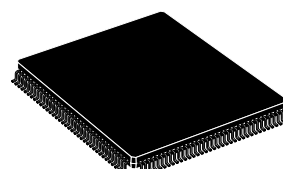




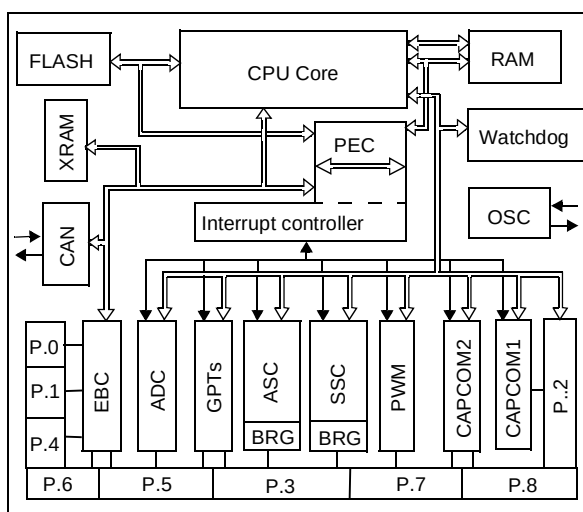
## 16-BIT MCU WITH 256K BYTE FLASH MEMORY AND 8K BYTE RAM

- **HIGH PERFORMANCE CPU**
  - 16-BIT CPU WITH 4-STAGE PIPELINE
  - 80ns INSTRUCTION CYCLE TIME AT 25MHz CPU CLOCK
  - 400ns 16 X 16-BIT MULTIPLICATION
  - 800ns 32 / 16-BIT DIVISION
  - ENHANCED BOOLEAN BIT MANIPULATION FACILITIES
  - ADDITIONAL INSTRUCTIONS TO SUPPORT HLL AND OPERATING SYSTEMS
  - SINGLE-CYCLE CONTEXT SWITCHING SUPPORT
- **MEMORY ORGANIZATION**
  - 256K BYTE ON-CHIP FLASH MEMORY
  - 10K ERASING / PROGRAMMING CYCLES
  - UP TO 16M BYTE LINEAR ADDRESS SPACE FOR CODE AND DATA (5M BYTE WITH CAN)
  - 2K BYTE ON-CHIP INTERNAL RAM (IRAM)
  - 6K BYTE ON-CHIP EXTENSION RAM (XRAM)
  - 20 YEAR DATA RETENTION TIME
- **FAST AND FLEXIBLE BUS**
  - PROGRAMMABLE EXTERNAL BUS CHARACTERISTICS FOR DIFFERENT ADDRESS RANGES
  - 8-BIT OR 16-BIT EXTERNAL DATA BUS
  - MULTIPLEXED OR DEMULTIPLEXED EXTERNAL ADDRESS / DATA BUSES
  - FIVE PROGRAMMABLE CHIP-SELECT SIGNALS
  - HOLD-ACKNOWLEDGE BUS ARBITRATION SUPPORT
- **INTERRUPT**
  - 8-CHANNEL PERIPHERAL EVENT CONTROLLER FOR SINGLE CYCLE, INTERRUPT DRIVEN DATA TRANSFER
  - 16-PRIORITY-LEVEL INTERRUPT SYSTEM WITH 56 SOURCES, SAMPLE-RATE DOWN TO 40ns
- **TIMERS**
  - TWO MULTI-FUNCTIONAL GENERAL PURPOSE TIMER UNITS WITH 5 TIMERS
  - TWO 16-CHANNEL CAPTURE / COMPARE UNITS.
- **4-CHANNEL PWM UNIT**
- **SERIAL CHANNELS**
  - SYNCHRONOUS / ASYNCHRONOUS SERIAL CHANNEL
  - HIGH-SPEED SYNCHRONOUS CHANNEL



**PQFP144 (28 x 28 mm)**  
(Plastic Quad Flat Pack)

- **A/D CONVERTER**
  - 16-CHANNEL 10-BIT
  - 7.76µs CONVERSION TIME
- **FAIL-SAFE PROTECTION**
  - PROGRAMMABLE WATCHDOG TIMER
  - OSCILLATOR WATCHDOG
- **ON-CHIP CAN 2.0B INTERFACE**
- **ON-CHIP BOOTSTRAP LOADER**
- **CLOCK GENERATION**
  - ON-CHIP PLL
  - DIRECT OR PRESCALED CLOCK INPUT.
- **UP TO 111 GENERAL PURPOSE I/O LINES**
  - INDIVIDUALLY PROGRAMMABLE AS INPUT, OUTPUT OR SPECIAL FUNCTION.
  - PROGRAMMABLE THRESHOLD (HYSTERESIS)
- **IDLE AND POWER DOWN MODES**
- **SINGLE VOLTAGE SUPPLY: 5V ±10%**
- **144-PIN PQFP PACKAGE**



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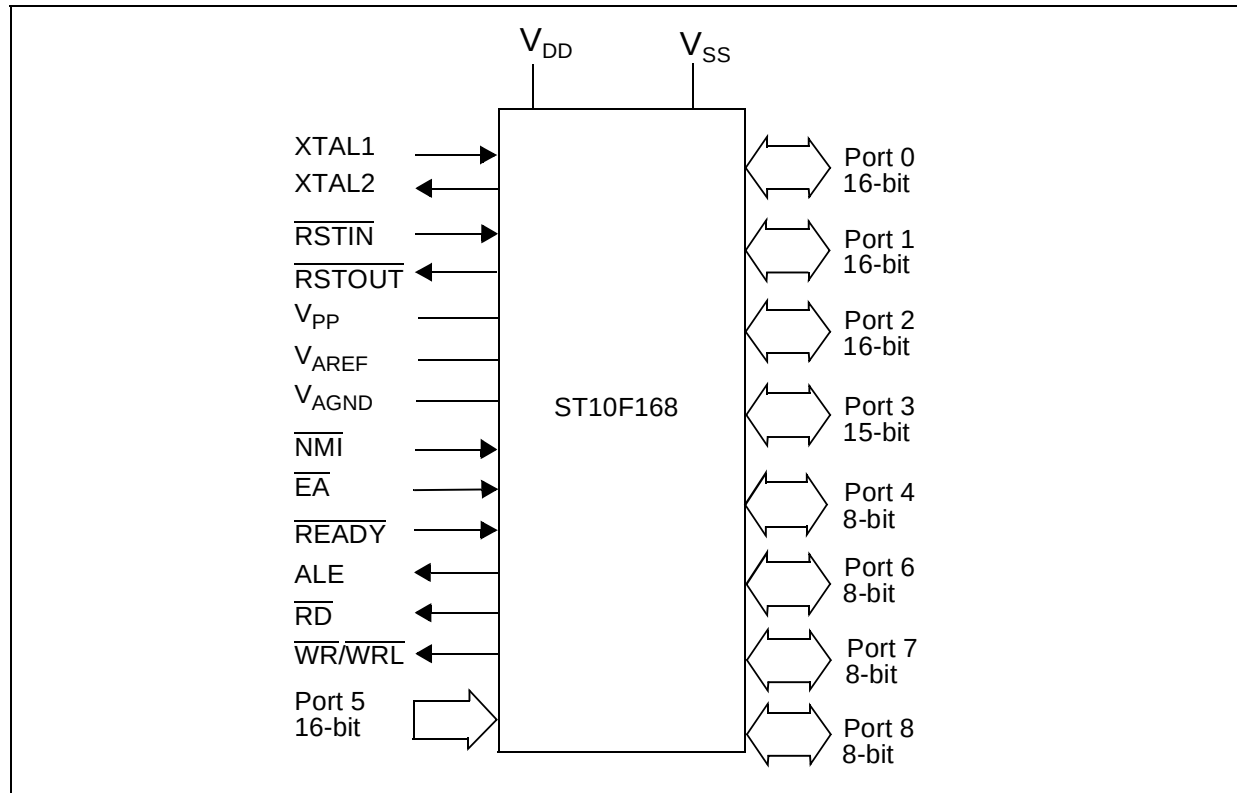
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## 1 - INTRODUCTION

The ST10F168 is a derivative of the STMicroelectronics 16-bit single-chip CMOS microcontrollers. It combines high CPU performance (up to 12.5 million instructions per second) with high

peripheral functionality and enhanced I/O capabilities. It also provides on-chip high-speed Flash memory, on-chip high-speed RAM, and clock generation via PLL.

**Figure 1 : Logic Symbol**



## 2 - PIN DATA

Figure 2 : Pin Configuration (top view)

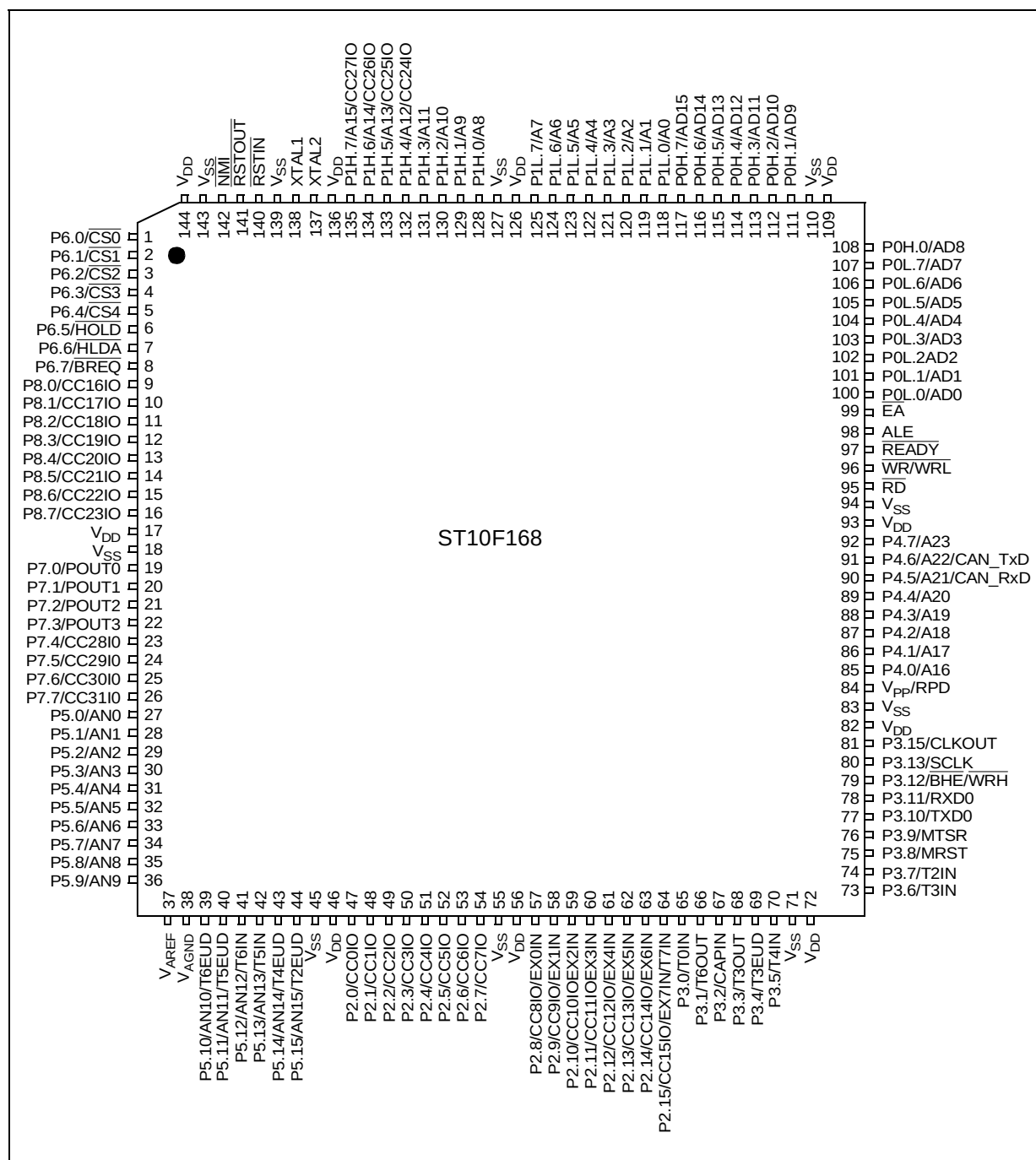


Table 1 : Pin Description

| Symbol                       | Pin            | Type   | Function                                                                                                                                                                                                                                                                                                                                                                          |                   |                                                |
|------------------------------|----------------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------|
| P6.0 - P6.7                  | 1 - 8          | I/O    | 8-bit bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to high impedance state. Port 6 outputs can be configured as push-pull or open drain drivers. The following Port 6 pins have alternate functions:                                                               |                   |                                                |
|                              | 1              | O      | P6.0                                                                                                                                                                                                                                                                                                                                                                              | $\overline{CS0}$  | Chip Select 0 Output                           |
|                              | ...            | ...    | ...                                                                                                                                                                                                                                                                                                                                                                               | ...               | ...                                            |
|                              | 5              | O      | P6.4                                                                                                                                                                                                                                                                                                                                                                              | $\overline{CS4}$  | Chip Select 4 Output                           |
|                              | 6              | I      | P6.5                                                                                                                                                                                                                                                                                                                                                                              | $\overline{HOLD}$ | External Master Hold Request Input             |
|                              | 7              | O      | P6.6                                                                                                                                                                                                                                                                                                                                                                              | $\overline{HLDA}$ | Hold Acknowledge Output                        |
|                              | 8              | O      | P6.7                                                                                                                                                                                                                                                                                                                                                                              | $\overline{BREQ}$ | Bus Request Output                             |
| P8.0 - P8.7                  | 9-16           | I/O    | 8-bit bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to 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 have alternate functions: |                   |                                                |
|                              | 9              | I/O    | P8.0                                                                                                                                                                                                                                                                                                                                                                              | CC16IO            | CAPCOM2: CC16 Capture Input / Compare Output   |
|                              | ...            | ...    | ...                                                                                                                                                                                                                                                                                                                                                                               | ...               | ...                                            |
|                              | 16             | I/O    | P8.7                                                                                                                                                                                                                                                                                                                                                                              | CC23IO            | CAPCOM2: CC23 Capture Input / Compare Output   |
| P7.0 - P7.7                  | 19-26          | I/O    | 8-bit bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to 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 have alternate functions: |                   |                                                |
|                              | 19             | O      | P7.0                                                                                                                                                                                                                                                                                                                                                                              | POUT0             | PWM Channel 0 Output                           |
|                              | ...            | ...    | ...                                                                                                                                                                                                                                                                                                                                                                               | ...               | ...                                            |
|                              | 22             | O      | P7.3                                                                                                                                                                                                                                                                                                                                                                              | POUT3             | PWM Channel 3 Output                           |
|                              | 23             | I/O    | P7.4                                                                                                                                                                                                                                                                                                                                                                              | CC28IO            | CAPCOM2: CC28 Capture Input / Compare Output   |
|                              | ...            | ...    | ...                                                                                                                                                                                                                                                                                                                                                                               | ...               | ...                                            |
|                              | 26             | I/O    | P7.7                                                                                                                                                                                                                                                                                                                                                                              | CC31IO            | CAPCOM2: CC31 Capture Input / Compare Output   |
| P5.0 - P5.9<br>P5.10 - P5.15 | 27-36<br>39-44 | I<br>I | 16-bit input-only port with Schmitt-Trigger characteristics. The pins of Port 5 can be the analog input channels (up to 16) for the A/D converter, where P5.x equals ANx (Analog input channel x), or they are timer inputs:                                                                                                                                                      |                   |                                                |
|                              | 39             | I      | P5.10                                                                                                                                                                                                                                                                                                                                                                             | T6EUD             | GPT2 Timer T6 External Up / Down Control Input |
|                              | 40             | I      | P5.11                                                                                                                                                                                                                                                                                                                                                                             | T5EUD             | GPT2 Timer T5 External Up / Down Control Input |
|                              | 41             | I      | P5.12                                                                                                                                                                                                                                                                                                                                                                             | T6IN              | GPT2 Timer T6 Count Input                      |
|                              | 42             | I      | P5.13                                                                                                                                                                                                                                                                                                                                                                             | T5IN              | GPT2 Timer T5 Count Input                      |
|                              | 43             | I      | P5.14                                                                                                                                                                                                                                                                                                                                                                             | T4EUD             | GPT1 Timer T4 External Up / Down Control Input |
|                              | 44             | I      | P5.15                                                                                                                                                                                                                                                                                                                                                                             | T2EUD             | GPT1 Timer T2 External Up / Down Control Input |

Table 1 : Pin Description (continued)

| Symbol                                | Pin                    | Type              | Function                                                                                                                                                                                                                                                                                                                                                                                                 |                         |                                                         |
|---------------------------------------|------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------------------------------------|
| P2.0 - P2.7<br>P2.8 - P2.15           | 47-54<br>57-64         | I/O               | 16-bit bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to 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).<br>The following Port 2 pins have alternate functions:                    |                         |                                                         |
|                                       | 47                     | I/O               | P2.0                                                                                                                                                                                                                                                                                                                                                                                                     | CC0IO                   | CAPCOM: CC0 Capture Input / Compare Output              |
|                                       | ...                    | ...               | ...                                                                                                                                                                                                                                                                                                                                                                                                      | ...                     | ...                                                     |
|                                       | 54                     | I/O               | P2.7                                                                                                                                                                                                                                                                                                                                                                                                     | CC7IO                   | CAPCOM: CC7 Capture Input / Compare Output              |
|                                       | 57                     | I/O               | P2.8                                                                                                                                                                                                                                                                                                                                                                                                     | CC8IO                   | CAPCOM: CC8 Capture Input / Compare Output              |
|                                       |                        | I                 |                                                                                                                                                                                                                                                                                                                                                                                                          | EX0IN                   | Fast External Interrupt 0 Input                         |
|                                       | ...                    | ...               | ...                                                                                                                                                                                                                                                                                                                                                                                                      | ...                     | ...                                                     |
|                                       | 64                     | I/O               | P2.15                                                                                                                                                                                                                                                                                                                                                                                                    | CC15IO                  | CAPCOM: CC15 Capture Input / Compare Output             |
|                                       |                        | I                 |                                                                                                                                                                                                                                                                                                                                                                                                          | EX7IN                   | Fast External Interrupt 7 Input                         |
|                                       |                        | I                 |                                                                                                                                                                                                                                                                                                                                                                                                          | T7IN                    | CAPCOM2 Timer T7 Count Input                            |
| P3.0 - P3.5<br>P3.6 - P3.13,<br>P3.15 | 65-70,<br>73-80,<br>81 | I/O<br>I/O<br>I/O | 15-bit (P3.14 is missing) bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to high impedance state. Port 3 outputs can be configured as push-pull or open drain drivers. The input threshold of Port 3 is selectable (TTL or special).<br>The following Port 3 pins have alternate functions: |                         |                                                         |
|                                       | 65                     | I                 | P3.0                                                                                                                                                                                                                                                                                                                                                                                                     | T0IN                    | CAPCOM Timer T0 Count Input                             |
|                                       | 66                     | O                 | P3.1                                                                                                                                                                                                                                                                                                                                                                                                     | T6OUT                   | GPT2 Timer T6 Toggle Latch Output                       |
|                                       | 67                     | I                 | P3.2                                                                                                                                                                                                                                                                                                                                                                                                     | CAPIN                   | GPT2 Register CAPREL Capture Input                      |
|                                       | 68                     | O                 | P3.3                                                                                                                                                                                                                                                                                                                                                                                                     | T3OUT                   | GPT1 Timer T3 Toggle Latch Output                       |
|                                       | 69                     | I                 | P3.4                                                                                                                                                                                                                                                                                                                                                                                                     | T3EUD                   | GPT1 Timer T3 External Up / Down Control Input          |
|                                       | 70                     | I                 | P3.5                                                                                                                                                                                                                                                                                                                                                                                                     | T4IN                    | GPT1 Timer T4 Input for Count / Gate / Reload / Capture |
|                                       | 73                     | I                 | P3.6                                                                                                                                                                                                                                                                                                                                                                                                     | T3IN                    | GPT1 Timer T3 Count / Gate Input                        |
|                                       | 74                     | I                 | P3.7                                                                                                                                                                                                                                                                                                                                                                                                     | T2IN                    | GPT1 Timer T2 Input for Count / Gate / Reload / Capture |
|                                       | 75                     | I/O               | P3.8                                                                                                                                                                                                                                                                                                                                                                                                     | MRST                    | SSC Master-Receiver / Slave-Transmitter I/O             |
|                                       | 76                     | I/O               | P3.9                                                                                                                                                                                                                                                                                                                                                                                                     | MTSR                    | SSC Master-Transmitter / Slave-Receiver O/I             |
|                                       | 77                     | O                 | P3.10                                                                                                                                                                                                                                                                                                                                                                                                    | TxD0                    | ASC0 Clock / Data Output (Asynchronous / Synchronous)   |
|                                       | 78                     | I/O               | P3.11                                                                                                                                                                                                                                                                                                                                                                                                    | RxD0                    | ASC0 Data Input (Asynchronous) or I/O (Synchronous)     |
|                                       | 79                     | O                 | P3.12                                                                                                                                                                                                                                                                                                                                                                                                    | $\overline{\text{BHE}}$ | External Memory High Byte Enable Signal                 |
|                                       |                        |                   |                                                                                                                                                                                                                                                                                                                                                                                                          | $\overline{\text{WRH}}$ | External Memory High Byte Write Strobe                  |
|                                       | 80                     | I/O               | P3.13                                                                                                                                                                                                                                                                                                                                                                                                    | SCLK                    | SSC Master Clock Output / Slave Clock Input             |
|                                       | 81                     | O                 | P3.15                                                                                                                                                                                                                                                                                                                                                                                                    | CLKOUT                  | System Clock Output (=CPU Clock)                        |

