Address hold time after $\overline{RD}/\overline{WR}$ rising edge | t_{41} | SR | 0 | – | ns | |
| Data turn on delay after \overline{RD} falling edge | Read | t_{42} | CC | 1 | – | ns |
| Data output valid delay after address latched | | t_{43} | CC | – | 40 | ns |
| Data turn off delay after \overline{RD} rising edge | | t_{44} | CC | 1 | 14 | ns |
| Write data setup time before \overline{WR} rising edge | Write | t_{45} | SR | 10 | – | ns |
| Write data hold time after \overline{WR} rising edge | | t_{46} | SR | 2 | – | ns |
| \overline{WR} pulse width | | t_{47} | SR | 20 | – | ns |
| \overline{WR} signal recovery time | | t_{48} | SR | t_{40} | – | ns |

1) The minimum access cycle time is 60 ns.

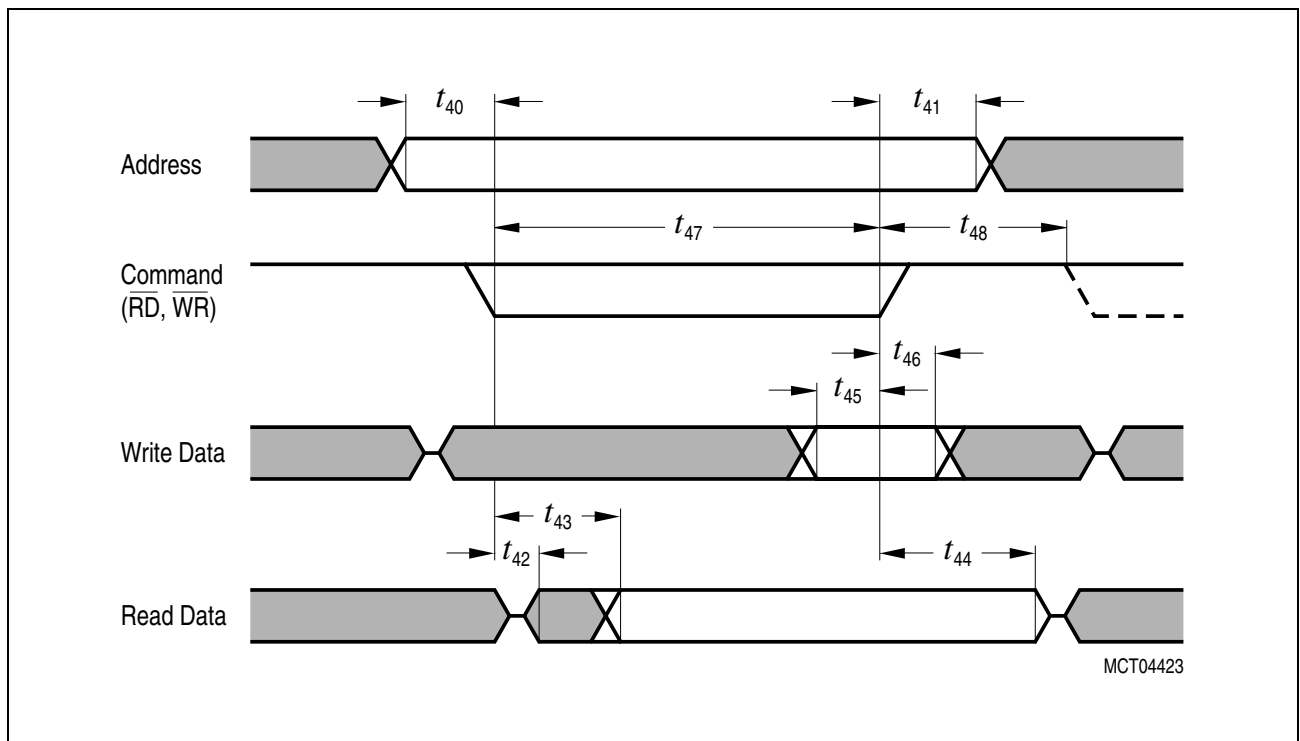


Figure 23 External Access to the XRAM

5 Package Outlines