Table 1 : Pin Description (continued)

| Symbol                                  | Pin                             | Type | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------------------|---------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P4.0 - P4.7                             | 85-92                           | I/O  | 8-bit bidirectional I/O port, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to high impedance state. For external bus configuration, Port 4 can be used to output the segment address lines:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                         | 85-89                           | O    | P4.0-P4.4    A16-A20       Segment Address Line                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                         | 90                              | O    | P4.5        A21        Segment Address Line                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                         |                                 | I    | CAN_RxD    CAN Receiver Data Input                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                         | 91                              | O    | P4.6        A22        Segment Address Line                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                         |                                 | O    | CAN_TxD    CAN Transmitter Data Output                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                         | 92                              | O    | P4.7        A23        Most Significant Segment Address Line                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| $\overline{RD}$                         | 95                              | O    | External Memory Read Strobe. $\overline{RD}$ is activated for every external instruction or data read access.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| $\overline{WR}/\overline{WRL}$          | 96                              | O    | External Memory Write Strobe. In $\overline{WR}$ -mode this pin is activated for every external data write access. In $\overline{WRL}$ 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 the SYSCON register for mode selection.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| $\overline{READY}/$<br>READY            | 97                              | I    | Ready Input. The active level is programmable. When the Ready function is enabled, the selected inactive level at this pin, during an external memory access, will force the insertion of wait state cycles until the pin returns to the selected active level.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| ALE                                     | 98                              | O    | Address Latch Enable Output. In case of use of external addressing or of multiplexed mode, this signal is the latch command of the address lines.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| $\overline{EA}$                         | 99                              | I    | External Access Enable pin. A low level at this pin during and after Reset forces the ST10F168 to start the program from the external memory space. A high level forces the ST10F168 to start in the internal memory space.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| P0L.0 - P0L.7<br>P0H.0<br>P0H.1 - P0H.7 | 100 - 107,<br>108,<br>111 - 117 | I/O  | Two 8-bit bidirectional I/O ports P0L and P0H, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to high impedance state.<br>In case of an external bus configuration, Port0 serves as the address (A) and as the address / data (AD) bus in multiplexed bus modes and as the data (D) bus in demultiplexed bus modes.<br><br><b>Demultiplexed bus modes</b><br><br>Data Path Width:        8-bit                                16-bit<br>P0L.0 – P0L.7:        D0 – D7                                D0 - D7<br>P0H.0 – P0H.7:        I/O                                        D8 - D15<br><br><b>Multiplexed bus modes</b><br><br>Data Path Width:        8-bit                                16-bit<br>P0L.0 – P0L.7:        AD0 – AD7                                AD0 - AD7<br>P0H.0 – P0H.7:        A8 – A15                                AD8 – AD15 |

Table 1 : Pin Description (continued)

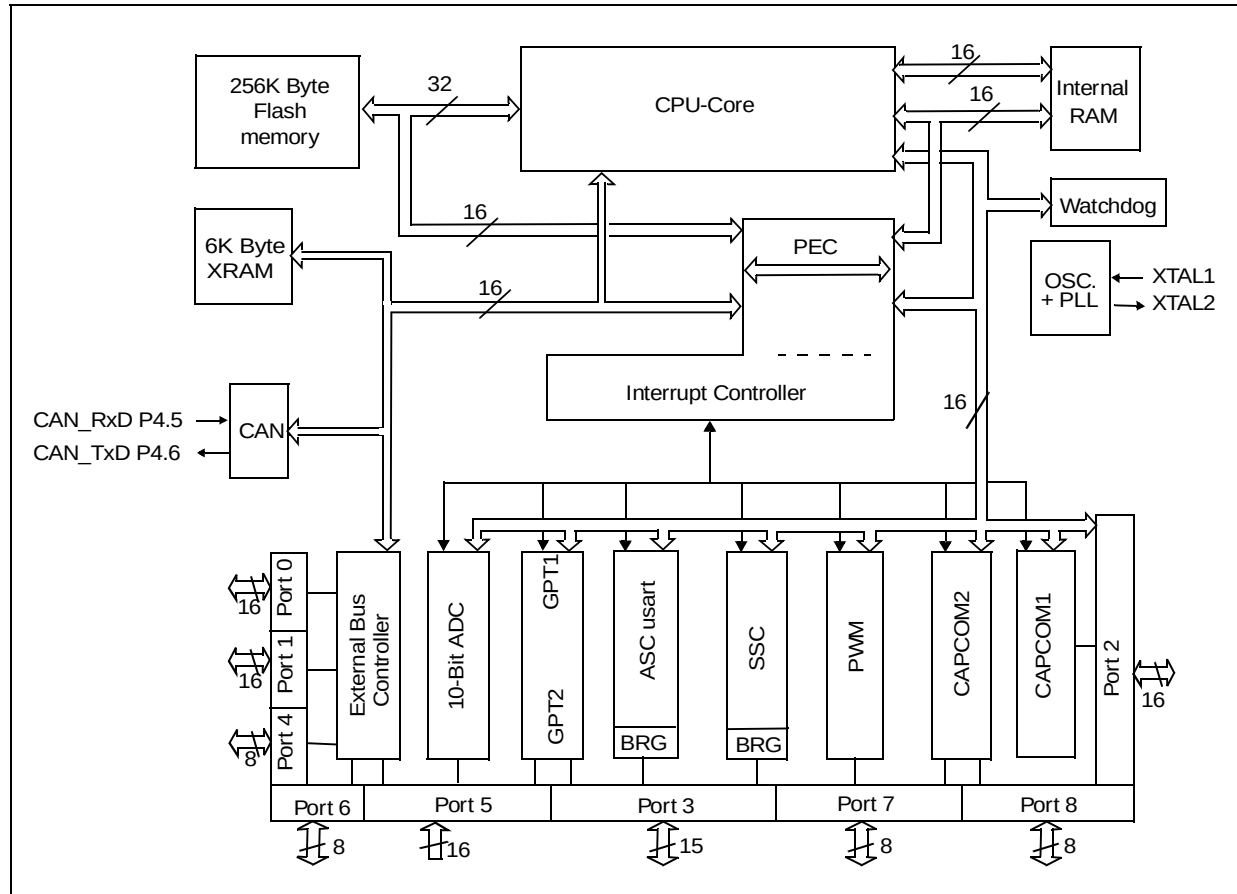
| Symbol                         | Pin                                                 | Type | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------|-----------------------------------------------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P1L.0 - P1L.7<br>P1H.0 - P1H.7 | 118-125<br>128-135                                  | I/O  | Two 8-bit bidirectional I/O ports P1L and P1H, bit-wise programmable for input or output via direction bit. Programming an I/O pin as input forces the corresponding output driver to 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.<br>The following Port1 pins have alternate functions:                                                                                                           |
|                                | 132                                                 | I    | P1H.4    CC24IO    CAPCOM2: CC24 Capture Input                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                | 133                                                 | I    | P1H.5    CC25IO    CAPCOM2: CC25 Capture Input                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                | 134                                                 | I    | P1H.6    CC26IO    CAPCOM2: CC26 Capture Input                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                | 135                                                 | I    | P1H.7    CC27IO    CAPCOM2: CC27 Capture Input                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| XTAL1                          | 138                                                 | I    | XTAL1    Oscillator amplifier and internal clock generator input                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| XTAL2                          | 137                                                 | O    | XTAL2:    Oscillator amplifier circuit output.<br><br>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.                                                                                                                                                                                                                                                                           |
| $\overline{\text{RSTIN}}$      | 140                                                 | I    | Reset Input with Schmitt-Trigger characteristics. A low level at this pin for a specified duration while the oscillator is running resets the ST10F168. An internal pullup resistor permits power-on reset using only a capacitor connected to $V_{SS}$ . In bidirectional reset mode (enabled by setting bit BDRSTEN in SYSCON register), the RSTIN line is pulled low for the duration of the internal reset sequence.                                                                                                             |
| $\overline{\text{RSTOUT}}$     | 141                                                 | O    | Internal Reset Indication Output. This pin is set to a low level during hardware, software or watchdog timer reset. $\overline{\text{RSTOUT}}$ remains low until the EINIT (end of initialization) instruction is executed.                                                                                                                                                                                                                                                                                                          |
| $\overline{\text{NMI}}$        | 142                                                 | I    | Non-Maskable Interrupt Input. A high to low transition at this pin causes the CPU to vector to the NMI trap routine. If bit PWDCFG = '0' in SYSCON register, when the PWRDN (power down) instruction is executed, the $\overline{\text{NMI}}$ pin must be low in order to force the ST10F168 to go into power down mode. If $\overline{\text{NMI}}$ is high and PWDCFG = '0', when PWRDN is executed, the part will continue to run in normal mode. If it is not used, pin $\overline{\text{NMI}}$ should be pulled high externally. |
| $V_{AREF}$                     | 37                                                  | -    | A/D converter reference voltage.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| $V_{AGND}$                     | 38                                                  | -    | A/D converter reference ground.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| $V_{PP}/RPD$                   | 84                                                  | -    | Flash programming voltage. Programming voltage of the on-chip Flash memory must be supplied to this pin. It is used also as the timing pin for the return from interruptible powerdown mode.                                                                                                                                                                                                                                                                                                                                         |
| $V_{DD}$                       | 17,46,<br>56,72,<br>82,93,<br>109, 126,<br>136, 144 | -    | Digital Supply Voltage:<br>= + 5V during normal operation and idle mode.<br>≥ 2.5V during power down mode.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| $V_{SS}$                       | 18,45,<br>55,71,<br>83,94,<br>110, 127,<br>139, 143 | -    | Digital Ground.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

### 3 - FUNCTIONAL DESCRIPTION

The architecture of the ST10F168 combines advantages of both RISC and CISC processors and an advanced peripheral subsystem.

The block diagram gives an overview of the different on-chip components and the high bandwidth internal bus structure of the ST10F168.

**Figure 3 : Block Diagram**



#### 4 - MEMORY ORGANIZATION

The memory space of the ST10F168 is configured in a Von Neumann architecture. Code memory, data memory, registers and I/O ports are organized within the same linear address space of 16M Byte. 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.

**FLASH:** 256K Byte of on-chip Flash memory. See *Flash Memory* on page 13

**IRAM:** 2K Byte of on-chip internal RAM (dual-port) is provided as a storage for data, system stack, general purpose register banks and code. A register bank is 16 word-wide (R0 to R15) and / or byte-wide (RL0, RH0, ..., RL7, RH7) general purpose registers.

**XRAM:** 6K Byte of on-chip extension RAM (single port XRAM) is provided as a storage for data, user stack and code. The XRAM is connected to the internal XBUS and is accessed like an external memory in 16-bit demultiplexed bus-mode without wait state or read / write delay (80ns access at 25MHz CPU clock). Byte and Word access are allowed.

The XRAM address range is 00'D000h - 00'E7FFh if the XRAM is enabled (XPEN bit 2 of SYSCON register). As the XRAM appears like external memory, it cannot be used for the ST10F168's system stack or register banks. The XRAM is not provided for single bit storage and

therefore is not bit addressable. If bit XPEN is cleared, then any access in the address range 00'D000h - 00'E7FFh will be directed to external memory interface, using the BUSCONx register corresponding to address matching ADDRSELx register.

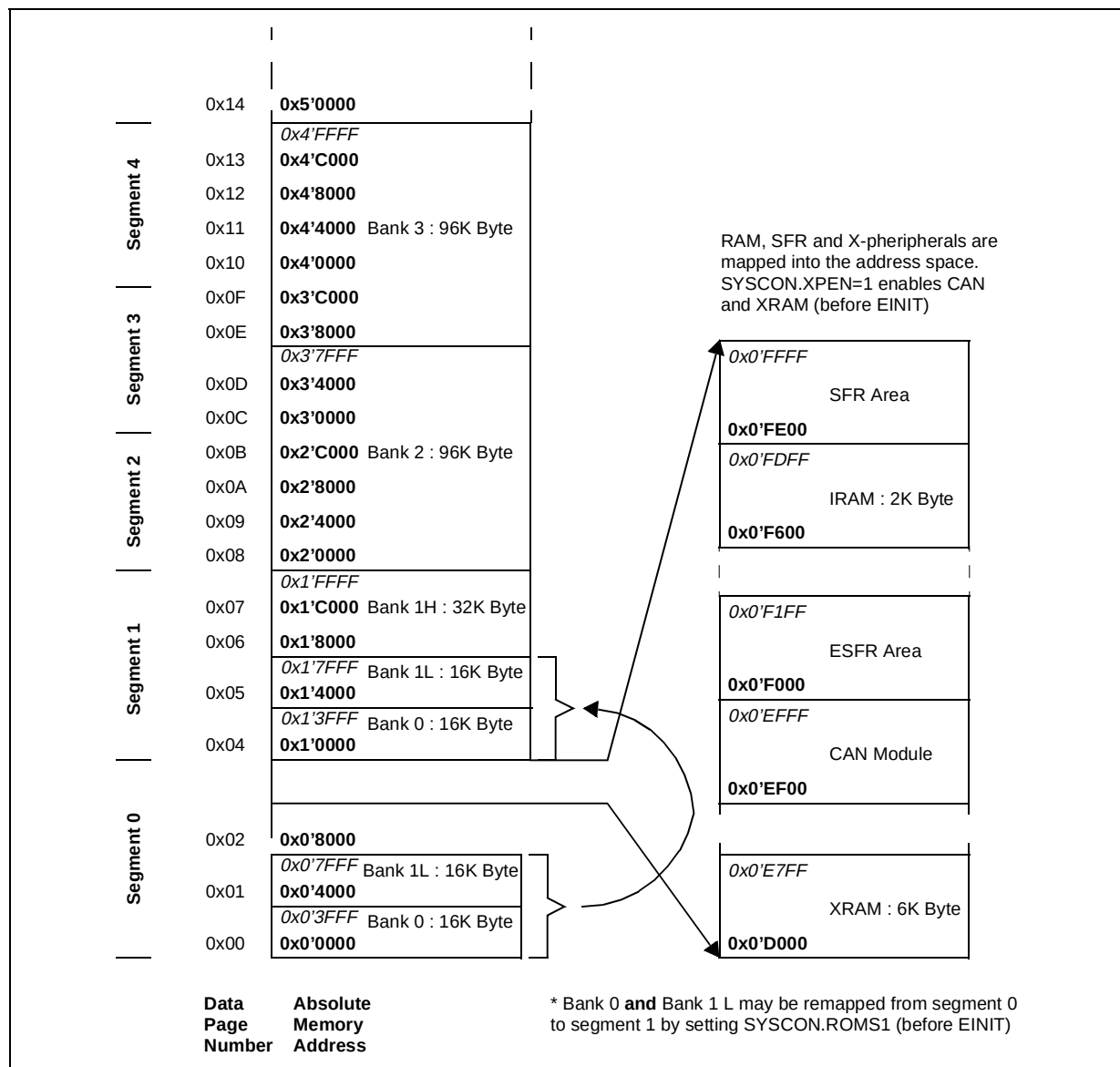
**SFR/ESFR:** 1024 Byte (2 x 512 Byte) of address space is reserved for the Special Function Register areas. SFRs are word-wide registers which are used for controlling and monitoring functions of the different on-chip units.

**CAN:** Address range 00'EF00h - 00'FFFFh is reserved for the CAN Module access. The CAN is enabled by setting XPEN bit 2 of the SYSCON register. Accesses to the CAN Module use demultiplexed addresses and a 16-bit data bus (Byte accesses are possible). Two wait states give an access time of 160ns at 25MHz CPU clock. No tristate wait state is used.

**Note:** If the CAN module is used, Port 4 can not be programmed to output all 8 segment address lines. Therefore, only 4 segment address lines can be used, reducing the external memory space to 5M Byte (1M Byte per  $\overline{CS}$  line)

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

Figure 4 : ST10F168 on-chip memory mapping



## 5 - FLASH MEMORY

The ST10F168 provides 256K Byte of an electrically erasable and reprogrammable Flash Memory on-chip.

The Flash Memory can be used both for code and data storage. It is organized into four 32-bit wide blocks allowing even double Word instructions to be fetched in one machine cycle. The four blocks of size 16K, 48K, 96K and 96K Byte can be erased and reprogrammed individually (see Table 2 and Table 3).

The Flash Memory can be programmed in a programming board or in the target system which provides high system flexibility. The algorithms to program or erase the flash memory are embedded in the Flash Memory itself (ST Embedded Algorithm Kernel, or STEAK™).

To start a program / erase operation, the user's software has just to load GPRs with the address and data to be programmed, or sector to be erased. STEAK uses embedded routines, which

check the validity of the programmed parameters, decode and then execute the programming or erase command. During operation, the STEAK routines carry out checks and retries to verify proper cell programming or erasing. When an error occurs, STEAK returns an error-code which identifies the cause of the error.

A Flash Memory protection option prevents the read-back of the Flash Memory contents from external memory, or from on-chip RAM. Code operation from within the Flash continues as normal.

The first bank (16K Byte) and part of the second bank (16K Byte out of 48K Byte) of the on-chip Flash Memory of the ST10F168 can be mapped to either segment 0 (addresses 00000h to 07FFFh) or to segment 1 (addresses 10000h to 17FFFh) during the initialization phase. External memory can be used for additional system flexibility.

$V_{DD} = 5V \pm 10\%$ ,  $V_{PP} = 12V \pm 5\%$ ,  $V_{SS} = 0V$ ,  $f_{CPU} = 25MHz$ , for Q6 version :  $T_A = -40^{\circ}C, +85^{\circ}C$  and for Q3 version  $T_A = -40^{\circ}C, +125^{\circ}C$ .

**Table 2 : Flash Memory Characteristics**

| Symbol     | Parameter                                            | Test Conditions               | Min. | Typ. | Max. | Unit    |
|------------|------------------------------------------------------|-------------------------------|------|------|------|---------|
| $f_{CPU}$  | CPU Frequency during erasing / programming operation |                               | 5    | -    | 32   | MHz     |
| Cyc        | Erasing / Programming Cycles                         | $f_{CPU} = 25MHz$             | -    | -    | 10K  |         |
| $t_{SPRG}$ | Single Word Programming Time                         | $f_{CPU} = 25MHz$             | -    | 40   | 1500 | $\mu s$ |
| $t_{DPRG}$ | Double Word Programming Time                         | $f_{CPU} = 25MHz$             | -    | 40   | 1500 | $\mu s$ |
| $t_{EBNK}$ | Sector Erasing Time                                  | $f_{CPU} = 25MHz$             | -    | 3    | 15   | s       |
| $t_{RET}$  | Data Retention Time                                  | Defectivity below 1ppm / year | 20   | -    | -    | year    |

**Table 3 : Flash Memory Bank Organisation**

| Bank | Addresses (segment 0)                   | Addresses (segment 1) | Size (Byte) |
|------|-----------------------------------------|-----------------------|-------------|
| 0    | 000000h to 003FFFh                      | 010000h to 013FFFh    | 16K         |
| 1    | 004000h to 007FFFh + 018000h to 01FFFFh | 014000h to 01FFFFh    | 48K         |
| 2    | 020000h to 037FFFh                      | 020000h to 03FFFFh    | 96K         |
| 3    | 038000h to 04FFFFh                      | 038000h to 04FFFFh    | 96K         |

### 5.1 - Programming / Erasing with ST Embedded Algorithm Kernel

There are three stages to run STEAK :

- To load the registers R0 to R4 with the STEAK command, the address and the data to be programmed, or sector to be erased. Table 4 gives the STEAK parameters for each type of Flash programming / erasing operation. Table 5 defines the codes used in Table 4.
- To initiate the Unlock Sequence. The Unlock Sequence is composed of two consecutive writes to an even address in the Flash active address space - the first write has direct addressing mode (MOV mem, Rwn) - the second write has indirect addressing mode (MOV [Rwm], Rwn). Rwn can be any unused Word-GPR (R6 to R15) loaded with a value resulting in the same even address as “mem”.

- To read the return values in R0. When the embedded programming / erasing algorithm returns to trigger point, return values are given in R0. Table 6 gives the error-code definitions, Table 7 gives the return values in each register for each type of Flash programming / erasing command.

Note: The Flash Embedded STEAK Algorithms require at least 50 words on the Internal System Stack. STEAK verifies that there is enough free space on the System Stack, before performing a programming or erasing operation. The MDH, MDL and MDC register content are modified.

Code examples for programming and erasing the Flash Memory using STEAK are given in Section 5.2.

Note For more details refer to STEAK application note on [www.st.com](http://www.st.com) web site.

**Table 4 : STEAK parameters**

| Command                        | R0    | R1        | R2        | R3         | R4   |
|--------------------------------|-------|-----------|-----------|------------|------|
| Single Word programming        | 55Ash | AddOff    | W         | nu         | 2TCL |
| Double Word programming        | DD4sh | AddOff    | DWL       | DWH        | 2TCL |
| Multiple (block) programming   | AA5sh | BegAddOff | EndAddOff | SourceAddr | 2TCL |
| Sector Erasing                 | EEEEh | 5555h     | Bnk       | Bnk        | 2TCL |
| Set Flash Protection UPROG bit | CCCCh | 5555h     | 3333h     | AAAAh      | 2TCL |
| Read Status                    | 7777h | nu        | nu        | nu         | 2TCL |

**Table 5 : Programming / erasing code definition**

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| s         | Segment of the Target Flash Memory cell,                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| AddOff    | Segment Offset of the Target Flash Memory cell. Must be even value (Word-aligned address).                                                                                                                                                                                                                                                                                                                                                                                            |
| W         | Data (Word) to be written in Flash.                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| DWL,DWH   | Data (double Word, DHL = low Word, DWH = high Word) to be written in Flash.                                                                                                                                                                                                                                                                                                                                                                                                           |
| BegAddOff | Segment Offset of the FIRST Target Flash Memory Word to be written in a Multiple programming command. Must be even value (Word-aligned address).                                                                                                                                                                                                                                                                                                                                      |
| EndAddOff | Segment Offset of the LAST Target Flash Memory Word to be written in a Multiple programming command.<br>Must be even value (Word-aligned address). The value D = (EndAddOff - BegAddOff) must be: $0 \leq D < 16384$ (ie. up to one page (16K Byte) can be written in the flash with one multi-Word programming command).                                                                                                                                                             |
| SourceAdd | Start address for the block to be programmed.<br>This address is using implicitly the data paging mechanism of the CPU. SourceAdd value must respect the following rules :<br>- $\text{SourceAdd} + (\text{EndAddOff} - \text{BegAddOff}) < 16384$ .<br>- Page 0 and 1 can NOT be used for source data if bit ROMS1 = '1' (in SYSCON register).<br>Note that source data can be located in Flash (In pages 0, 1, 6 to 19 if bit ROMS1 = '0', or in pages 4 to 19 if bit ROMS1 = '1'). |
| Bnk       | Number of the Bank to be erased. For security, R2 and R3 must hold the same value.                                                                                                                                                                                                                                                                                                                                                                                                    |
| 2TCL      | CPU clock period in nano-seconds (eg. R4 = 50 (32h) means CPU frequency is 20MHz).                                                                                                                                                                                                                                                                                                                                                                                                    |

**Table 6 : Error Code Definition (R0 content after STEAK execution)**

| Error Code | Meaning                                                                                                      |
|------------|--------------------------------------------------------------------------------------------------------------|
| 00h        | Operation was successful                                                                                     |
| 01h        | Flash Protection is active                                                                                   |
| 02h        | Vpp voltage not present                                                                                      |
| 03h        | Programming operation failed                                                                                 |
| 04h        | Address value (R1) incorrect: not in Flash address area or odd                                               |
| 05h        | CPU period out of range (must be between 30 ns to 500 ns)                                                    |
| 06h        | Not enough free space on system stack for proper operation                                                   |
| 07h        | Incorrect bank number (R2,R3) specified                                                                      |
| 08h        | Erase operation failed (phase 1)                                                                             |
| 09h        | Bad source address for Multiple Word programming command                                                     |
| 0Ah        | Bad number of words to be copied in Multiple Word programming command: one destination will be out of flash. |
| 0Bh        | PLL Unlocked or Oscillator watchdog overflow occurred during programming or erasing the flash.               |
| 0Ch        | Erase operation failed (phase 2)                                                                             |
| FFh        | Unknown or bad command                                                                                       |

**Table 7 : Return values for each programming / erase command**

| Programming Command               | R0         | R1                                                                                                                   | R2                                                                     | R3                                                                          | R4-R15    |           |
|-----------------------------------|------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------|-----------|
| Single or double Word programming | Error code | Unchanged                                                                                                            | Data in Flash for location Segment + Segment Offset (R0.[3:0] with R1) | Data in Flash for location Segment + Segment Offset + 2 (R0[3:0] with R1+2) | Unchanged |           |
| Block programming                 | Error code | The last segment offset address of the last written Word in Flash (failing Flash address if R0 is not equal to zero) | Undefined                                                              |                                                                             |           | Unchanged |
| Erasing                           | Error code | Undefined                                                                                                            |                                                                        |                                                                             |           | Unchanged |
| After status read                 | Error code | Flash embedded rev<br>MSByte = major release<br>LSByte = minor revision                                              | Circuit identifiers :<br>R2 = #0787h<br>R3 = #0101h for this device    |                                                                             |           | Unchanged |

Note: The Flash Embedded STEAK Algorithms require at least **50 words** on the Internal System Stack for proper operation. The program itself verifies that there is enough free space on the System Stack before performing a programming or erasing operation, by computing the Word number between Stack Pointer (SP) and Stack Overflow register (STKOV). The MDH, MDL and MDC register content are modified. Registers R0 to R4 are used as Input Data for STEAK, and are modified as explained above (Return Values).