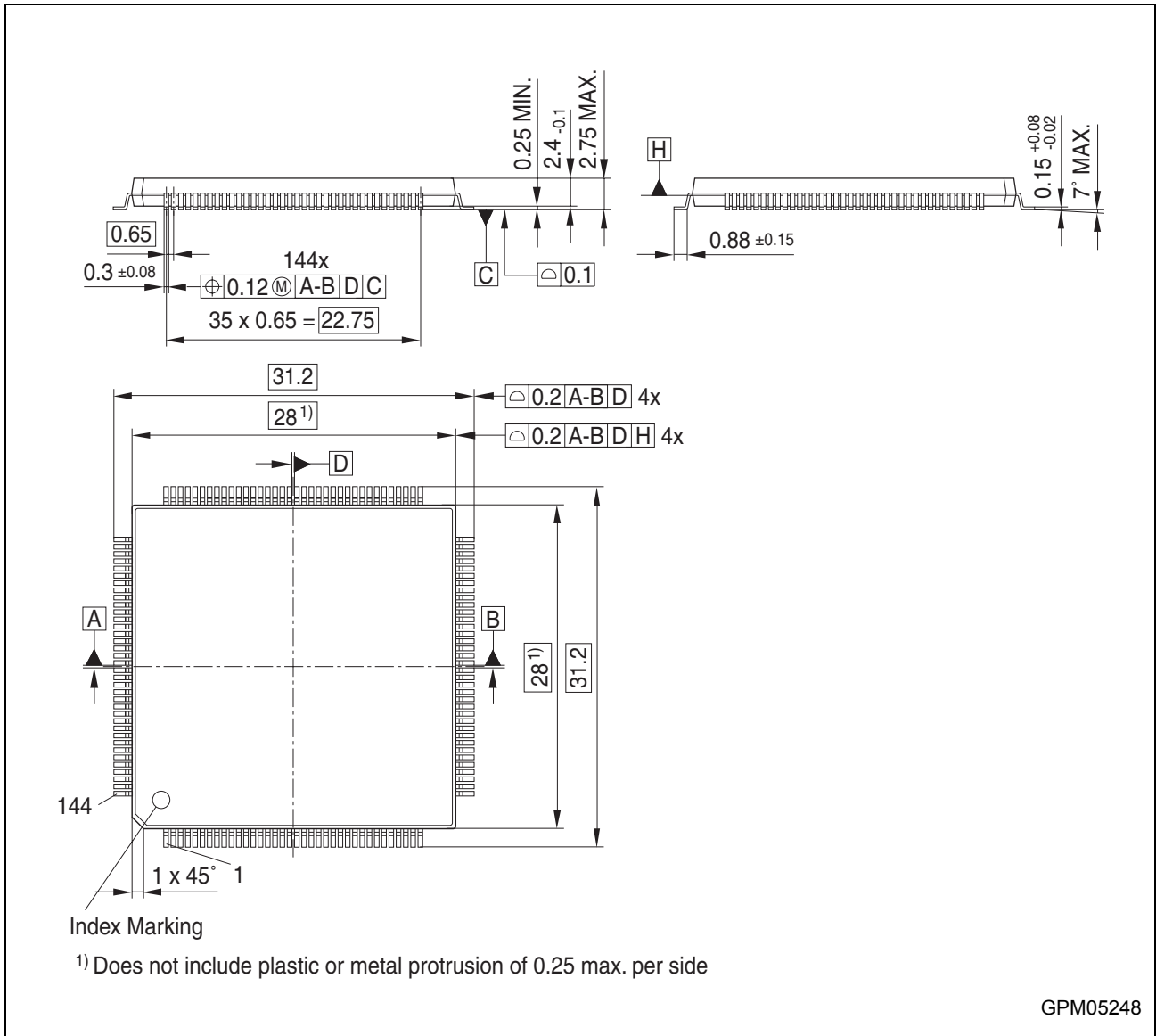
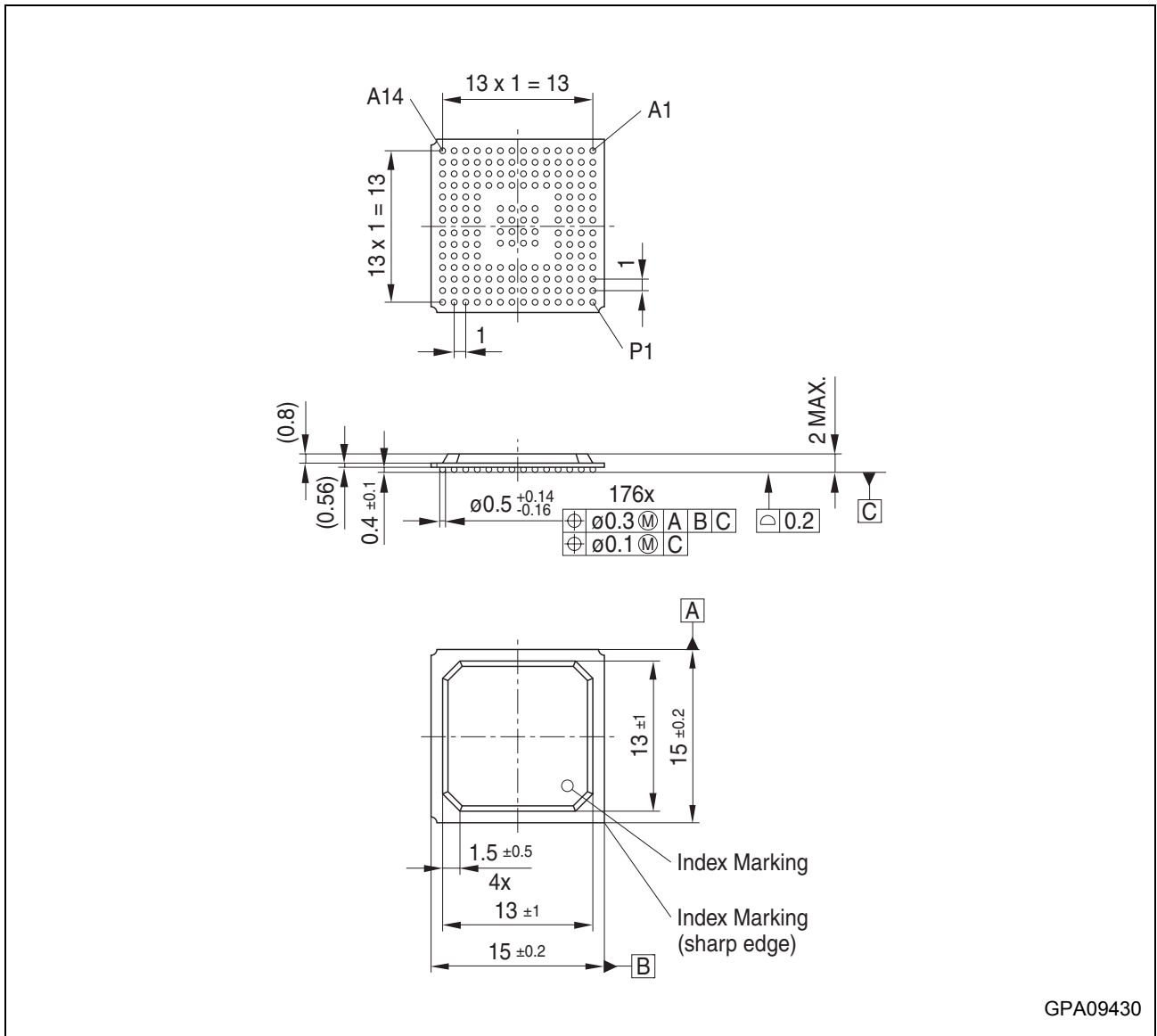


Figure 24 P-MQFP-144-8 (Plastic Metric Quad Flat Package)

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Dimensions in mm



GPA09430

Figure 25 P-BGA-176-2 (Plastic Ball Grid Array Package)

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Dimensions in mm

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