Registers R5 to R15 are used internally by STEAK, but preserved on entry and restore on exit of STEAK.

IT IS VERY IMPORTANT TO TAKE INTO ACCOUNT THE FACT THAT STEAK USES UP TO 50 WORDS ON THE SYSTEM STACK. TO PREVENT ANY ABNORMAL SITUATION, IT IS VERY IMPORTANT TO INITIALIZE CORRECTLY THE STACK SIZE TO AT LEAST 64 WORDS, AND TO CORRECTLY INITIALIZE REGISTER STKOV.

## 5.2 - Programming Examples

### Programming a double Word

```
; code shown below assumes that Flash is mapped in segment 1
; ie. bit ROMS1 = '1' in SYSCON register
; Flash must be enabled, ie. bit ROMEN = '1' in SYSCON.
MOV    R0, #0DD40h    ; DD4xh : Double Word programming command
OR     R0, #01h       ; Selects segment 1 in flash memory
MOV    R1, #00224h    ; Address to be programmed is 01'0224h
MOV    R2, #03456h    ; Data to be programmed at 01'0224h
MOV    R3, #04567h    ; Data to be programmed at 01'0226h
MOV    R4, #050d      ; 50ns is 20MHz CPU clock frequency
MOV    R7, #08000h    ; R7 used for Flash trigger sequence
#define FCR 08000h
; Flash Unlock Sequence consists in two consecutive writes, with the direct
; addressing mode and then the indirect addressing mode. FCR must represent an
; even address in the active address space of the Flash memory, and Rwn can be
; any unused Word GPR (R6 to R15) loaded with a value resulting in the same even
; address than FCR
EXTS   #1, #2         ; Flash can be mapped in segment 0 or 1
MOV    FCR, R7        ; first part
MOV    [R7], R7       ; second part
NOP    ; WARNING: place 2 NOP operations after
NOP    ; the Unlock sequence to avoid all possible
        ; pipeline conflicts in STEAK programs
```

Note: For easier coding, the standard data paging addressing scheme is overridden for the two MOV instructions of the Flash Trigger Sequence (EXTS instruction). However this coding also locks both standard and PEC interrupts and class A hardware traps. This override can be replaced by an ATOMIC instruction if the standard DPP addressing scheme must be preserved.

**Programming a block of data**

The following code is provided as an example to program a block of data. Flash to be programmed is from address 01'9000h to 01'9FFEh (included). Source data (data to be copied into flash) is located in external RAM from address 05'1000h (to 05'1FFEh, implicitly) :

```
; code shown below assumes that flash is mapped in segment 1
; ie. bit R0MS1 = '1' in SYSCON register
; Flash must be enabled, ie. bit ROMEN = '1' in SYSCON.
MOV    R0, #0AA50h    ; AA5xh : Multi Word programming command
OR     R0, #01h       ; Selects segment 1 in Flash memory
MOV    R1, #09000h    ; First Flash Segment Offset Address
MOV    R2, #09FFEh    ; Last Flash Segment Offset Address
MOV    R3, #09000h    ; Source data address: use DPP2 as
                        ; data page pointer
SCXT   DPP2, #20d     ; Source is in page 20 (first page of
                        ; segment 5): save previous DPP2 value
                        ; and load it with source page number
MOV    R4, #050d      ; 50ns is 20MHz CPU clock frequency
MOV    R7, #08000h    ; R7 used for Flash trigger sequence
#define FCR 08000h
EXTS   #1, #2         ; Flash can be mapped in segment 0 or 1
MOV    FCR, R7         ; first part
MOV    [R7], R7        ; second part
NOP                      ; WARNING: place 2 NOP operations after
NOP                      ; the Unlock sequence to avoid all possible
                        ; pipeline conflicts in STEAK programs
POP    DPP2            ; restore DPP2
```

### 5.3 - Flash Memory Configuration

The default memory configuration of the ST10F168 Memory is determined by the state of the EA pin at reset. This value is stored in the Internal ROM Enable bit : ROMEN of the SYSCON Register.

When ROMEN = 0, the internal FLASH is disabled and external ROM is used for startup control. Flash memory can be enabled later by setting the ROMEN bit of SYSCON to 1. Ensure that the code which performs this setting is NOT running from external ROM in a segment that will be replaced by FLASH memory, otherwise unexpected behaviour may occur.

For example, if the external ROM code is located in the first 32K Byte of segment 0, the first 32K Byte of the FLASH must then be enabled in segment 1. This is done by setting the ROMS1 bit of SYSCON to 0, before or simultaneously with setting the ROMEN bit. This must be done in the externally supplied program, before the execution of the EINIT instruction. If program execution starts from external memory, but the Flash memory mapped in segment 0 is accessed later, then the code that sets the ROMEN bit must be executed either in segment 0 but above address 00'8000h, or from the internal RAM.

Bit ROMS1 only affects the mapping of the first 32K Byte of the Flash memory. All other parts of the Flash memory (addresses 01'8000h - 04'FFFFh) remain unaffected.

Note: The SGTDIS Segmentation Disable / Enable must also be set to 0 to enable the use of the full 256K Byte of on-chip memory in addition to the external boot memory. The correct procedure for changing the segmentation registers must be observed to prevent an unwanted trap condition :

- Instructions that configure the internal memory must only be executed from external memory or from the internal RAM.
- An Absolute Inter-Segment Jump (JMPS) instruction must be executed after Flash enabling, before the next instruction, even if the next instruction is located in the consecutive address.
- Whenever the internal memory is disabled, enabled or remapped, the DPPs must be explicitly (re)loaded to enable correct data accesses to the internal memory and / or external memory.

### 5.4 - Flash Protection

If Flash Protection is active, data operands in the on-chip Flash Memory area can only be read by a program executed from the Flash Memory itself.

Program branches from or into the on-chip Flash memory are possible in the Flash protection mode. Erasing and programming of the Flash memory is not possible as long as protection is active.

Flash protection is controlled by the Protection UPROM Programming Bit (UPROG). UPROG is a 'hidden' one-time programmable bit only accessible in a special mode which can be entered via a Flash EPROM programming board for example. If UPROG is set to "1", Flash protection is active after reset. By default Flash Protection is disabled (UPROG=0).

When flash protection is active (the default after reset if UPROG bit is set), then any read access in the flash by a code executed from external or internal RAM (IRAM or XRAM) will return the value 0B88Bh. Any call of STEAK will return the error code '01' (Protected flash).

Normally Flash protection should never be deactivated, once activated. If this has to be done, for example because the Flash memory has to be reprogrammed with updated program / variables, a zero value has to be written at any even address in the active address space of the Flash memory. This write can be done only by an instruction executed from the internal Flash Memory itself.

For example:

```
MOV FLASH,ZEROS ; Deactivate Flash Protection.
```

; Flash is any even address in Flash memory space. This instruction MUST be executed from Flash memory itself.

After this instruction, the flash is temporarily de-protected, thus any read access of the flash from code executed from external memory or internal RAMs will be correctly executed, and calls of STEAK can be correctly performed (programming, erasing or status reading).

Note: 1. That all STEAK commands re-activate the flash protection if bit UPROG is set when completed.

### 5.5 - Bootstrap Loader Mode

Pin P0L.4 (BSL) activates the on-chip bootstrap loader, when low during hardware reset. The bootstrap loader allows moving the start code into the internal RAM of the ST10F168 via the serial interface ASC0. The ST10F168 will remain in bootstrap loader mode until a hardware reset with P0L.4 high or a software reset occurs. The bootstrap loader acknowledge byte is D5h.

## 6 - CENTRAL PROCESSING UNIT (CPU)

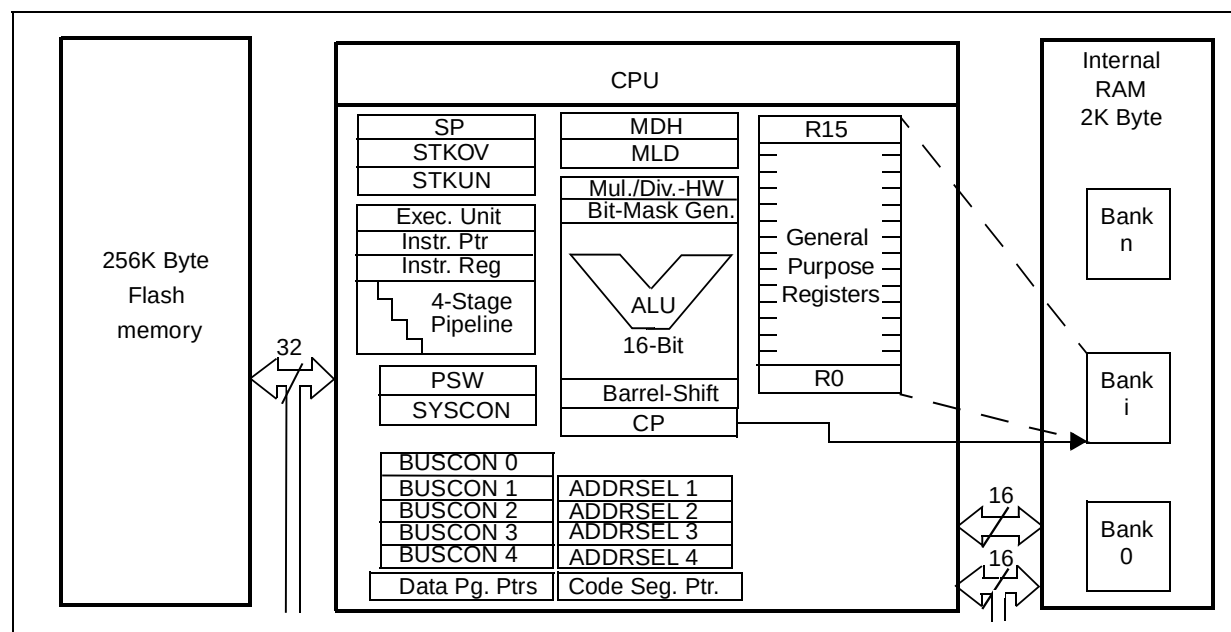
The CPU includes a 4-stage instruction pipeline, a 16-bit arithmetic and logic unit (ALU) and dedicated SFRs. Additional hardware has been added for a separate multiply and divide unit, a bit-mask generator and a barrel shifter.

Most of the ST10F168's instructions can be executed in one instruction cycle which requires 62.5ns at 32MHz CPU clock. For example, shift and rotate instructions are processed in one instruction cycle independent of the number of bit to be shifted. Multiple-cycle instructions have been optimized: branches are carried out in 2 cycles, 16 x 16-bit multiplication in 5 cycles and a 32/16 bit division in 10 cycles. The jump cache reduces the execution time of repeatedly performed jumps in a loop, from 2 cycles to 1 cycle.

The CPU uses a bank of 16 word registers to run the current context. This bank of General Purpose Registers (GPR) is physically stored 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. The number of register banks is only restricted by the available internal RAM space. For easy parameter passing, one register bank may overlap others.

A system stack of up to 2048 Byte stores 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 on each stack access, for the detection of a stack overflow or underflow.

**Figure 5 : CPU Block Diagram**



### 6.1 - Instruction Set Summary

The Table 8 lists the instructions of the ST10F168. The various addressing modes, instruction operation, parameters for conditional execution of

instructions, opcodes and a detailed description of each instruction can be found in the “ST10 Family Programming Manual”.

**Table 8 :** 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 x 16-bit)                                        | 2     |
| DIV(U)           | (Un)Signed divide register MDL by direct GPR (16 / 16-bit)                                        | 2     |
| DIVL(U)          | (Un)Signed long divide register MD by direct GPR (32 / 16-bit)                                    | 2     |
| CPL(B)           | Complement direct Word (Byte) GPR                                                                 | 2     |
| NEG(B)           | Negate direct Word (Byte) GPR                                                                     | 2     |
| AND(B)           | Bitwise AND, (Word / Byte operands)                                                               | 2 / 4 |
| OR(B)            | Bitwise OR, (Word / Byte operands)                                                                | 2 / 4 |
| XOR(B)           | Bitwise XOR, (Word / Byte operands)                                                               | 2 / 4 |
| BCLR             | Clear direct bit                                                                                  | 2     |
| BSET             | Set direct bit                                                                                    | 2     |
| BMOV(N)          | Move (negated) direct bit to direct bit                                                           | 4     |
| BAND, BOR, BXOR  | AND / OR / XOR direct bit with direct bit                                                         | 4     |
| BCMP             | Compare direct bit to direct bit                                                                  | 4     |
| BFLDH/L          | Bitwise modify masked high / low Byte of bit-addressable direct Word memory with immediate data   | 4     |
| CMP(B)           | Compare Word (Byte) operands                                                                      | 2 / 4 |
| CMPD1/2          | Compare Word data to GPR and decrement GPR by 1/2                                                 | 2 / 4 |
| CMPI1/2          | Compare Word data to GPR and increment GPR by 1/2                                                 | 2 / 4 |
| PRIOR            | Determine number of shift cycles to normalize direct Word GPR and store result in direct Word GPR | 2     |
| SHL/SHR          | Shift left / right direct Word GPR                                                                | 2     |
| ROL/ROR          | Rotate left / right direct Word GPR                                                               | 2     |
| ASHR             | Arithmetic (sign bit) shift right direct Word GPR                                                 | 2     |
| 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     |

**Table 8** : Instruction set summary

| Mnemonic            | Description                                                                         | Bytes |
|---------------------|-------------------------------------------------------------------------------------|-------|
| 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     |
| 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     |

## 7 - EXTERNAL BUS CONTROLLER

All external memory accesses are performed by the on-chip external bus controller. The EBC can be programmed to single chip mode when no external memory is required, or to one of four different external memory access modes :

- 16 / 18 / 20 / 24-bit addresses and 16-bit data, demultiplexed.
- 16 / 18 / 20 / 24-bit addresses and 16-bit data, multiplexed.
- 16 / 18 / 20 / 24-bit addresses and 8-bit data, multiplexed.
- 16 / 18 / 20 / 24-bit addresses and 8-bit data, demultiplexed.

In demultiplexed bus modes addresses are output on Port1 and data are input / output on Port0 or P0L, respectively. In the multiplexed bus modes both addresses and data use Port0 for input / output.

Timing characteristics of the external bus interface (memory cycle time, memory tri-state time, length of ALE and read / write delay) are programmable giving the choice of a wide range of memories and external peripherals. Up to 4 independent address windows may be defined (using register pairs ADDRSELx / BUSCONx) to access different resources and 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 CS signals (4 windows plus default) can be generated in

order to save external glue logic. Access to very slow memories is supported by a 'Ready' function.

A  $\overline{\text{HOLD}}/\overline{\text{HLDA}}$  protocol is available for bus arbitration which shares external resources with other bus masters. The bus arbitration is enabled by setting bit HLDEN in register SYSCON. After setting HLDEN once, pins P6.7...P6.5 ( $\overline{\text{BREQ}}$ , HLDA,  $\overline{\text{HOLD}}$ ) 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 directly connects the slave controller to another master controller without glue logic.

For applications which require less external memory space, the address space can be restricted to 1M Byte, 256K Byte or to 64K Byte. Port4 outputs all 8 address lines if an address space of 16M Byte is used, otherwise four, two or no address lines.

Chip select timing can be programmed. By default (after reset), the CSx lines change half a CPU clock cycle after the rising edge of ALE. With the CSCFG bit set in the SYSCON register the CSx lines can change with the rising edge of ALE.

The active level of the READY pin can be set by bit RDYPOLx in the BUSCONx registers. When the READY function is enabled for a specific address window, each bus cycle within the window must be terminated with the active level defined by bit RDYPOLx in the associated BUSCONx register.

## 8 - INTERRUPT SYSTEM

The interrupt response time for internal program execution is from 157ns to 375ns at 32MHz CPU clock.

The ST10F168 architecture 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 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 to perform the transmission or the reception of blocks of data.

The ST10F168 has 8 PEC channels, each of them offers such fast interrupt-driven data transfer capabilities.

A interrupt control register which contains an interrupt request flag, an interrupt enable flag and an interrupt priority bitfield is dedicated to each existing interrupt source. Thanks to its related register, each source can be programmed to one of sixteen interrupt priority levels. Once starting to be processed 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 9 shows all the available ST10F168 interrupt sources and the corresponding hardware-related interrupt flags, vectors, vector locations and trap (interrupt) numbers:

**Table 9 :** Interrupt sources

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location | Trap Number |
|--------------------------------------------|--------------|-------------|------------------|-----------------|-------------|
| CAPCOM Register 0                          | CC0IR        | CC0IE       | CC0INT           | 00'0040h        | 10h         |
| CAPCOM Register 1                          | CC1IR        | CC1IE       | CC1INT           | 00'0044h        | 11h         |
| CAPCOM Register 2                          | CC2IR        | CC2IE       | CC2INT           | 00'0048h        | 12h         |
| CAPCOM Register 3                          | CC3IR        | CC3IE       | CC3INT           | 00'004Ch        | 13h         |
| CAPCOM Register 4                          | CC4IR        | CC4IE       | CC4INT           | 00'0050h        | 14h         |
| CAPCOM Register 5                          | CC5IR        | CC5IE       | CC5INT           | 00'0054h        | 15h         |
| CAPCOM Register 6                          | CC6IR        | CC6IE       | CC6INT           | 00'0058h        | 16h         |
| CAPCOM Register 7                          | CC7IR        | CC7IE       | CC7INT           | 00'005Ch        | 17h         |
| CAPCOM Register 8                          | CC8IR        | CC8IE       | CC8INT           | 00'0060h        | 18h         |
| CAPCOM Register 9                          | CC9IR        | CC9IE       | CC9INT           | 00'0064h        | 19h         |
| CAPCOM Register 10                         | CC10IR       | CC10IE      | CC10INT          | 00'0068h        | 1Ah         |
| CAPCOM Register 11                         | CC11IR       | CC11IE      | CC11INT          | 00'006Ch        | 1Bh         |
| CAPCOM Register 12                         | CC12IR       | CC12IE      | CC12INT          | 00'0070h        | 1Ch         |
| CAPCOM Register 13                         | CC13IR       | CC13IE      | CC13INT          | 00'0074h        | 1Dh         |
| CAPCOM Register 14                         | CC14IR       | CC14IE      | CC14INT          | 00'0078h        | 1Eh         |
| CAPCOM Register 15                         | CC15IR       | CC15IE      | CC15INT          | 00'007Ch        | 1Fh         |
| CAPCOM Register 16                         | CC16IR       | CC16IE      | CC16INT          | 00'00C0h        | 30h         |
| CAPCOM Register 17                         | CC17IR       | CC17IE      | CC17INT          | 00'00C4h        | 31h         |

Table 9 : Interrupt sources (continued)

| Source of Interrupt or PEC Service Request | Request Flag | Enable Flag | Interrupt Vector | Vector Location | Trap Number |
|--------------------------------------------|--------------|-------------|------------------|-----------------|-------------|
| CAPCOM Register 18                         | CC18IR       | CC18IE      | CC18INT          | 00'00C8h        | 32h         |
| CAPCOM Register 19                         | CC19IR       | CC19IE      | CC19INT          | 00'00CCh        | 33h         |
| CAPCOM Register 20                         | CC20IR       | CC20IE      | CC20INT          | 00'00D0h        | 34h         |
| CAPCOM Register 21                         | CC21IR       | CC21IE      | CC21INT          | 00'00D4h        | 35h         |
| CAPCOM Register 22                         | CC22IR       | CC22IE      | CC22INT          | 00'00D8h        | 36h         |
| CAPCOM Register 23                         | CC23IR       | CC23IE      | CC23INT          | 00'00DCh        | 37h         |
| CAPCOM Register 24                         | CC24IR       | CC24IE      | CC24INT          | 00'00E0h        | 38h         |
| CAPCOM Register 25                         | CC25IR       | CC25IE      | CC25INT          | 00'00E4h        | 39h         |
| CAPCOM Register 26                         | CC26IR       | CC26IE      | CC26INT          | 00'00E8h        | 3Ah         |
| CAPCOM Register 27                         | CC27IR       | CC27IE      | CC27INT          | 00'00ECh        | 3Bh         |
| CAPCOM Register 28                         | CC28IR       | CC28IE      | CC28INT          | 00'00F0h        | 3Ch         |
| CAPCOM Register 29                         | CC29IR       | CC29IE      | CC29INT          | 00'0110h        | 44h         |
| CAPCOM Register 30                         | CC30IR       | CC30IE      | CC30INT          | 00'0114h        | 45h         |
| CAPCOM Register 31                         | CC31IR       | CC31IE      | CC31INT          | 00'0118h        | 46h         |
| CAPCOM Timer 0                             | T0IR         | T0IE        | T0INT            | 00'0080h        | 20h         |
| CAPCOM Timer 1                             | T1IR         | T1IE        | T1INT            | 00'0084h        | 21h         |
| CAPCOM Timer 7                             | T7IR         | T7IE        | T7INT            | 00'00F4h        | 3Dh         |
| CAPCOM Timer 8                             | T8IR         | T8IE        | T8INT            | 00'00F8h        | 3Eh         |
| GPT1 Timer 2                               | T2IR         | T2IE        | T2INT            | 00'0088h        | 22h         |
| GPT1 Timer 3                               | T3IR         | T3IE        | T3INT            | 00'008Ch        | 23h         |
| GPT1 Timer 4                               | T4IR         | T4IE        | T4INT            | 00'0090h        | 24h         |
| GPT2 Timer 5                               | T5IR         | T5IE        | T5INT            | 00'0094h        | 25h         |
| GPT2 Timer 6                               | T6IR         | T6IE        | T6INT            | 00'0098h        | 26h         |
| GPT2 CAPREL Register                       | CRIR         | CRIE        | CRINT            | 00'009Ch        | 27h         |
| A/D Conversion Complete                    | ADCIR        | ADCIE       | ADCINT           | 00'00A0h        | 28h         |
| A/D Overrun Error                          | ADEIR        | ADEIE       | ADEINT           | 00'00A4h        | 29h         |
| ASC0 Transmitter                           | S0TIR        | S0TIE       | S0TINT           | 00'00A8h        | 2Ah         |
| ASC0 Transmitter Buffer                    | S0TBIR       | S0TBIE      | S0TBINT          | 00'011Ch        | 47h         |
| ASC0 Receiver                              | S0RIR        | S0RIE       | S0RINT           | 00'00ACh        | 2Bh         |
| ASC0 Error                                 | S0EIR        | S0EIE       | S0EINT           | 00'00B0h        | 2Ch         |
| SSC Transmitter                            | SCTIR        | SCTIE       | SCTINT           | 00'00B4h        | 2Dh         |
| SSC Receiver                               | SCRIR        | SCRIE       | SCRINT           | 00'00B8h        | 2Eh         |
| SSC Error                                  | SCEIR        | SCEIE       | SCEINT           | 00'00BCh        | 2Fh         |
| PWM Channel 0...3                          | PWMIR        | PWMIE       | PWMINT           | 00'00FCh        | 3Fh         |
| CAN Interface                              | XP0IR        | XP0IE       | XP0INT           | 00'0100h        | 40h         |
| X-Peripheral Node                          | XP1IR        | XP1IE       | XP1INT           | 00'0104h        | 41h         |
| X-Peripheral Node                          | XP2IR        | XP2IE       | XP2INT           | 00'0108h        | 42h         |
| PLL Unlock                                 | XP3IR        | XP3IE       | XP3INT           | 00'010Ch        | 43h         |

Hardware traps are exceptions or error conditions that arise during run-time. They cause immediate non-maskable system reaction 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 other program execution.

Hardware trap services cannot not be interrupted by standard interrupt or by PEC interrupts.

Table 10 shows all of the possible exceptions or error conditions that can arise during run-time :

**Table 10** : Exceptions or error conditions that can arise during run-time

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

## 9 - CAPTURE / COMPARE (CAPCOM) UNIT

The ST10F168 has two 16 channel CAPCOM units which support generation and control of timing sequences on up to 32 channels with a maximum resolution of 320ns at 32MHz CPU clock.

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 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.

Each 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 functions. Each register has one associated port pin 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 dedicated capture / compare register in response to an external event at the corresponding 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 the 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.

The input frequencies  $f_{Tx}$ , for the timer input selector TxI, are determined as a function of the CPU clock. The timer input frequencies, the resolution and the periods which result from the selected pre-scaler option in TxI when using a 25MHz CPU clock are listed in the Table 12.

The numbers of the timer periods are based on a reload value of 0000h. Note that some numbers are rounded to 3 significant figures.

**Table 11 : Compare Modes**

| 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. |

**Table 12** : CAPCOM timer input frequencies, resolution and periods

| $f_{\text{CPU}} = 25\text{MHz}$ | Timer Input Selection TxI |         |              |              |              |               |               |               |
|---------------------------------|---------------------------|---------|--------------|--------------|--------------|---------------|---------------|---------------|
|                                 | 000b                      | 001b    | 010b         | 011b         | 100b         | 101b          | 110b          | 111b          |
| $f_{\text{CPU}}$ pre-scaler     | 8                         | 16      | 32           | 64           | 128          | 256           | 512           | 1024          |
| Input Frequency                 | 3.125MHz                  | 1.56MHz | 781KHz       | 391KHz       | 195KHz       | 97.7KHz       | 48.8KHz       | 24.4KHz       |
| Resolution                      | 320ns                     | 640ns   | 1.28 $\mu$ s | 2.56 $\mu$ s | 5.12 $\mu$ s | 10.24 $\mu$ s | 20.48 $\mu$ s | 40.96 $\mu$ s |
| Period                          | 21.0ms                    | 41.9ms  | 83.9ms       | 167ms        | 336ms        | 671ms         | 1.34s         | 2.68s         |

**Table 13** : CAPCOM Channels Pin Assignement

| CAPCOM Unit | Channel    | 0    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8                | 9                | 10                | 11                | 12   | 13   | 14   | 15   |
|-------------|------------|------|------|------|------|------|------|------|------|------------------|------------------|-------------------|-------------------|------|------|------|------|
| CAPCOM1     | I/O        | CC0  | CC1  | CC2  | CC3  | CC4  | CC5  | CC6  | CC7  | CC8 <sup>1</sup> | CC9 <sup>1</sup> | CC10 <sup>1</sup> | CC11 <sup>1</sup> | CC12 | CC13 | CC14 | CC15 |
|             | Port       | 2.0  | 2.1  | 2.2  | 2.3  | 2.4  | 2.5  | 2.6  | 2.7  | 2.8              | 2.9              | 2.10              | 2.11              | 2.12 | 2.13 | 2.14 | 2.15 |
|             | Pin Number | 47   | 48   | 49   | 50   | 51   | 52   | 53   | 54   | 57               | 58               | 59                | 60                | 61   | 62   | 63   | 64   |
| CAPCOM2     | I/O        | CC16 | CC17 | CC18 | CC19 | CC20 | CC21 | CC22 | CC23 | CC24             | CC25             | CC26              | CC27              | CC28 | CC29 | CC30 | CC31 |
|             | Port       | 8.0  | 8.1  | 8.2  | 8.3  | 8.4  | 8.5  | 8.6  | 8.7  | 1H.4             | 1H.5             | 1H.6              | 1H.7              | 7.4  | 7.5  | 7.6  | 7.7  |
|             | Pin Number | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 132              | 133              | 134               | 135               | 23   | 24   | 25   | 26   |

Note: 1. Input only.

## 10 - GENERAL PURPOSE TIMER UNIT

The GPT unit is a flexible multifunctional timer / counter structure which is used for time related tasks such as event timing and counting, pulse width and duty cycle measurements, pulse generation, or pulse multiplication. The GPT unit contains five 16-bit timers organized into two separate modules GPT1 and GPT2. Each timer in each module may operate independently in several different modes, or may be concatenated with another timer of the same module.

### 10.1 - GPT1

Each of the three timers T2, T3, T4 of the GPT1 module can be configured individually for one of four basic modes of operation: **timer, gated timer, counter mode and incremental interface mode**. In timer mode, the input clock for a timer is derived from the CPU clock, divided by a programmable prescaler. In counter mode, the timer is 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.

Table 14 lists the timer input frequencies, resolution and periods for each pre-scaler option at 25MHz CPU clock. This also applies to the Gated Timer Mode of T3 and to the auxiliary timers T2 and T4 in Timer and Gated Timer Mode.

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

In Incremental Interface Mode, the GPT1 timers (T2, T3, T4) can be connected directly to the incremental position sensor signals A and B by their respective inputs TxIN and TxEUD. Direction and count signals are internally derived from these two input signals so that 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 output toggle latches (TxOTL) which changes state on each timer over-flow / under-flow. The state of this latch may be output on port pins (TxOUT) e. g. for time out monitoring of external hardware components, or may be used internally to clock timers T2 and T4 for high resolution of long duration measurements.

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.

### 10.2 - GPT2

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.

**Table 14** : GPT1 timer input frequencies, resolution and periods

| $f_{CPU} = 25MHz$ | Timer Input Selection T2I / T3I / T4I |          |          |        |          |          |          |          |
|-------------------|---------------------------------------|----------|----------|--------|----------|----------|----------|----------|
|                   | 000b                                  | 001b     | 010b     | 011b   | 100b     | 101b     | 110b     | 111b     |
| Pre-scaler Factor | 8                                     | 16       | 32       | 64     | 128      | 256      | 512      | 1024     |
| Input Frequency   | 3.125MHz                              | 1.563MHz | 781.3MHz | 390KHz | 195.3KHz | 97.66KHz | 48.83KHz | 24.41KHz |
| Resolution        | 320ns                                 | 640ns    | 1.28µs   | 2.56µs | 5.12µs   | 10.24µs  | 20.48µs  | 40.96µs  |
| Period            | 21.0ms                                | 41.9ms   | 83.9ms   | 167ms  | 336ms    | 671ms    | 1.34s    | 2.68s    |

The state of this latch may be used to clock timer T5, or it may be output on a port pin (T6OUT).

The overflows / underflows of timer T6 can also be used to clock the CAPCOM timers T0 or T1, and to cause a reload from the CAPREL register.

The CAPREL register can capture the contents of T5 from an external signal transition on the corresponding port pin (CAPIN), and T5 may be optionally cleared after the capture procedure. This allows absolute time differences to be measured or pulse multiplication to be performed without software overhead.

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

Table 15 GPT2 timer input frequencies, resolution and periods lists the timer input frequencies, resolution and periods for each pre-scaler option at 25MHz CPU clock. This also applies to the Gated Timer Mode of T6 and to the auxiliary timer T5 in Timer and Gated Timer Mode.

**Table 15 :** GPT2 timer input frequencies, resolution and periods

| $f_{CPU} = 25MHz$ | Timer Input Selection T5I / T6I |          |          |              |              |              |               |               |
|-------------------|---------------------------------|----------|----------|--------------|--------------|--------------|---------------|---------------|
|                   | 000b                            | 001b     | 010b     | 011b         | 100b         | 101b         | 110b          | 111b          |
| Pre-scaler Factor | 4                               | 8        | 16       | 32           | 64           | 128          | 256           | 512           |
| Input Frequency   | 6.25MHz                         | 3.125MHz | 1.563MHz | 781.3KHz     | 390KHz       | 195.3KHz     | 97.66KHz      | 48.83KHz      |
| Resolution        | 160ns                           | 320ns    | 640ns    | 1.28 $\mu$ s | 2.56 $\mu$ s | 5.12 $\mu$ s | 10.24 $\mu$ s | 20.48 $\mu$ s |
| Period            | 10.49ms                         | 21.0ms   | 41.9ms   | 83.9ms       | 167ms        | 336ms        | 671ms         | 1.34s         |

**Figure 6 :** Block Diagram of GPT1

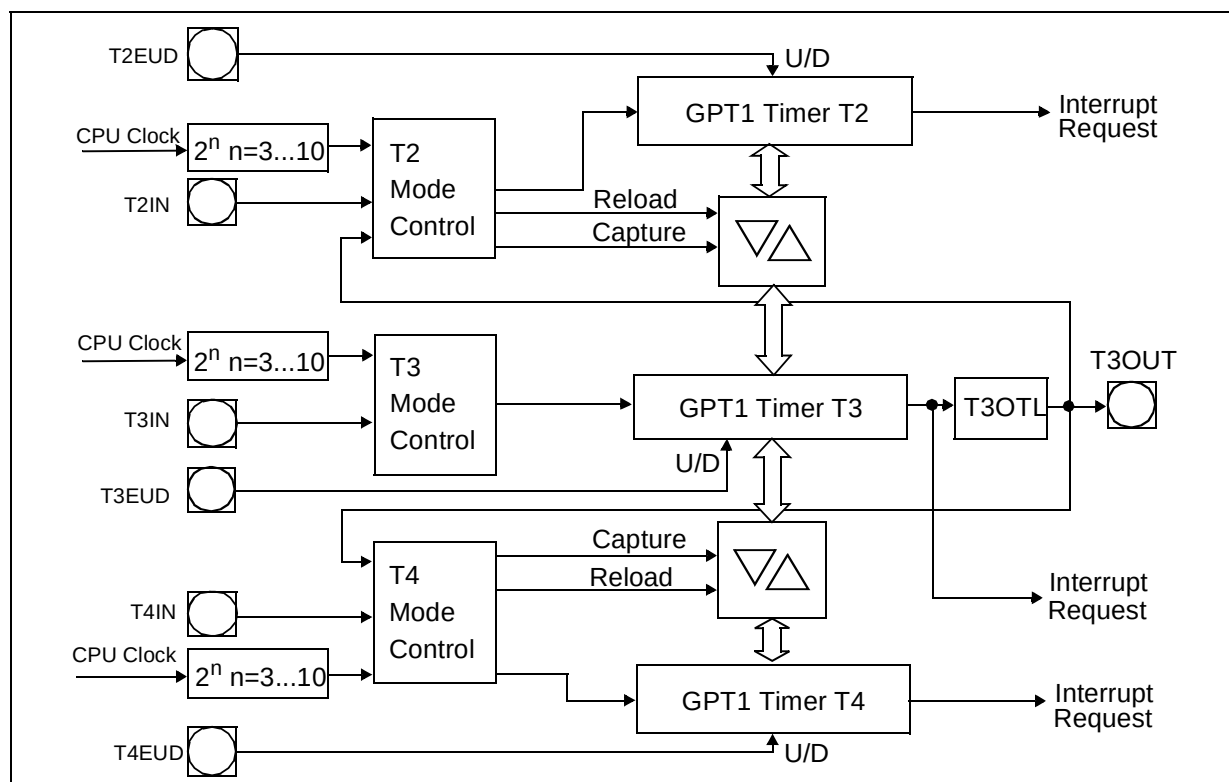
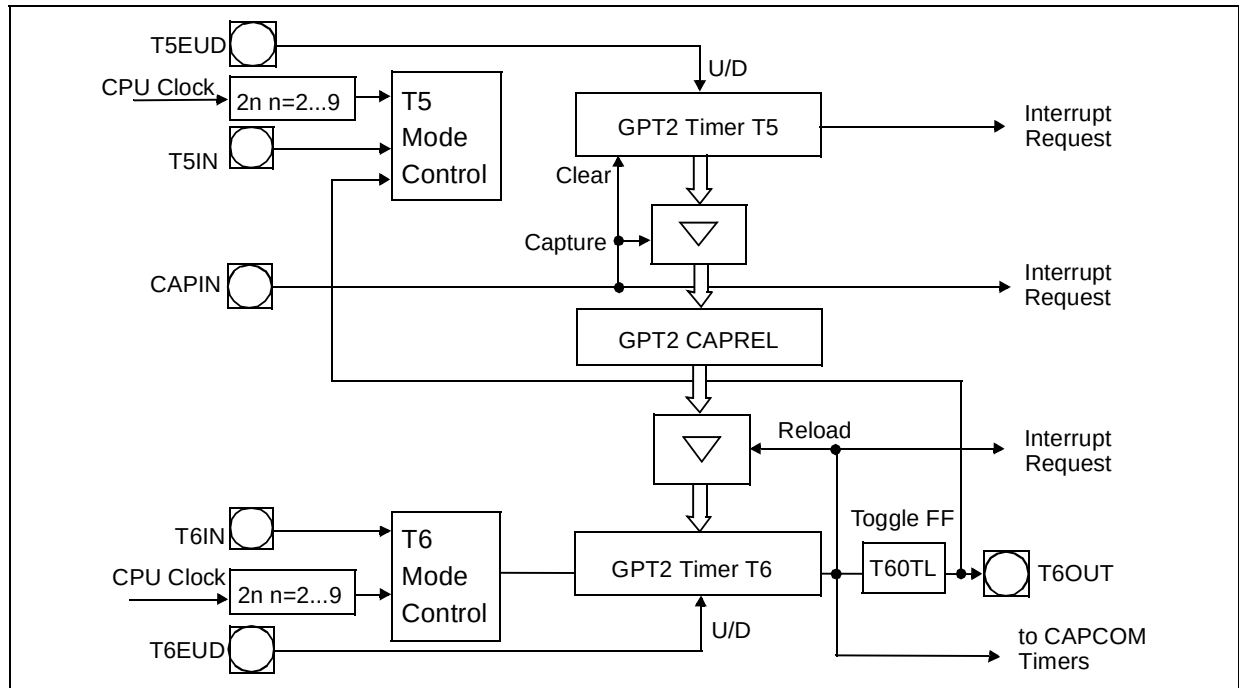


Figure 7 : Block Diagram of GPT2



## 11 - PWM MODULE

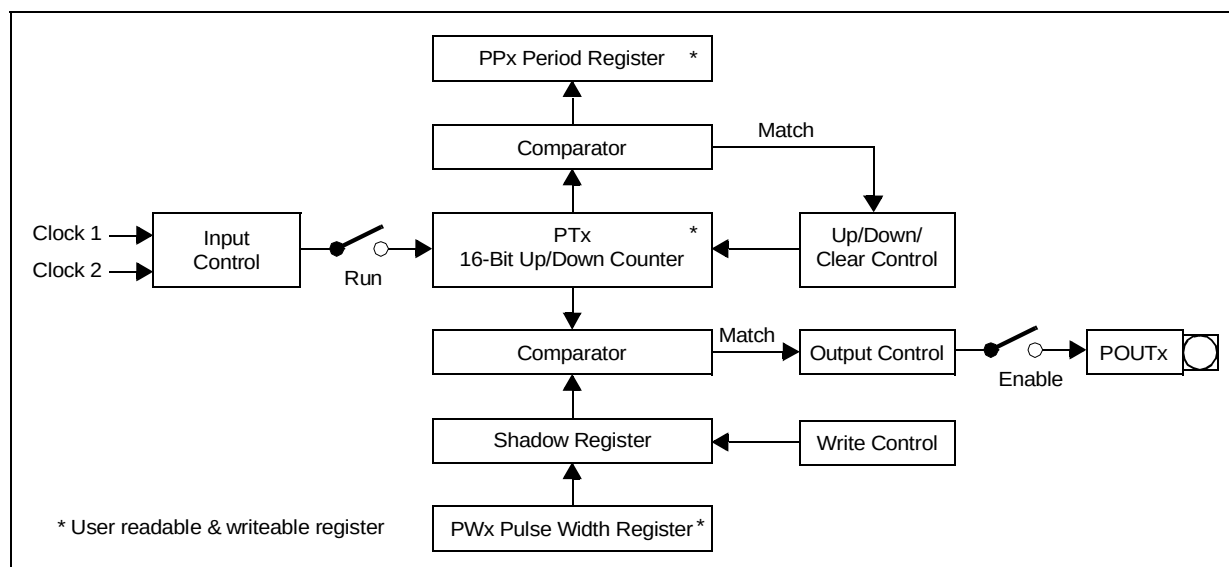
The pulse width modulation module can generate up to four PWM output signals using edge-aligned or centre-aligned PWM. In addition, the PWM module can generate PWM burst signals and single

shot outputs. The Table 16 shows the PWM frequencies for different resolutions. The level of the output signals is selectable and the PWM module can generate interrupt requests.

**Table 16 :** PWM unit frequencies and resolution at 25MHz CPU clock

| Mode 0         | Resolution | 8-bit    | 10-bit   | 12-bit   | 14-bit   | 16-bit  |
|----------------|------------|----------|----------|----------|----------|---------|
| CPU Clock / 1  | 40ns       | 97.66KHz | 24.41KHz | 6.104KHz | 1.526KHz | 0.381Hz |
| CPU Clock / 64 | 2.56µs     | 1.526KHz | 381.5Hz  | 95.37Hz  | 23.84Hz  | 5.96Hz  |
| Mode 1         | Resolution | 8-bit    | 10-bit   | 12-bit   | 14-bit   | 16-bit  |
| CPU Clock / 1  | 40ns       | 48.82KHz | 12.20KHz | 3.05KHz  | 762.9Hz  | 190.7Hz |
| CPU Clock / 64 | 2.56µs     | 762.9Hz  | 190.7Hz  | 47.68Hz  | 11.92Hz  | 2.98Hz  |

**Figure 8 :** PWM Module Block Diagram



## 12 - PARALLEL PORTS

The ST10F168 provides up to 111 I/O lines 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 input or output 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 7 and Port 8 is selectable (TTL or CMOS-like), where the special CMOS-like input threshold reduces noise sensitivity to the input hysteresis. The input thresholds are selected with bit of PICON register dedicated to blocks of 8 input pins (2-bit for Port2, 2-bit for Port3, 1-bit for Port7, 1-bit for Port8).

All pins of I/O ports also support an alternate programmable function:

- Port0 and Port1 may be used as address and data lines when accessing external memory.
- Port 2, Port 7 and Port 8 are associated with the capture inputs or with the compare outputs of the CAPCOM units and / or with the outputs of the PWM module.
- Port 3 includes the alternate functions of timers, serial interfaces, the optional bus control signal  $\overline{\text{BHE}}$  and the system clock output (CLKOUT).
- Port 4 outputs the additional segment address bit A16 to A23 in systems where segmentation is enabled to access more than 64K Byte of memory.
- Port 5 is used as analog input channels of the A/D converter or as timer control signals.
- Port 6 provides optional bus arbitration signals ( $\overline{\text{BREQ}}$ ,  $\overline{\text{HLDA}}$ ,  $\overline{\text{HOLD}}$ ) and chip select signals.

All port lines that are not used for alternate functions may be used as general purpose I/O lines.

### 13 - A/D CONVERTER

A10-bit A/D converter with 16 multiplexed input channels and a sample and hold circuit is integrated on-chip. The sample time (for loading the capacitors) and the conversion time is programmable and can be adjusted to the external circuitry.

Overrun error detection / protection is controlled by the ADDAT register. Either an interrupt request is 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 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 ST10F168 supports different conversion modes :

- **Single channel single conversion** : the analog level of the selected channel is sampled once and converted. The result of the conversion is stored in the ADDAT register.
- **Single channel continuous conversion** : the analog level of the selected channel is repeatedly sampled and converted. The result of the conversion is stored in the ADDAT register.
- **Auto scan single conversion** : the analog level of the selected channels are sampled once and converted. After each conversion the result is stored in the ADDAT register. The data can be transferred to the RAM by interrupt software management or using the powerfull Peripheral Event Controller data transfert.
- **Auto scan continuous conversion** : the analog level of the selected channels are repeatedly sampled and converted. The result of the conversion is stored in the ADDAT register. The data can be transferred to the RAM by interrupt software management or using the powerfull Peripheral Event Controller data transfert.
- **Wait for ADDAT read mode** : when using continuous modes, in order to avoid to overwrite

the result of the current conversion by the next one, the ADWR bit of ADCON control register must be activated. Then, until the ADDAT register is read, the new result is stored in a temporary buffer and the conversion is on hold.

- **Channel injection mode** : when using continuous modes, a selected channel can be converted in between without changing the current operating mode. The 10 bit data of the conversion are stored in ADRES field of ADDAT2. The current continuous mode remains active after the single conversion is completed.

The Table 17 ADC sample clock and conversion clock shows conversion clock and sample clock of the ADC unit. A complete conversion will take  $14t_{CC} + 2t_{SC} + 4TCL$ . This time includes the conversion it self, the sampling time and the time required to transfer the digital value to the result register. For example at 25MHz of CPU clock, the minimum complete conversion time is 7.76µs.

The A/D converter provides automatic offset and linearity self calibration. The calibration operation is performed in two ways :

- A full calibration sequence is performed after a reset and lasts 1.25ms minimum (at 25MHz CPU clock). During this time, the ADBSY flag is set to indicate the operation. Normal conversion can be performed during this time. The duration of the calibration sequence is then extended by the time consumed by the conversions.

Note : After a power-on reset, the total unadjusted error (TUE) of the ADC might be worse than  $\pm 2LSB$  (max.  $\pm 4LSB$ ). During the full calibration sequence, the TUE is constantly improved until at the end of the cycle, TUE is within the specified limits of  $\pm 2LSB$ .

- One calibration cycle is performed after each conversion : each calibration cycle takes 4 ADC clock cycles. These operation cycles ensure constant updating of the ADC accuracy, compensating changing operating conditions.

**Table 17** : ADC sample clock and conversion clock

| ADCTC | Conversion Clock $t_{CC}$     |                      | ADSTC | Sample Clock $t_{SC}$ |                      |
|-------|-------------------------------|----------------------|-------|-----------------------|----------------------|
|       | $TCL^1 = 1/2 \times f_{XTAL}$ | At $f_{CPU} = 25MHz$ |       | $t_{SC} =$            | At $f_{CPU} = 25MHz$ |
| 00    | $TCL \times 24$               | 0.48µs               | 00    | $t_{CC}$              | $0.48\mu s^2$        |
| 01    | Reserved, do not use          | Reserved             | 01    | $t_{CC} \times 2$     | $0.96\mu s^2$        |
| 10    | $TCL \times 96$               | 1.92µs               | 10    | $t_{CC} \times 4$     | $1.92\mu s^2$        |
| 11    | $TCL \times 48$               | 0.96µs               | 11    | $t_{CC} \times 8$     | $3.84\mu s^2$        |

Notes: 1. See Section 20.5.5 - Direct Drive on page 55.

2.  $t_{CC} = TCL \times 24$ .

## 14 - SERIAL CHANNELS

Serial communication with other microcontrollers, processors, terminals or external peripheral components is provided by two serial interfaces: the asynchronous / synchronous serial channel (ASC0) and the high-speed synchronous serial channel (SSC).

Two dedicated Baud rate generators set up all standard Baud rates without the requirement of oscillator tuning. For transmission, reception and erroneous reception, 3 separate interrupt vectors are provided for each serial channel.

### ASC0

ASC0 supports full-duplex asynchronous communication at up to 781.25K Baud and half-duplex

synchronous communication up to 5M Baud at 25MHz system clock.

For asynchronous operation, the Baud rate generator provides a clock with 16 times the rate of the established Baud rate.

Table 18 lists various commonly used Baud rates together with the required reload values and the deviation errors compared to the intended Baud rate.

For synchronous operation, the Baud rate generator provides a clock with 4 times the rate of the established Baud rate.

**Table 18** : Commonly used Baud rates by reload value and deviation errors

| S0BRS = '0', f <sub>CPU</sub> = 25MHz |                 |               | S0BRS = '1', f <sub>CPU</sub> = 25MHz |                 |               |
|---------------------------------------|-----------------|---------------|---------------------------------------|-----------------|---------------|
| Baud Rate (Baud)                      | Deviation Error | Reload Value  | Baud Rate (Baud)                      | Deviation Error | Reload Value  |
| 781 250                               | ±0.0%           | 0000h         | 520 833                               | ±0.0%           | 0000h         |
| 56 000                                | +7.3% / -0.4%   | 000Ch / 000Dh | 56 000                                | +3.3% / -7.0%   | 0008h / 0009h |
| 38 400                                | +1.7% / -3.1%   | 0013h / 0014h | 38 400                                | +4.3% / -3.1%   | 000Ch / 000Dh |
| 19 200                                | +1.7% / -0.8%   | 0027h / 0028h | 19 200                                | +0.5% / -3.1%   | 001Ah / 001Bh |
| 9 600                                 | +0.5% / -0.8%   | 0050h / 0051h | 9 600                                 | +0.5% / -1.4%   | 0035h / 0036h |
| 4 800                                 | +0.5% / -0.1%   | 00A1h / 00A2h | 4 800                                 | +0.5% / -0.5%   | 006Bh / 006Ch |
| 2 400                                 | +0.2% / -0.1%   | 0144h / 0145h | 2 400                                 | +0.0% / -0.5%   | 00D8h / 00D9h |
| 1 200                                 | +0.0% / -0.1%   | 028Ah / 028Bh | 1 200                                 | +0.0% / -0.2%   | 01B1h / 01B2h |
| 600                                   | +0.0% / -0.1%   | 0515h / 0516h | 600                                   | +0.0% / -0.1%   | 0363h / 0364h |
| 95                                    | +0.4%           | 1FFFh / 1FFFh | 75                                    | +0.0% / -0.0%   | 1B1Fh / 1B20h |
|                                       |                 |               | 63                                    | +0.9%           | 1FFFh / 1FFFh |

### High Speed Synchronous Serial Channel (SSC)

The High-Speed Synchronous Serial Interface SSC provides flexible high-speed serial communication between the ST10F168 and other microcontrollers, microprocessors or external peripherals. The SSC supports full-duplex and half-duplex synchronous communication; The serial clock signal can be generated by the SSC itself (master mode) or be received from an external master (slave mode). Data width, shift direction, clock polarity and phase are programmable.

This allows communication with SPI-compatible devices. Transmission and reception of data is double-buffered. A 16-bit Baud rate generator provides the SSC with a separate serial clock signal. The serial channel SSC has its own dedicated 16-bit Baud rate generator with 16-bit reload capability, allowing Baud rate generation independent from the timers.

SSCBR is the dual-function Baud rate Generator / Reload register. Table 19 lists some possible Baud rates against the required reload values and the resulting bit times for a 25MHz CPU clock.

Note: The deviation errors given in the Table 18 are rounded. To avoid deviation errors use a Baud rate crystal (providing a multiple of the ASC0/SSC sampling frequency).

**Table 19** : Synchronous Baud rate and reload values

| Baud Rate                        | Bit Time | Reload Value |
|----------------------------------|----------|--------------|
| Reserved use a reload value > 0. | ---      | 0000h        |
| 5M Baud                          | 200ns    | 0001h        |
| 3.3M Baud                        | 303ns    | 0002h        |
| 2.5M Baud                        | 400ns    | 0004h        |
| 2M Baud                          | 500ns    | 0005h        |
| 1M Baud                          | 1μs      | 000Bh        |
| 100K Baud                        | 10μs     | 007Ch        |
| 10K Baud                         | 100μs    | 04E1h        |
| 1K Baud                          | 1ms      | 30D3h        |
| 190.7 Baud                       | 5.2ms    | FFFFh        |

## 15 - CAN MODULE

The integrated CAN module completely handles the autonomous transmission and the reception of CAN frames according to the CAN specification V2.0 part B (active). 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 CAN Module Provides full CAN functionality on up to 15 message objects. Message object 15 can be configured for basic CAN functionality. Both modes provide separate masks for acceptance filtering, allowing a number of identifiers in full CAN mode to be accepted and disregarding a number of identifiers in basic CAN mode. All message objects can be updated independently from 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 1M Baud. The CAN module uses two pins to interface to a bus transceiver.

## 16 - WATCHDOG TIMER

The Watchdog Timer is a fail-safe mechanism which prevents the microcontroller from malfunctioning for long 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.

Therefore, the chip start-up procedure is always monitored. The software must 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. It pulls the  $\overline{\text{RSTOUT}}$  pin low in order to allow external hardware components to be reset.

The Watchdog Timer is 16-bit, clocked with the system clock divided by 2 or 128. The high Byte of the watchdog timer register can be set to a pre-specified reload value (stored in WDTREL). Each time it is serviced by the application software, the high Byte of the watchdog timer is reloaded. *For security, rewrite WDTCON each time before the watchdog timer is serviced.*

Table 20 shows the watchdog time range for 25MHz CPU clock.

**Table 20** : Watchdog time range (25MHz clock)

| Reload value<br>in WDTREL | Prescaler for $f_{\text{CPU}}$ |                   |
|---------------------------|--------------------------------|-------------------|
|                           | 2 (WDTIN = '0')                | 128 (WDTIN = '1') |
| FFh                       | 20.48 $\mu$ s                  | 1.31ms            |
| 00h                       | 5.24ms                         | 336ms             |

## 17 - SYSTEM RESET

**Table 21** : Reset event definition

| Reset Source                                     | Short-cut | Conditions                                        |
|--------------------------------------------------|-----------|---------------------------------------------------|
| Power-on reset                                   | PONR      | Power-on                                          |
| Long Hardware reset (synchronous & asynchronous) | LHWR      | $t_{RSTIN} > 1032 \text{ TCL}$                    |
| Short Hardware reset (synchronous reset)         | SHWR      | $4 \text{ TCL} < t_{RSTIN} \leq 1032 \text{ TCL}$ |
| Watchdog Timer reset                             | WDTR      | WDT overflow                                      |
| Software reset                                   | SWR       | SRST execution                                    |

System reset initializes the MCU in a predefined state. There are five ways to activate a reset state. The system start-up configuration is different for each case as shown in Table 21.

### 17.1 - Asynchronous Reset (Long Hardware Reset)

An asynchronous reset is triggered when  $\overline{RSTIN}$  pin is pulled low while  $V_{PP}$  pin is at low level. Then the MCU is immediately forced in reset default state. It pulls low  $RSTOUT$  pin, it cancels pending internal hold states if any, it waits for any internal access cycles to finish, it aborts external bus cycle, it switches buses (data, address and control signals) and I/O pin drivers to high-impedance, it pulls high Port0 pins and the reset sequence starts.

#### Power-on Reset

The asynchronous reset must be used during the power-on of the MCU. Depending on crystal frequency, the on-chip oscillator needs about 10ms to 50ms to stabilize. The logic of the MCU does not need a stabilized clock signal to detect an asynchronous reset, so it is suitable for power-on

conditions. To ensure a proper reset sequence, the  $\overline{RSTIN}$  pin and the  $V_{PP}$  pin must be held at low level until the MCU clock signal is stabilized and the system configuration value on Port0 is settled.

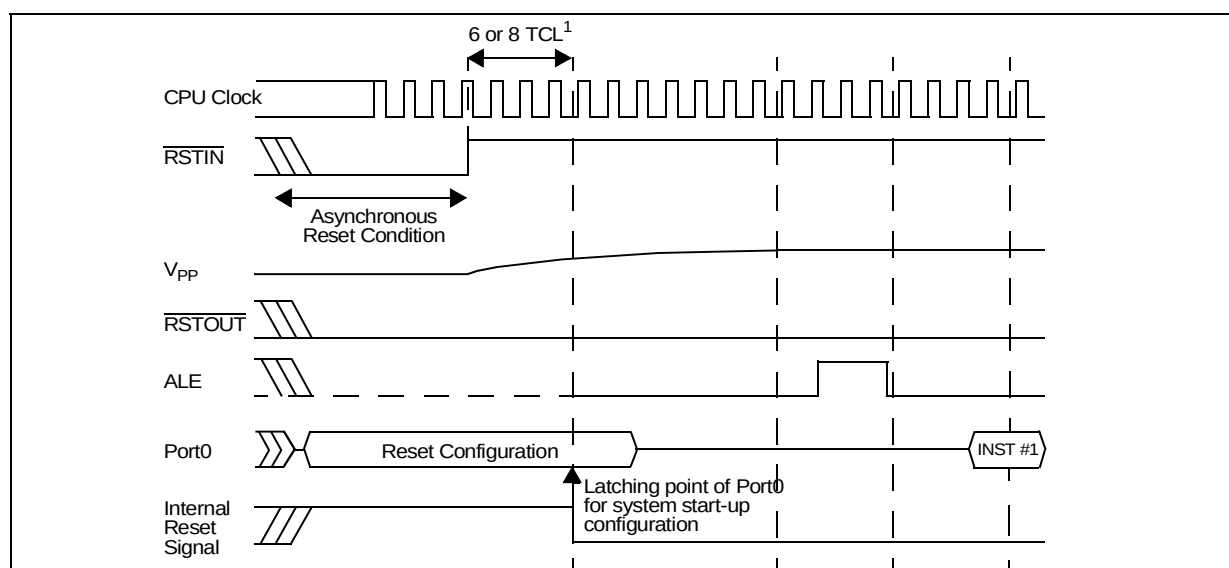
#### Hardware Reset

The asynchronous reset must be used to recover from catastrophic situations of the application. It may be triggered by the hardware of the application. Internal hardware logic and application circuitry are described in Reset circuitry chapter and Figures 12, 13 and 14.

#### Exit of Asynchronous Reset State

When the  $\overline{RSTIN}$  pin is pulled high, the MCU restarts. The system configuration is latched from Port0 and ALE,  $\overline{RD}$  and  $\overline{R/W}$  pins are driven to their inactive level. The MCU starts program execution from memory location 00'0000h in code segment 0. This starting location will typically point to the general initialization routine. Timing of asynchronous reset sequence are summarized in Figure 9.

**Figure 9** : Asynchronous Reset Timing



Note: 1.  $\overline{RSTIN}$  rising edge to internal latch of Port0 is 3CPU clock cycles (6 TCL) if the PLL is bypassed and the prescaler is on ( $f_{CPU} = f_{XTAL} / 2$ ), else it is 4 CPU clock cycles (8 TCL).

## 17.2 - Synchronous Reset (Warm Reset)

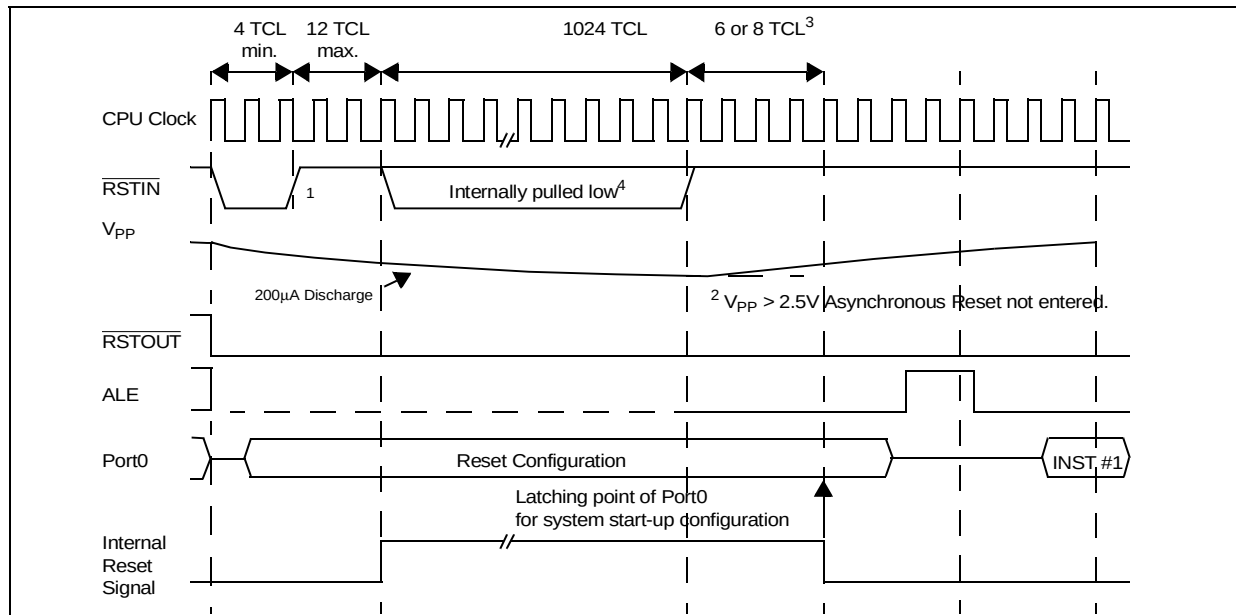
A synchronous reset is triggered when  $\overline{\text{RSTIN}}$  pin is pulled low while  $V_{PP}$  pin is at high level. In order to properly activate the internal reset logic of the MCU, the  $\overline{\text{RSTIN}}$  pin must be held low, at least, during 4 TCL (2 periods of CPU clock). The I/O pins are set to high impedance and  $\overline{\text{RSTOUT}}$  pin is driven low. After  $\overline{\text{RSTIN}}$  level is detected, a short duration of 12 TCL (approximately 6 periods of CPU clock) elapses, during which pending internal hold states are cancelled and the current internal access cycle if any is completed. External bus cycle is aborted. The internal pulldown of  $\overline{\text{RSTIN}}$  pin is activated if bit  $\text{BDRSTEN}$  of  $\text{SYSCON}$  register was previously set by software. This bit is

always cleared on power-on or after a reset sequence.

### Exit of Synchronous Reset State

The internal reset sequence starts for 1024 TCL (512 periods of CPU clock) and  $\overline{\text{RSTIN}}$  pin level is sampled. The reset sequence is extended until  $\overline{\text{RSTIN}}$  level becomes high. Then, the MCU restarts. The system configuration is latched from Port0 and ALE,  $\overline{\text{RD}}$  and  $\overline{\text{RW}}$  pins are driven to their inactive level. The MCU starts program execution from memory location 00'0000h in code segment 0. This starting location will typically point to the general initialization routine. Timing of synchronous reset sequence are summarized in Figure 10 and 11.

**Figure 10 :** Synchronous Warm Reset: Short low pulse on  $\overline{\text{RSTIN}}$

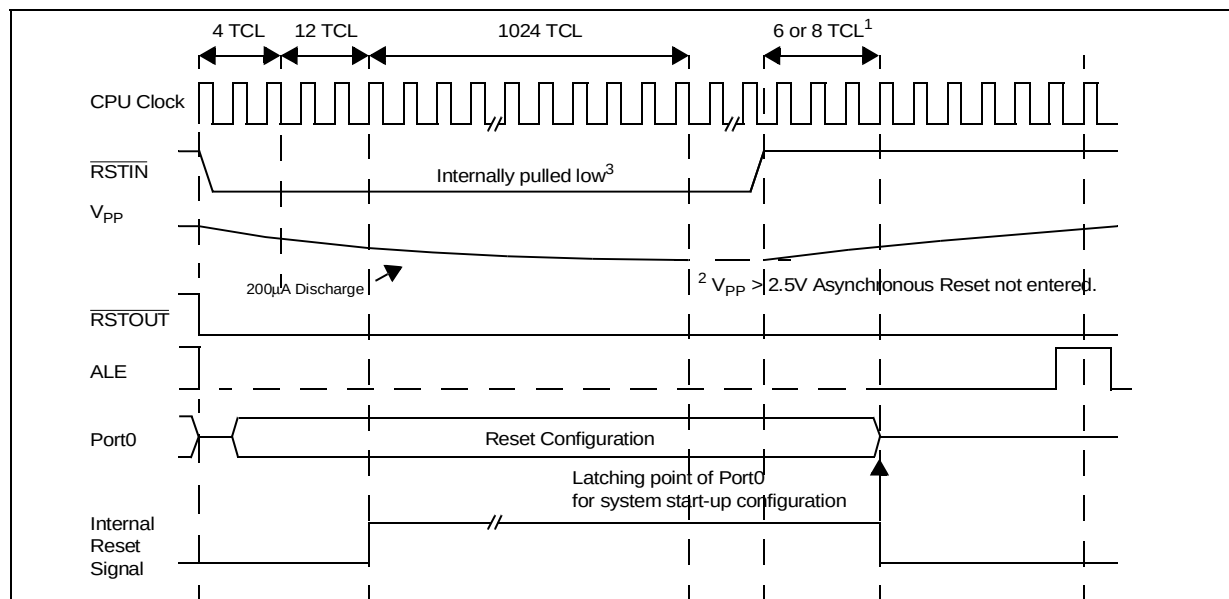


Notes: 1.  $\overline{\text{RSTIN}}$  assertion can be released there.

2. If during the reset condition ( $\overline{\text{RSTIN}}$  low),  $V_{pp}$  voltage drops below the threshold voltage (about 2.5V for 5V operation), the asynchronous reset is then immediately entered.

3.  $\overline{\text{RSTIN}}$  rising edge to internal latch of Port0 is 3CPU clock cycles (6 TCL) if the PLL is bypassed and the prescaler is on ( $f_{CPU} = f_{XTAL} / 2$ ), else it is 4 CPU clock cycles (8 TCL).

4)  $\overline{\text{RSTIN}}$  pin is pulled low if bit  $\text{BDRSTEN}$  (bit 5 of  $\text{SYSCON}$  register) was previously set by software. Bit  $\text{BDRSTEN}$  is cleared after reset.

**Figure 11 : Synchronous Warm Reset: Long low pulse on  $\overline{\text{RSTIN}}$** 

Notes: 1.  $\overline{\text{RSTIN}}$  rising edge to internal latch of Port0 is 3CPU clock cycles (6 TCL) if the PLL is bypassed and the prescaler is on ( $f_{\text{CPU}} = f_{\text{XTAL}} / 2$ ), else it is 4 CPU clock cycles (8 TCL).

2. If during the reset condition ( $\overline{\text{RSTIN}}$  low),  $V_{PP}$  voltage drops below the threshold voltage (about 2.5V for 5V operation), the asynchronous reset is then immediately entered.

3.  $\overline{\text{RSTIN}}$  pin is pulled low if bit BDRSTEN (bit 5 of SYSCON register) was previously set by software. Bit BDRSTEN is cleared after reset.

### 17.3 - Software Reset

A software reset sequence can be triggered at any time by the protected SRST (software reset) instruction. This instruction can be deliberately executed within a program, e.g. to leave bootstrap loader mode, or on a hardware trap that reveals system failure.

On execution of the SRST instruction, the internal reset sequence is started. The microcontroller behaviour is the same as for a synchronous reset, except that only bit P0.12...P0.8 are latched at the end of the reset sequence, while previously latched, bit P0.7...P0.2 are cleared.

### 17.4 - Watchdog Timer Reset

When the watchdog timer is not disabled during the initialization, or serviced regularly during program execution, it will overflow and trigger the reset sequence.

Unlike hardware and software resets, the watchdog reset completes a running external bus cycle if this bus cycle either does not use  $\overline{\text{READY}}$ , or if

$\overline{\text{READY}}$  is sampled active (low) after the programmed wait states. When  $\overline{\text{READY}}$  is sampled inactive (high) after the programmed wait states the running external bus cycle is aborted. Then the internal reset sequence is started.

Bit P0.12...P0.8 are latched at the end of the reset sequence and bit P0.7...P0.2 are cleared.

### 17.5 - Reset Circuitry

Internal reset circuitry is described in Figure 13. The  $\overline{\text{RSTIN}}$  pin provides an internal pullup resistor of 50K $\Omega$  to 250K $\Omega$  (The minimum reset time must be calculated using the lowest value). It also provides a programmable (BDRSTEN bit of SYSCON register) pulldown to output internal reset state signal (synchronous reset, watchdog timer reset or software reset).

This bidirectional reset function is useful in applications where external devices require a reset signal but cannot be connected to  $\overline{\text{RSTOUT}}$  pin.

This is the case of an external memory running codes before EINIT (end of initialization) instruction is executed.  $\overline{\text{RSTOUT}}$  pin is pulled high only when EINIT is executed.

The  $V_{PP}$  pin provides an internal weak pulldown resistor which discharges external capacitor at a typical rate of 200  $\mu\text{A}$ . If bit PWDCFG of SYSCON register is set, an internal pullup resistor is activated at the end of the reset sequence. This pulldown will charge any capacitor connected on  $V_{PP}$  pin.

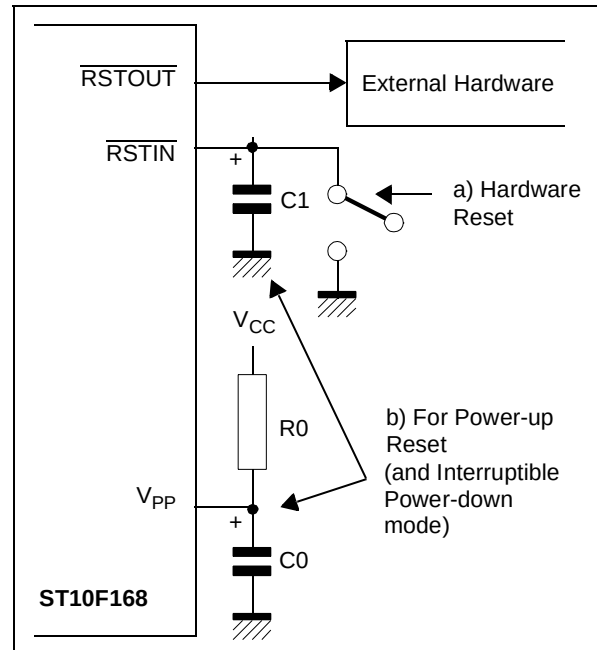
The simplest way to reset the ST10F168 is to insert a capacitor C1 between  $\overline{\text{RSTIN}}$  pin and  $V_{SS}$ , and a capacitor between  $V_{PP}$  pin and  $V_{SS}$  (C0) with a pullup resistor R0 between  $V_{PP}$  pin and  $V_{CC}$ . The input  $\overline{\text{RSTIN}}$  provides an internal pullup device equalling a resistor of 50k $\Omega$  to 150k $\Omega$  (the minimum reset time must be determined by the lowest value). Select C1 that produce a sufficient discharge time to permit the internal or external oscillator and / or internal PLL to stabilize.

To insure correct power-up reset with controlled supply current consumption, specially if clock signal requires a long period of time to stabilized, an asynchronous hardware reset is required during power-up. It is recommended to connect the external R0C0 circuit shown in Figure 12 to the  $V_{PP}$  pin. On power-up, the logical low level on  $V_{PP}$  pin forces an asynchronous hardware reset when  $\overline{\text{RSTIN}}$  is asserted.

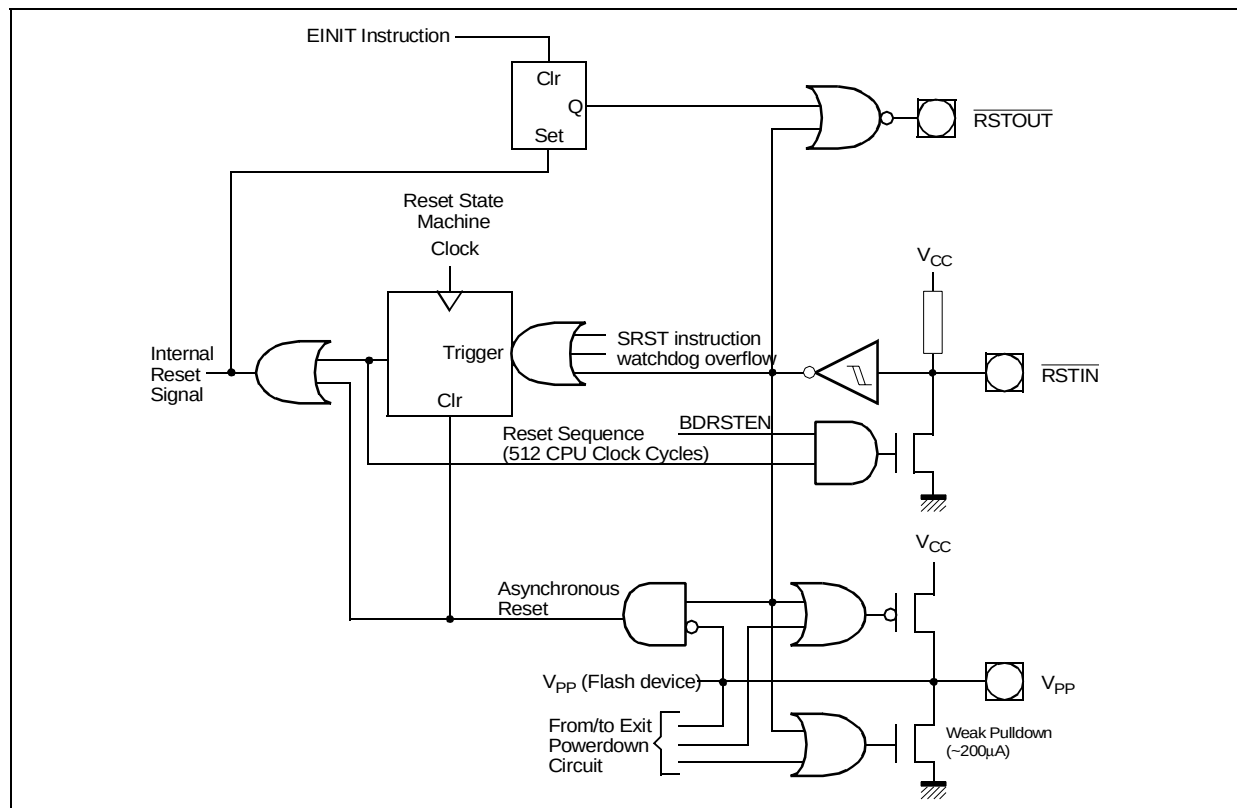
The external pullup R0 will then charge the capacitor C0. Note that an internal pulldown device on  $V_{PP}$  pin is turned on when  $\overline{\text{RSTIN}}$  pin is low, and causes the external capacitor (C0) to begin discharging at a typical rate of 100 $\mu\text{A}$  to 200 $\mu\text{A}$ . With this mechanism, after power-up reset, short low pulses applied on  $\overline{\text{RSTIN}}$  produce synchronous hardware reset. If  $\overline{\text{RSTIN}}$  is asserted longer than

the time needed for C0 to be discharged by the internal pulldown device, then the device is forced in an asynchronous reset. This mechanism insures recovery from very catastrophic failure.

**Figure 12 : Minimum External Reset Circuitry**



**Figure 13 : Internal (simplified) Reset Circuitry**



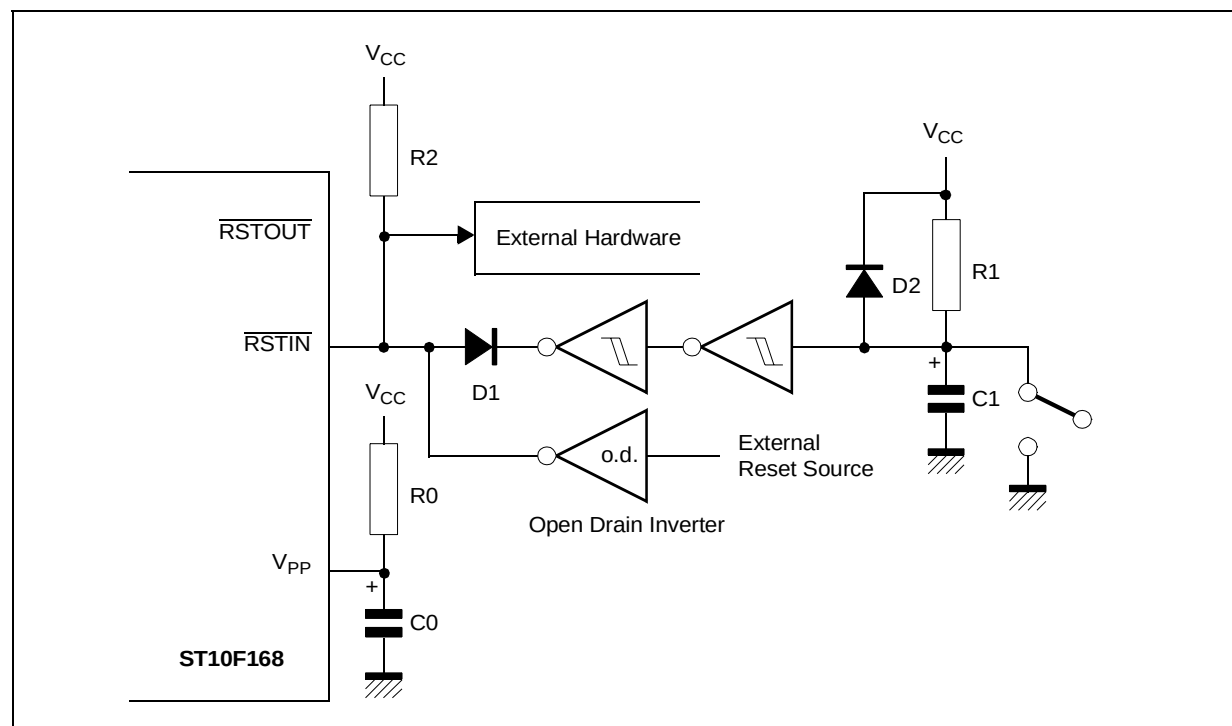
The minimum reset circuit of Figure 14 is not adequate when the  $\overline{\text{RSTIN}}$  pin is driven from the ST10F168 itself during software or watchdog triggered resets, because of the capacitor C1 that will keep the voltage on  $\overline{\text{RSTIN}}$  pin above  $V_{IL}$  after the end of the internal reset sequence, and thus will trigger an asynchronous reset sequence.

Figure 14 shows an example of a reset circuit. In this example, R1C1 external circuit is only used to

generate power-up or manual reset, and R0C0 circuit on  $V_{PP}$  is used for power-up reset and to exit from powerdown mode. Diode D1 creates a wired-OR gate connection to the reset pin and may be replaced by open-collector schmitt trigger buffer. Diode D2 provides a faster cycle time for repetitive power-on resets.

R2 is an optional pullup for faster recovery and correct biasing of TTL Open Collector drivers.

**Figure 14** : System Reset Circuit



## 18 - POWER REDUCTION MODES

Two different power reduction modes with different levels of power reduction can be entered under software control.

In **Idle mode** the CPU is stopped, while the peripherals continue their operation. Idle mode can be terminated by any reset or interrupt request.

In **Power Down mode** both the CPU and the peripherals are stopped. Power Down mode can be configured by software in order to be terminated only by a hardware reset or by an external interrupt source on fast external interrupt pins. There are two different operating Power Down modes:

- **Protected power down mode:** selected by setting bit PWDCFG in the SYSCON register to '0'. This mode can be used in conjunction with an external power failure signal which pulls the  $\overline{\text{NMI}}$  pin low when a power failure is imminent. The microcontroller enters the  $\overline{\text{NMI}}$  trap routine and saves the internal state into RAM. The trap routine then sets a flag or writes a bit pattern into specific RAM locations, and executes the PWRDN instruction. If the  $\overline{\text{NMI}}$  pin is still low at this time, Power Down mode will be entered, if not program execution continues. During power

down the voltage at the  $V_{CC}$  pins can be lowered to 2.5 V and the contents of the internal RAM will still be preserved.

- **Interruptible power down mode:** this mode is selected by setting bit PWDCFG in the SYSCON register. The CPU and peripheral clocks are frozen, and the oscillator and PLL are stopped. To exit power down mode with an external interrupt, an EXxIN ( $x = 7 \dots 0$ ) pin has to be asserted for at least 40ns. This signal enables the internal oscillator and PLL circuitry, and turns on the weak pulldown. If the Interrupt was enabled before entering power down mode, the device executes the interrupt service routine, and then resumes execution after the PWRDN instruction. If the interrupt was disabled, the device executes the instruction following PWRDN instruction, and the Interrupt Request Flag remains set until it is cleared by software.

All external bus actions are completed before Idle or Power Down mode is entered. However, Idle or Power Down mode is **not** entered if READY is enabled, but has not been activated (driven low for negative polarity, or driven high for positive polarity) during the last bus access.

## 19 - SPECIAL FUNCTION REGISTER OVERVIEW

Table 22 lists all SFRs which are implemented in the ST10F168 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".

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

**Table 22** : Special Function Registers listed by name

| Name      | Physical address | 8-bit address | Description                                                | Reset value |
|-----------|------------------|---------------|------------------------------------------------------------|-------------|
| ADCIC b   | FF98h            | CCh           | A/D Converter End Of Conversion Interrupt Control Register | 0000h       |
| ADCON b   | FFA0h            | D0h           | A/D Converter Control Register                             | 0000h       |
| ADDAT     | FEA0h            | 50h           | A/D Converter Result Register                              | 0000h       |
| ADDAT2    | F0A0h E          | 50h           | A/D Converter 2 Result Register                            | 0000h       |
| ADDRSEL1  | FE18h            | 0Ch           | Address Select Register 1                                  | 0000h       |
| ADDRSEL2  | FE1Ah            | 0Dh           | Address Select Register 2                                  | 0000h       |
| ADDRSEL3  | FE1Ch            | 0Eh           | Address Select Register 3                                  | 0000h       |
| ADDRSEL4  | FE1Eh            | 0Fh           | Address Select Register 4                                  | 0000h       |
| ADEIC b   | FF9Ah            | CDh           | A/D converter Overrun Error Interrupt Control Register     | 0000h       |
| BUSCON0 b | FF0Ch            | 86h           | Bus Configuration Register 0                               | 0XX0h       |
| BUSCON1 b | FF14h            | 8Ah           | Bus Configuration Register 1                               | 0000h       |
| BUSCON2 b | FF16h            | 8Bh           | Bus Configuration Register 2                               | 0000h       |
| BUSCON3 b | FF18h            | 8Ch           | Bus Configuration Register 3                               | 0000h       |
| BUSCON4 b | FF1Ah            | 8Dh           | Bus Configuration Register 4                               | 0000h       |
| CAPREL    | FE4Ah            | 25h           | GPT2 Capture / Reload Register                             | 0000h       |
| CC0       | FE80h            | 40h           | CAPCOM Register 0                                          | 0000h       |
| CC0IC b   | FF78h            | BCh           | CAPCOM Register 0 Interrupt Control Register               | 0000h       |
| CC1       | FE82h            | 41h           | CAPCOM Register 1                                          | 0000h       |
| CC1IC b   | FF7Ah            | BDh           | CAPCOM Register 1 Interrupt Control Register               | 0000h       |
| CC2       | FE84h            | 42h           | CAPCOM Register 2                                          | 0000h       |
| CC2IC b   | FF7Ch            | BEh           | CAPCOM Register 2 Interrupt Control Register               | 0000h       |
| CC3       | FE86h            | 43h           | CAPCOM Register 3                                          | 0000h       |
| CC3IC b   | FF7Eh            | BFh           | CAPCOM Register 3 Interrupt Control Register               | 0000h       |
| CC4       | FE88h            | 44h           | CAPCOM Register 4                                          | 0000h       |
| CC4IC b   | FF80h            | C0h           | CAPCOM Register 4 Interrupt Control Register               | 0000h       |
| CC5       | FE8Ah            | 45h           | CAPCOM Register 5                                          | 0000h       |
| CC5IC b   | FF82h            | C1h           | CAPCOM Register 5 Interrupt Control Register               | 0000h       |
| CC6       | FE8Ch            | 46h           | CAPCOM Register 6                                          | 0000h       |
| CC6IC b   | FF84h            | C2h           | CAPCOM Register 6 Interrupt Control Register               | 0000h       |
| CC7       | FE8Eh            | 47h           | CAPCOM Register 7                                          | 0000h       |
| CC7IC b   | FF86h            | C3h           | CAPCOM Register 7 Interrupt Control Register               | 0000h       |
| CC8       | FE90h            | 48h           | CAPCOM Register 8                                          | 0000h       |
| CC8IC b   | FF88h            | C4h           | CAPCOM Register 8 Interrupt Control Register               | 0000h       |
| CC9       | FE92h            | 49h           | CAPCOM Register 9                                          | 0000h       |

Table 22 : Special Function Registers listed by name

| Name     | Physical address | 8-bit address | Description                                   | Reset value |
|----------|------------------|---------------|-----------------------------------------------|-------------|
| CC9IC b  | FF8Ah            | C5h           | CAPCOM Register 9 Interrupt Control Register  | 0000h       |
| CC10     | FE94h            | 4Ah           | CAPCOM Register 10                            | 0000h       |
| CC10IC b | FF8Ch            | C6h           | CAPCOM Register 10 Interrupt Control Register | 0000h       |
| CC11     | FE96h            | 4Bh           | CAPCOM Register 11                            | 0000h       |
| CC11IC b | FF8Eh            | C7h           | CAPCOM Register 11 Interrupt Control Register | 0000h       |
| CC12     | FE98h            | 4Ch           | CAPCOM Register 12                            | 0000h       |
| CC12IC b | FF90h            | C8h           | CAPCOM Register 12 Interrupt Control Register | 0000h       |
| CC13     | FE9Ah            | 4Dh           | CAPCOM Register 13                            | 0000h       |
| CC13IC b | FF92h            | C9h           | CAPCOM Register 13 Interrupt Control Register | 0000h       |
| CC14     | FE9Ch            | 4Eh           | CAPCOM Register 14                            | 0000h       |
| CC14IC b | FF94h            | CAh           | CAPCOM Register 14 Interrupt Control Register | 0000h       |
| CC15     | FE9Eh            | 4Fh           | CAPCOM Register 15                            | 0000h       |
| CC15IC b | FF96h            | CBh           | CAPCOM Register 15 Interrupt Control Register | 0000h       |
| CC16     | FE60h            | 30h           | CAPCOM Register 16                            | 0000h       |
| CC16IC b | F160h E          | B0h           | CAPCOM Register 16 Interrupt Control Register | 0000h       |
| CC17     | FE62h            | 31h           | CAPCOM Register 17                            | 0000h       |
| CC17IC b | F162h E          | B1h           | CAPCOM Register 17 Interrupt Control Register | 0000h       |
| CC18     | FE64h            | 32h           | CAPCOM Register 18                            | 0000h       |
| CC18IC b | F164h E          | B2h           | CAPCOM Register 18 Interrupt Control Register | 0000h       |
| CC19     | FE66h            | 33h           | CAPCOM Register 19                            | 0000h       |
| CC19IC b | F166h E          | B3h           | CAPCOM Register 19 Interrupt Control Register | 0000h       |
| CC20     | FE68h            | 34h           | CAPCOM Register 20                            | 0000h       |
| CC20IC b | F168h E          | B4h           | CAPCOM Register 20 Interrupt Control Register | 0000h       |
| CC21     | FE6Ah            | 35h           | CAPCOM Register 21                            | 0000h       |
| CC21IC b | F16Ah E          | B5h           | CAPCOM Register 21 Interrupt Control Register | 0000h       |
| CC22     | FE6Ch            | 36h           | CAPCOM Register 22                            | 0000h       |
| CC22IC b | F16Ch E          | B6h           | CAPCOM Register 22 Interrupt Control Register | 0000h       |
| CC23     | FE6Eh            | 37h           | CAPCOM Register 23                            | 0000h       |
| CC23IC b | F16Eh E          | B7h           | CAPCOM Register 23 Interrupt Control Register | 0000h       |
| CC24     | FE70h            | 38h           | CAPCOM Register 24                            | 0000h       |
| CC24IC b | F170h E          | B8h           | CAPCOM Register 24 Interrupt Control Register | 0000h       |
| CC25     | FE72h            | 39h           | CAPCOM Register 25                            | 0000h       |
| CC25IC b | F172h E          | B9h           | CAPCOM Register 25 Interrupt Control Register | 0000h       |
| CC26     | FE74h            | 3Ah           | CAPCOM Register 26                            | 0000h       |
| CC26IC b | F174h E          | BAh           | CAPCOM Register 26 Interrupt Control Register | 0000h       |
| CC27     | FE76h            | 3Bh           | CAPCOM Register 27                            | 0000h       |
| CC27IC b | F176h E          | BBh           | CAPCOM Register 27 Interrupt Control Register | 0000h       |
| CC28     | FE78h            | 3Ch           | CAPCOM Register 28                            | 0000h       |
| CC28IC b | F178h E          | BCh           | CAPCOM Register 28 Interrupt Control Register | 0000h       |
| CC29     | FE7Ah            | 3Dh           | CAPCOM Register 29                            | 0000h       |

Table 22 : Special Function Registers listed by name

| Name    | Physical address | 8-bit address | Description                                   | Reset value        |
|---------|------------------|---------------|-----------------------------------------------|--------------------|
| CC29IC  | b F184h E        | C2h           | CAPCOM Register 29 Interrupt Control Register | 0000h              |
| CC30    | FE7Ch            | 3Eh           | CAPCOM Register 30                            | 0000h              |
| CC30IC  | b F18Ch E        | C6h           | CAPCOM Register 30 Interrupt Control Register | 0000h              |
| CC31    | FE7Eh            | 3Fh           | CAPCOM Register 31                            | 0000h              |
| CC31IC  | b F194h E        | CAh           | CAPCOM Register 31 Interrupt Control Register | 0000h              |
| CCM0    | b FF52h          | A9h           | CAPCOM Mode Control Register 0                | 0000h              |
| CCM1    | b FF54h          | AAh           | CAPCOM Mode Control Register 1                | 0000h              |
| CCM2    | b FF56h          | ABh           | CAPCOM Mode Control Register 2                | 0000h              |
| CCM3    | b FF58h          | ACH           | CAPCOM Mode Control Register 3                | 0000h              |
| CCM4    | b FF22h          | 91h           | CAPCOM Mode Control Register 4                | 0000h              |
| CCM5    | b FF24h          | 92h           | CAPCOM Mode Control Register 5                | 0000h              |
| CCM6    | b FF26h          | 93h           | CAPCOM Mode Control Register 6                | 0000h              |
| CCM7    | b FF28h          | 94h           | CAPCOM Mode Control Register 7                | 0000h              |
| CP      | FE10h            | 08h           | CPU Context Pointer Register                  | FC00h              |
| CRIC    | b FF6Ah          | B5h           | GPT2 CAPREL Interrupt Control Register        | 0000h              |
| CSP     | FE08h            | 04h           | CPU Code Segment Pointer Register (read only) | 0000h              |
| DP0L    | b F100h E        | 80h           | P0L Direction Control Register                | 00h                |
| DP0H    | b F102h E        | 81h           | P0h Direction Control Register                | 00h                |
| DP1L    | b F104h E        | 82h           | P1L Direction Control Register                | 00h                |
| DP1H    | b F106h E        | 83h           | P1h Direction Control Register                | 00h                |
| DP2     | b FFC2h          | E1h           | Port 2 Direction Control Register             | 0000h              |
| DP3     | b FFC6h          | E3h           | Port 3 Direction Control Register             | 0000h              |
| DP4     | b FFCAh          | E5h           | Port 4 Direction Control Register             | 00h                |
| DP6     | b FFCEh          | E7h           | Port 6 Direction Control Register             | 00h                |
| DP7     | b FFD2h          | E9h           | Port 7 Direction Control Register             | 00h                |
| DP8     | b FFD6h          | EBh           | Port 8 Direction Control Register             | 00h                |
| DPP0    | FE00h            | 00h           | CPU Data Page Pointer 0 Register (10-bit)     | 0000h              |
| DPP1    | FE02h            | 01h           | CPU Data Page Pointer 1 Register (10-bit)     | 0001h              |
| DPP2    | FE04h            | 02h           | CPU Data Page Pointer 2 Register (10-bit)     | 0002h              |
| DPP3    | FE06h            | 03h           | CPU Data Page Pointer 3 Register (10-bit)     | 0003h              |
| EXICON  | b F1C0h E        | E0h           | External Interrupt Control Register           | 0000h              |
| IDCHIP  | F07Ch E          | 3Eh           | Device Identifier Register                    | 0A8Xh <sup>1</sup> |
| IDMANUF | F07Eh E          | 3Fh           | Manufacturer Identifier Register              | 0400h              |
| IDMEM   | F07Ah E          | 3Dh           | On-chip Memory Identifier Register            | 3040h              |
| IDPROG  | F078h E          | 3Ch           | Programming Voltage Identifier Register       | 9A40h              |
| MDC     | b FF0Eh          | 87h           | CPU Multiply Divide Control Register          | 0000h              |
| MDH     | FE0Ch            | 06h           | CPU Multiply Divide Register – High Word      | 0000h              |
| MDL     | FE0Eh            | 07h           | CPU Multiply Divide Register – Low Word       | 0000h              |
| ODP2    | b F1C2h E        | E1h           | Port 2 Open Drain Control Register            | 0000h              |
| ODP3    | b F1C6h E        | E3h           | Port 3 Open Drain Control Register            | 0000h              |

Table 22 : Special Function Registers listed by name

| Name    | Physical address | 8-bit address | Description                                | Reset value |
|---------|------------------|---------------|--------------------------------------------|-------------|
| ODP6    | b F1CEh E        | E7h           | Port 6 Open Drain Control Register         | 00h         |
| ODP7    | b F1D2h E        | E9h           | Port 7 Open Drain Control Register         | 00h         |
| ODP8    | b F1D6h E        | EBh           | Port 8 Open Drain Control Register         | 00h         |
| ONES    | b FF1Eh          | 8Fh           | Constant Value 1's Register (read only)    | FFFFh       |
| P0L     | b FF00h          | 80h           | Port 0 Low Register (Lower half of Port0)  | 00h         |
| P0H     | b FF02h          | 81h           | Port 0 High Register (Upper half of Port0) | 00h         |
| P1L     | b FF04h          | 82h           | Port 1 Low Register (Lower half of Port1)  | 00h         |
| P1H     | b FF06h          | 83h           | Port 1 High Register (Upper half of Port1) | 00h         |
| P2      | b FFC0h          | E0h           | Port 2 Register                            | 0000h       |
| P3      | b FFC4h          | E2h           | Port 3 Register                            | 0000h       |
| P4      | b FFC8h          | E4h           | Port 4 Register (8-bit)                    | 00h         |
| P5      | b FFA2h          | D1h           | Port 5 Register (read only)                | XXXXh       |
| P6      | b FFCCh          | E6h           | Port 6 Register (8-bit)                    | 00h         |
| P7      | b FFD0h          | E8h           | Port 7 Register (8-bit)                    | 00h         |
| P8      | b FFD4h          | EAh           | Port 8 Register (8-bit)                    | 00h         |
| PECC0   | FEC0h            | 60h           | PEC Channel 0 Control Register             | 0000h       |
| PECC1   | FEC2h            | 61h           | PEC Channel 1 Control Register             | 0000h       |
| PECC2   | FEC4h            | 62h           | PEC Channel 2 Control Register             | 0000h       |
| PECC3   | FEC6h            | 63h           | PEC Channel 3 Control Register             | 0000h       |
| PECC4   | FEC8h            | 64h           | PEC Channel 4 Control Register             | 0000h       |
| PECC5   | FECAh            | 65h           | PEC Channel 5 Control Register             | 0000h       |
| PECC6   | FECCh            | 66h           | PEC Channel 6 Control Register             | 0000h       |
| PECC7   | FECEh            | 67h           | PEC Channel 7 Control Register             | 0000h       |
| PICON   | F1C4h E          | E2h           | Port Input Threshold Control Register      | 0000h       |
| PP0     | F038h E          | 1Ch           | PWM Module Period Register 0               | 0000h       |
| PP1     | F03Ah E          | 1Dh           | PWM Module Period Register 1               | 0000h       |
| PP2     | F03Ch E          | 1Eh           | PWM Module Period Register 2               | 0000h       |
| PP3     | F03Eh E          | 1Fh           | PWM Module Period Register 3               | 0000h       |
| PSW     | b FF10h          | 88h           | CPU Program Status Word                    | 0000h       |
| PT0     | F030h E          | 18h           | PWM Module Up / Down Counter 0             | 0000h       |
| PT1     | F032h E          | 19h           | PWM Module Up / Down Counter 1             | 0000h       |
| PT2     | F034h E          | 1Ah           | PWM Module Up / Down Counter 2             | 0000h       |
| PT3     | F036h E          | 1Bh           | PWM Module Up / Down Counter 3             | 0000h       |
| PW0     | FE30h            | 18h           | PWM Module Pulse Width Register 0          | 0000h       |
| PW1     | FE32h            | 19h           | PWM Module Pulse Width Register 1          | 0000h       |
| PW2     | FE34h            | 1Ah           | PWM Module Pulse Width Register 2          | 0000h       |
| PW3     | FE36h            | 1Bh           | PWM Module Pulse Width Register 3          | 0000h       |
| PWMCON0 | b FF30h          | 98h           | PWM Module Control Register 0              | 0000h       |
| PWMCON1 | b FF32h          | 99h           | PWM Module Control Register 1              | 0000h       |

Table 22 : Special Function Registers listed by name

| Name   | Physical address | 8-bit address | Description                                                 | Reset value        |
|--------|------------------|---------------|-------------------------------------------------------------|--------------------|
| PWMIC  | b F17Eh E        | BFh           | PWM Module Interrupt Control Register                       | 0000h              |
| RP0H   | b F108h E        | 84h           | System Start-up Configuration Register (read only)          | XXh                |
| S0BG   | FEB4h            | 5Ah           | Serial Channel 0 Baud Rate Generator Reload Register        | 0000h              |
| S0CON  | b FFB0h          | D8h           | Serial Channel 0 Control Register                           | 0000h              |
| S0EIC  | b FF70h          | B8h           | Serial Channel 0 Error Interrupt Control Register           | 0000h              |
| S0RBUF | FEB2h            | 59h           | Serial Channel 0 Receive Buffer Register (read only)        | XXh                |
| S0RIC  | b FF6Eh          | B7h           | Serial Channel 0 Receive Interrupt Control Register         | 0000h              |
| S0TBIC | b F19Ch E        | CEh           | Serial Channel 0 Transmit Buffer Interrupt Control Register | 0000h              |
| S0TBUF | FEB0h            | 58h           | Serial Channel 0 Transmit Buffer Register (write only)      | 00h                |
| S0TIC  | b FF6Ch          | B6h           | Serial Channel 0 Transmit Interrupt Control Register        | 0000h              |
| SP     | FE12h            | 09h           | CPU System Stack Pointer Register                           | FC00h              |
| SSCBR  | F0B4h E          | 5Ah           | SSC Baud Rate Register                                      | 0000h              |
| SSCCON | b FFB2h          | D9h           | SSC Control Register                                        | 0000h              |
| SSCEIC | b FF76h          | BBh           | SSC Error Interrupt Control Register                        | 0000h              |
| SSCRB  | F0B2h E          | 59h           | SSC Receive Buffer (read only)                              | XXXXh              |
| SSCRIC | b FF74h          | BAh           | SSC Receive Interrupt Control Register                      | 0000h              |
| SSCTB  | F0B0h E          | 58h           | SSC Transmit Buffer (write only)                            | 0000h              |
| SSCTIC | b FF72h          | B9h           | SSC Transmit Interrupt Control Register                     | 0000h              |
| STKOV  | FE14h            | 0Ah           | CPU Stack Overflow Pointer Register                         | FA00h              |
| STKUN  | FE16h            | 0Bh           | CPU Stack Underflow Pointer Register                        | FC00h              |
| SYSCON | b FF12h          | 89h           | CPU System Configuration Register                           | 0xx0h <sup>2</sup> |
| T0     | FE50h            | 28h           | CAPCOM Timer 0 Register                                     | 0000h              |
| T01CON | b FF50h          | A8h           | CAPCOM Timer 0 and Timer 1 Control Register                 | 0000h              |
| T0IC   | b FF9Ch          | CEh           | CAPCOM Timer 0 Interrupt Control Register                   | 0000h              |
| T0REL  | FE54h            | 2Ah           | CAPCOM Timer 0 Reload Register                              | 0000h              |
| T1     | FE52h            | 29h           | CAPCOM Timer 1 Register                                     | 0000h              |
| T1IC   | b FF9Eh          | CFh           | CAPCOM Timer 1 Interrupt Control Register                   | 0000h              |
| T1REL  | FE56h            | 2Bh           | CAPCOM Timer 1 Reload Register                              | 0000h              |
| T2     | FE40h            | 20h           | GPT1 Timer 2 Register                                       | 0000h              |
| T2CON  | b FF40h          | A0h           | GPT1 Timer 2 Control Register                               | 0000h              |
| T2IC   | b FF60h          | B0h           | GPT1 Timer 2 Interrupt Control Register                     | 0000h              |
| T3     | FE42h            | 21h           | GPT1 Timer 3 Register                                       | 0000h              |
| T3CON  | b FF42h          | A1h           | GPT1 Timer 3 Control Register                               | 0000h              |
| T3IC   | b FF62h          | B1h           | GPT1 Timer 3 Interrupt Control Register                     | 0000h              |
| T4     | FE44h            | 22h           | GPT1 Timer 4 Register                                       | 0000h              |
| T4CON  | b FF44h          | A2h           | GPT1 Timer 4 Control Register                               | 0000h              |
| T4IC   | b FF64h          | B2h           | GPT1 Timer 4 Interrupt Control Register                     | 0000h              |
| T5     | FE46h            | 23h           | GPT2 Timer 5 Register                                       | 0000h              |
| T5CON  | b FF46h          | A3h           | GPT2 Timer 5 Control Register                               | 0000h              |
| T5IC   | b FF66h          | B3h           | GPT2 Timer 5 Interrupt Control Register                     | 0000h              |

Table 22 : Special Function Registers listed by name

| Name     | Physical address | 8-bit address | Description                               | Reset value        |
|----------|------------------|---------------|-------------------------------------------|--------------------|
| T6       | FE48h            | 24h           | GPT2 Timer 6 Register                     | 0000h              |
| T6CON b  | FF48h            | A4h           | GPT2 Timer 6 Control Register             | 0000h              |
| T6IC b   | FF68h            | B4h           | GPT2 Timer 6 Interrupt Control Register   | 0000h              |
| T7       | F050h E          | 28h           | CAPCOM Timer 7 Register                   | 0000h              |
| T78CON b | FF20h            | 90h           | CAPCOM Timer 7 and 8 Control Register     | 0000h              |
| T7IC b   | F17Ah E          | BEh           | CAPCOM Timer 7 Interrupt Control Register | 0000h              |
| T7REL    | F054h E          | 2Ah           | CAPCOM Timer 7 Reload Register            | 0000h              |
| T8       | F052h E          | 29h           | CAPCOM Timer 8 Register                   | 0000h              |
| T8IC b   | F17Ch E          | BFh           | CAPCOM Timer 8 Interrupt Control Register | 0000h              |
| T8REL    | F056h E          | 2Bh           | CAPCOM Timer 8 Reload Register            | 0000h              |
| TFR b    | FFACh            | D6h           | Trap Flag Register                        | 0000h              |
| WDT      | FEAEh            | 57h           | Watchdog Timer Register (read only)       | 0000h              |
| WDTCN b  | FFAEh            | D7h           | Watchdog Timer Control Register           | 000xh <sup>3</sup> |
| XP0IC b  | F186h E          | C3h           | CAN Module Interrupt Control Register     | 0000h <sup>4</sup> |
| XP1IC b  | F18Eh E          | C7h           | X-Peripheral 1 Interrupt Control Register | 0000h <sup>4</sup> |
| XP2IC b  | F196h E          | CBh           | X-Peripheral 2 Interrupt Control Register | 0000h <sup>4</sup> |
| XP3IC b  | F19Eh E          | CFh           | PLL unlock Interrupt Control Register     | 0000h <sup>4</sup> |
| ZEROS b  | FF1Ch            | 8Eh           | Constant Value 0's Register (read only)   | 0000h              |

Notes: 1. The value depends on the silicon revision and is described in the chapter 19.1.

2. The system configuration is selected during reset.

3. Bit WDTR indicates a watchdog timer triggered reset.

4. The XPnIC Interrupt Control Registers control the interrupt requests from integrated X-Bus peripherals. Nodes where no X-Peripherals are connected may be used to generate software controlled interrupt requests by setting the respective XPnIR bit.

## 19.1 - Identification Registers

The ST10F168 has four Identification registers, mapped in ESFR space. These register contain:

- A manufacturer identifier,
- A chip identifier, with its revision,
- A internal memory and size identifier,
- Programming voltage description.

### IDMANUF (F07Eh / 3Fh)

ESFR

|       |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
|-------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 15    | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MANUF |    |    |    |    |    |   |   |   |   |   | - | - | - | - | - |
| R     |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |

#### Description

MANUF : Manufacturer Identifier - 020h: STmicroelectronics Manufacturer (JTAG worldwide normalisation).

### IDCHIP (F07Ch / 3Eh)

ESFR

|        |    |    |    |    |    |   |   |   |   |   |   |       |   |   |   |
|--------|----|----|----|----|----|---|---|---|---|---|---|-------|---|---|---|
| 15     | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3     | 2 | 1 | 0 |
| CHIPID |    |    |    |    |    |   |   |   |   |   |   | REVID |   |   |   |
| R      |    |    |    |    |    |   |   |   |   |   |   | R     |   |   |   |

#### Description

REVID : Device Revision Identifier - 1h for the first step, 2h for the second step,...

CHIPID : Device Identifier - 0A8h is the identifier of ST10F168.

### IDMEM (F07Ah / 3Dh)

ESFR

|        |    |    |    |         |    |   |   |   |   |   |   |   |   |   |   |
|--------|----|----|----|---------|----|---|---|---|---|---|---|---|---|---|---|
| 15     | 14 | 13 | 12 | 11      | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MEMTYP |    |    |    | MEMSIZE |    |   |   |   |   |   |   |   |   |   |   |
| R      |    |    |    | R       |    |   |   |   |   |   |   |   |   |   |   |

#### Description

MEMSIZE : Internal Memory Size - 040h for ST10F168 (256K Bytes).  
Internal Memory size is 4 \* <MEMSIZE> (in K Byte).

MEMTYP : Internal Memory Type - 3h for ST10F168 (Flash memory).

### IDPROG (F078h / 3Ch)

ESFR

|         |    |    |    |    |    |   |   |         |   |   |   |   |   |   |   |
|---------|----|----|----|----|----|---|---|---------|---|---|---|---|---|---|---|
| 15      | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7       | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PROGVPP |    |    |    |    |    |   |   | PROGVDD |   |   |   |   |   |   |   |
| R       |    |    |    |    |    |   |   | R       |   |   |   |   |   |   |   |

#### Description

PROGVDD : Programming  $V_{DD}$  Voltage  
 $V_{DD}$  voltage when programming EPROM or Flash devices is calculated using the following formula:  $V_{DD} = 20 * \text{<PROGVDD>} / 256 [V]$  - 40h for ST10F168 (5V).

PROGVPP : Programming  $V_{PP}$  Voltage  
 $V_{PP}$  voltage when programming EPROM or Flash devices is calculated using the following formula:  $V_{PP} = 20 * \text{<PROGVDD>} / 256 [V]$  - 9Ah for ST10F168 (12V).

## 20 - ELECTRICAL CHARACTERISTICS

### 20.1 - Absolute Maximum Ratings

| Symbol    | Parameter                                                                                                    | Value                    | Unit     |
|-----------|--------------------------------------------------------------------------------------------------------------|--------------------------|----------|
| $V_{DD}$  | Voltage on $V_{DD}$ pins with respect to ground <sup>1</sup>                                                 | -0.5, +6.5               | V        |
| $V_{IO}$  | Voltage on any pin with respect to ground <sup>1</sup>                                                       | -0.5, ( $V_{DD} + 0.5$ ) | V        |
| $I_{OV}$  | Input Current on any pin during overload condition <sup>1</sup>                                              | -10, +10                 | mA       |
| $I_{TOV}$ | Absolute Sum of all input currents during overload condition <sup>1</sup>                                    | 100 mA                   | mA       |
| $P_{tot}$ | Power Dissipation <sup>1</sup>                                                                               | 1.5                      | W        |
| $T_A$     | Ambient Temperature under bias for - Q6 <sup>1</sup><br>Ambient Temperature under bias for - Q3 <sup>1</sup> | -40, +85<br>-40, +125    | °C<br>°C |
| $T_{stg}$ | Storage Temperature <sup>1</sup>                                                                             | -65, +150                | °C       |

Note: 1. 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 overload conditions ( $V_{IN} > V_{DD}$  or  $V_{IN} < V_{SS}$ ) the voltage on pins with respect to ground ( $V_{SS}$ ) must not exceed the values defined by the Absolute Maximum Ratings.

### 20.2 - Parameter Interpretation

The parameters listed in the following tables represent the characteristics of the ST10F168 and its demands on the system.

Where the ST10F168 logic provides signals with their respective timing characteristics, the symbol "CC" for Controller Characteristics is included in the "Symbol" column.

Where the external system must provide signals with their respective timing characteristics to the ST10F168, the symbol "SR" for System Requirement is included in the "Symbol" column.

### 20.3 - DC Characteristics

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , Reset active, for Q6 version :  $T_A = -40, +85^\circ C$  and for Q3 version  $T_A = -40, +125^\circ C$ , unless otherwise specified.

| Symbol       | Parameter                                                                                                                          | Test Conditions                           | Min.                | Max.               | Unit    |
|--------------|------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------|--------------------|---------|
| $V_{IL}$ SR  | Input low voltage                                                                                                                  | —                                         | - 0.5               | $0.2 V_{DD} - 0.1$ | V       |
| $V_{ILS}$ SR | Input low voltage (special threshold)                                                                                              | —                                         | - 0.5               | 2.0                | V       |
| $V_{IH}$ SR  | Input high voltage<br>(all except $\overline{RSTIN}$ and XTAL1)                                                                    | —                                         | $0.2 V_{DD} + 0.9$  | $V_{DD} + 0.5$     | V       |
| $V_{IH1}$ SR | Input high voltage $\overline{RSTIN}$                                                                                              | —                                         | $0.6 V_{DD}$        | $V_{DD} + 0.5$     | V       |
| $V_{IH2}$ SR | Input high voltage XTAL1                                                                                                           | —                                         | $0.7 V_{DD}$        | $V_{DD} + 0.5$     | V       |
| $V_{IHS}$ SR | Input high voltage (special threshold)                                                                                             | —                                         | $0.8 V_{DD} - 0.2$  | $V_{DD} + 0.5$     | V       |
| HYS          | Input Hysteresis (special threshold)                                                                                               | —                                         | 300                 | -                  | mV      |
| $V_{OL}$ CC  | Output low voltage <sup>1</sup> (Port0, Port1, Port 4, ALE, $\overline{RD}$ , $\overline{WR}$ , $\overline{BHE}$ , CLKOUT, RSTOUT) | $I_{OL} = 2.4mA$                          | —                   | 0.45               | V       |
| $V_{OL1}$ CC | Output low voltage <sup>1</sup> (all other outputs)                                                                                | $I_{OL1} = 1.6mA$                         | —                   | 0.45               | V       |
| $V_{OH}$ CC  | Output high voltage <sup>1</sup> (Port0, Port1, Port4, ALE, $\overline{RD}$ , $\overline{WR}$ , $\overline{BHE}$ , CLKOUT, RSTOUT) | $I_{OH} = -500\mu A$<br>$I_{OH} = -2.4mA$ | $0.9 V_{DD}$<br>2.4 | —<br>—             | V       |
| $V_{OH1}$ CC | Output high voltage <sup>1 2</sup> (all other outputs)                                                                             | $I_{OH} = -250\mu A$<br>$I_{OH} = -1.6mA$ | $0.9 V_{DD}$<br>2.4 | —<br>—             | V<br>V  |
| $I_{OZ1}$ CC | Input leakage current (Port 5)                                                                                                     | $0V < V_{IN} < V_{DD}$                    | —                   | $\pm 0.5$          | $\mu A$ |

| Symbol                         | Parameter                                                  | Test Conditions                                                    | Min. | Max.                      | Unit |
|--------------------------------|------------------------------------------------------------|--------------------------------------------------------------------|------|---------------------------|------|
| I <sub>OZ2</sub> CC            | Input leakage current (all other)                          | 0V < V <sub>IN</sub> < V <sub>DD</sub>                             | –    | ±1                        | µA   |
| I <sub>OV</sub> SR             | Overload current                                           | <sup>3</sup> 4                                                     | –    | ±5                        | mA   |
| R <sub>RST</sub> CC            | RSTIN pull-up resistor <sup>3</sup>                        | 0V < V <sub>IN</sub> < V <sub>ILmax</sub>                          | 50   | 250                       | kΩ   |
| I <sub>RWH</sub> <sup>5</sup>  | Read / Write inactive current <sup>6</sup>                 | V <sub>OUT</sub> = 2.4V                                            | –    | -40                       | µA   |
| I <sub>RWL</sub> <sup>7</sup>  | Read / Write active current <sup>6</sup>                   | V <sub>OUT</sub> = V <sub>OLmax</sub>                              | -500 | –                         | µA   |
| I <sub>ALEL</sub> <sup>6</sup> | ALE inactive current <sup>6</sup>                          | V <sub>OUT</sub> = V <sub>OLmax</sub>                              | 40   | –                         | µA   |
| I <sub>ALEH</sub> <sup>6</sup> | ALE active current <sup>6</sup>                            | V <sub>OUT</sub> = 2.4V                                            | –    | 600                       | µA   |
| I <sub>P6H</sub> <sup>6</sup>  | Port 6 inactive current <sup>6</sup>                       | V <sub>OUT</sub> = 2.4V                                            | –    | -40                       | µA   |
| I <sub>P6L</sub> <sup>7</sup>  | Port 6 active current <sup>6</sup>                         | V <sub>OUT</sub> = V <sub>OL1max</sub>                             | -500 | –                         | µA   |
| I <sub>P0H</sub> <sup>6</sup>  | Port 0 configuration current <sup>6</sup>                  | V <sub>IN</sub> = V <sub>IHmin</sub>                               | –    | -10                       | µA   |
| I <sub>P0L</sub> <sup>7</sup>  |                                                            | V <sub>IN</sub> = V <sub>ILmax</sub>                               | -100 | –                         | µA   |
| I <sub>IL</sub> CC             | XTAL1 input current                                        | 0V < V <sub>IN</sub> < V <sub>DD</sub>                             | –    | ±20                       | µA   |
| C <sub>IO</sub> CC             | Pin capacitance <sup>6</sup> (digital inputs / outputs)    | f = 1MHz,<br>T <sub>A</sub> = 25°C                                 | –    | 10                        | pF   |
| I <sub>CC</sub>                | Power supply current                                       | RSTIN = V <sub>IH1</sub><br>f <sub>CPU</sub> in [MHz] <sup>8</sup> | –    | 20 + 6 × f <sub>CPU</sub> | mA   |
| I <sub>ID</sub>                | Idle mode supply current                                   | RSTIN = V <sub>IH1</sub><br>f <sub>CPU</sub> in [MHz] <sup>9</sup> | –    | 20 + 3 × f <sub>CPU</sub> | mA   |
| I <sub>PD</sub>                | Power-down mode supply current                             | V <sub>DD</sub> = 5.5V <sup>10</sup>                               | –    | 100                       | µA   |
| I <sub>PPR</sub>               | V <sub>PP</sub> Read Current                               | V <sub>PP</sub> < V <sub>DD</sub>                                  | –    | 200                       | µA   |
| I <sub>PPW</sub>               | V <sub>PP</sub> Programming / Erasing Current <sup>3</sup> | V <sub>PP</sub> = 12V,<br>f <sub>CPU</sub> = 25MHz                 | –    | 20                        | mA   |
| V <sub>PP</sub> <sup>11</sup>  | V <sub>PP</sub> during Programming / Erasing Operations    |                                                                    | 11,4 | 12,6                      | V    |

Notes: 1. ST10F168 pins are equipped with low-noise output drivers which significantly improve the device's EMI performance. These low-noise drivers deliver their maximum current only until the respective target output level is reached. After this, the output current is reduced. This results in increased impedance of the driver, which attenuates electrical noise from the connected PCB tracks. The current specified in column "Test Conditions" is delivered in all cases.

2. 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.

3. Partially tested, guaranteed by design characterization.

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

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

6. This specification is only valid during Reset, or during Hold-mode or Adapt-mode. Port 6 pins are only affected if they are used for CS output and the open drain function is not enabled.

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

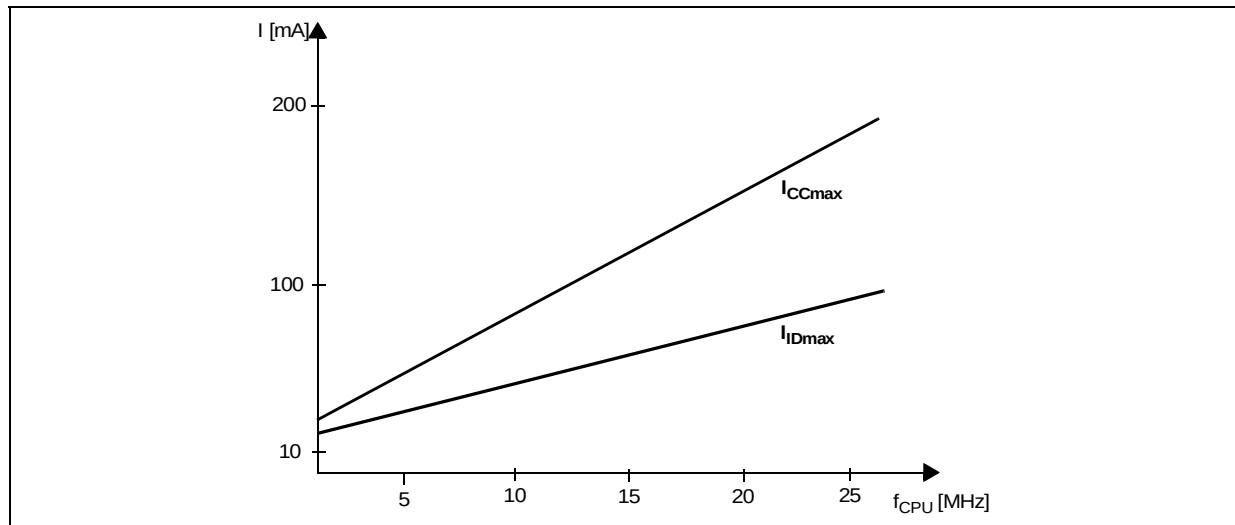
8. The power supply current is a function of the operating frequency. This dependency is illustrated in the Figure 15. These parameters are tested at V<sub>DDmax</sub> and 25MHz CPU clock with all outputs disconnected and all inputs at V<sub>IL</sub> or V<sub>IH</sub>. The chip is configured with a demultiplexed 16-bit bus, direct clock drive, 5 chip select lines and 2 segment address lines, EA pin is low during reset. After reset, Port 0 is driven with the value '00CCh' that produces infinite execution of NOP instruction with 15 wait-state, R/W delay, memory tristate wait state, normal ALE. Peripherals are not activated.

9. Idle mode supply current is a function of the operating frequency. This dependency is illustrated in the Figure 15. These parameters are tested at V<sub>DDmax</sub> and 25MHz CPU clock with all outputs disconnected and all inputs at V<sub>IL</sub> or V<sub>IH</sub>.

10. This parameter value includes leakage currents. With all inputs (including pins configured as inputs) at 0 V to 0.1V or at V<sub>DD</sub> - 0.1V to V<sub>DD</sub>, V<sub>REF</sub> = 0V, all outputs (including pins configured as outputs) disconnected.

11. Apply 12V on V<sub>PP</sub> 10ms after V<sub>DD</sub> is stable at power up. V<sub>PP</sub> pin must be switched to 0V before to switch off V<sub>DD</sub> (5V).

Figure 15 : Supply / idle current as a function of operation frequency



## 20.4 - A/D Converter Characteristics

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ ,  $4.0V \leq V_{AREF} \leq V_{DD} + 0.1V$ ,  $V_{SS} - 0.1V \leq V_{AGND} \leq V_{SS} + 0.2V$ , Q6 version :  $T_A = -40, +85^\circ C$  and for Q3 version  $T_A = -40^\circ C, +125^\circ C$ , unless otherwise specified

| Symbol        | Parameter                                       | Test Conditions                 | Min.       | Max.                    | Unit       |
|---------------|-------------------------------------------------|---------------------------------|------------|-------------------------|------------|
| $V_{AIN}$ SR  | Analog input voltage range                      | 1 - 8                           | $V_{AGND}$ | $V_{AREF}$              | V          |
| $t_S$ CC      | Sample time                                     | 2 - 4                           | 48 TCL     | 1 536 TCL               |            |
| $t_C$ CC      | Conversion time                                 | 3 - 4                           | 388 TCL    | 2 884 TCL               |            |
| TUE CC        | Total unadjusted error                          | 5                               | —          | $\pm 2$                 | LSB        |
| $R_{AREF}$ SR | Internal resistance of reference voltage source | $t_{CC}$ in [ns] <sup>6-7</sup> | —          | $(t_{CC} / 165) - 0.25$ | k $\Omega$ |
| $R_{ASRC}$ SR | Internal resistance of analog source            | $t_S$ in [ns] <sup>2-7</sup>    | —          | $(t_S / 330) - 0.25$    | k $\Omega$ |
| $C_{AIN}$ CC  | ADC input capacitance                           | 7                               | —          | 33                      | pF         |

Notes: 1.  $V_{AIN}$  may exceed  $V_{AGND}$  or  $V_{AREF}$  up to the absolute maximum ratings. However, the conversion result in these cases will be X000h or X3FFh, respectively.

2. During the  $t_S$  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 the  $t_S$  sample time. After the end of the  $t_S$  sample time, changes of the analog input voltage have no effect on the conversion result. Values for the  $t_{SC}$  sample clock depend on the programming. Referring to the  $t_C$  conversion time formula of chapter 13, to the table 17 of page 33 and to the table below:

$$t_S \text{ min} = 2 t_{SC} \text{ min} = 2 t_{CC} \text{ min} = 2 \times 24 \times \text{TCL} = 48 \text{ TCL}$$

$$t_S \text{ max} = 2 t_{SC} \text{ max} = 2 \times 8 t_{CC} \text{ max} = 2 \times 8 \times 96 \text{ TCL} = 1536 \text{ TCL}$$

TCL is defined in section 20.5.5 at page 55.

3. The conversion time formula is:

$$t_C = 14 t_{CC} + t_S + 4 \text{ TCL} (= 14 t_{CC} + 2 t_{SC} + 4 \text{ TCL})$$

The  $t_C$  parameter includes the  $t_S$  sample time, the time for determining the digital result and the time to load the result register with the result of the conversion. Values for the  $t_{CC}$  conversion clock depend on the programming. Referring to the table 17 of page 33 and to the table below:

$$t_C \text{ min} = 14 t_{CC} \text{ min} + t_S \text{ min} + 4 \text{ TCL} = 14 \times 24 \times \text{TCL} + 48 \text{ TCL} + 4 \text{ TCL} = 388 \text{ TCL}$$

$$t_C \text{ max} = 14 t_{CC} \text{ max} + t_S \text{ max} + 4 \text{ TCL} = 14 \times 96 \text{ TCL} + 1536 \text{ TCL} + 4 \text{ TCL} = 2884 \text{ TCL}$$

4. This parameter is fixed by ADC control logic.

5. TUE is tested at  $V_{AREF} = 5.0V$ ,  $V_{AGND} = 0V$ ,  $V_{CC} = 4.9V$ . It is guaranteed by design characterization for all other voltages within the defined voltage range. The specified TUE is guaranteed only if an overload condition (see Iov specification) occurs on maximum of 2 not selected analog input pins and the absolute sum of input overload currents on all analog input pins does not exceed 10mA. During the reset calibration sequence the maximum TUE may be  $\pm 4$  LSB.

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  $t_{CC}$ . The maximum internal resistance results from the programmed conversion timing.

7. Partially tested, guaranteed by design characterization.

8. To remove noise and undesirable high frequency components from the analog input signal, a low-pass filter must be connected at the ADC input. The cut-off frequency of this filter must be twice the highest conversion frequency used in the application as described in the formula:

$$f_{\text{cut-off}} = 2 / t_{c \text{ app}}$$

where  $t_{c \text{ app}}$  is the shorter conversion time used in the application, calculated with the following formula:

$$t_{c \text{ app}} = 14 t_{CC} + t_S + 4 \text{ TCL} (= 14 t_{CC} + 2 t_{SC} + 4 \text{ TCL}).$$

ADC Sample time and conversion time are programmable. The table below should be used to calculate the above timings.

| Conversion Time     |                           | Sample Time         |                       |
|---------------------|---------------------------|---------------------|-----------------------|
| ADCON.15 14 (ADCTC) | Conversion clock $t_{CC}$ | ADCON.13 12 (ADSTC) | Sample clock $t_{SC}$ |
| 00                  | TCL x 24                  | 00                  | $t_{CC}$              |
| 01                  | Reserved, do not use      | 01                  | $t_{CC} \times 2$     |
| 10                  | TCL x 96                  | 10                  | $t_{CC} \times 4$     |
| 11                  | TCL x 48                  | 11                  | $t_{CC} \times 8$     |

## 20.5 - AC Characteristics

### 20.5.1 - Test Waveforms

Figure 16 : Input / output waveforms

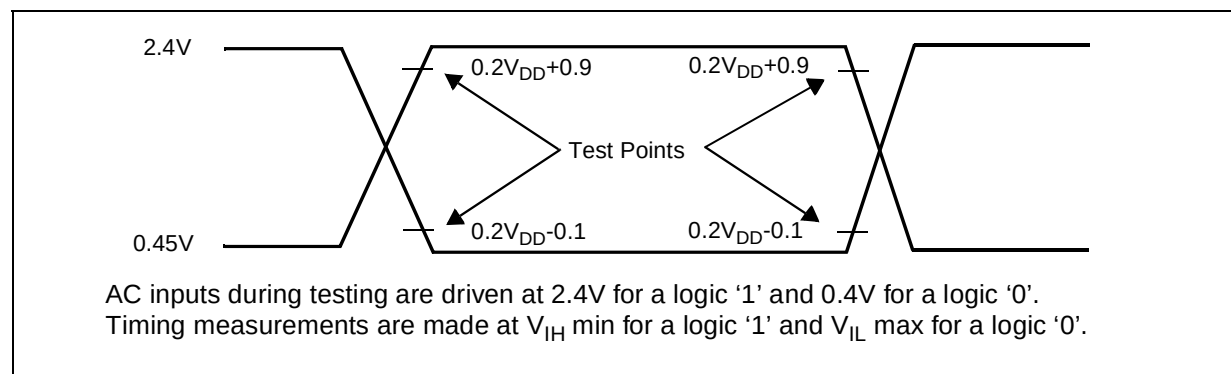
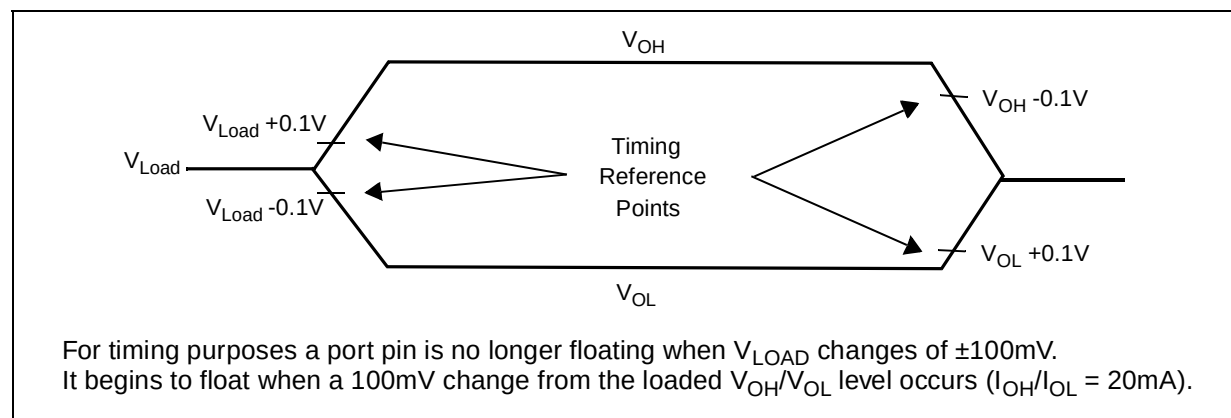


Figure 17 : Float waveforms



### 20.5.2 - Definition of Internal Timing

The internal operation of the ST10F168 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.

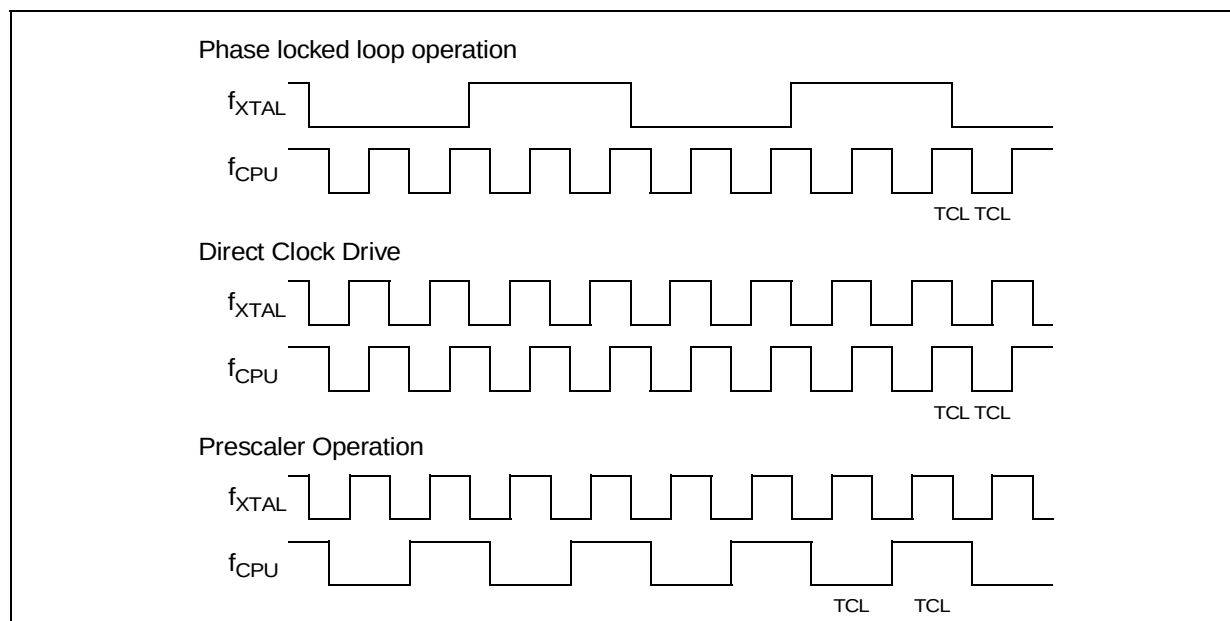
The specification of the external timing (AC Characteristics) therefore depends on the time between two consecutive edges of the CPU clock, called "TCL" (see Figure 18).

The CPU clock signal can be generated by different mechanisms. The duration of TCL and its variation (and also the derived external timing) depends on the mechanism used to generate  $f_{CPU}$ . This influence must be regarded when calculating the timings for the ST10F168.

The example for PLL operation shown in the Figure 18 refers to a PLL factor of 4.

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

**Figure 18** : Generation Mechanisms for the CPU Clock



### 20.5.3 - Clock Generation Modes

The Table 23 associates the combinations of these three bit with the respective clock generation mode.

**Table 23** : CPU Frequency Generation

| P0H.7 | P0H.6 | P0H.5 | CPU Frequency $f_{CPU} = f_{XTAL} \times F$ | External Clock Input Range <sup>1</sup> | Notes                                |
|-------|-------|-------|---------------------------------------------|-----------------------------------------|--------------------------------------|
| 1     | 1     | 1     | $f_{XTAL} \times 4$                         | 2.5 to 6.25MHz                          | Default configuration                |
| 1     | 1     | 0     | $f_{XTAL} \times 3$                         | 3.33 to 8.33MHz                         |                                      |
| 1     | 0     | 1     | $f_{XTAL} \times 2$                         | 5 to 12.5MHz                            |                                      |
| 1     | 0     | 0     | $f_{XTAL} \times 5$                         | 2 to 5MHz                               |                                      |
| 0     | 1     | 1     | $f_{XTAL} \times 1$                         | 1 to 25MHz                              | Direct drive <sup>2</sup>            |
| 0     | 1     | 0     | $f_{XTAL} \times 1.5$                       | 6.66 to 16.6MHz                         |                                      |
| 0     | 0     | 1     | $f_{XTAL} / 2$                              | 2 to 50MHz                              | CPU clock via prescaler <sup>3</sup> |
| 0     | 0     | 0     | $f_{XTAL} \times 2.5$                       | 4 to 10MHz                              |                                      |

Notes: 1. The external clock input range refers to a CPU clock range of 1...25MHz.

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

3. The maximum input frequency is 25MHz when using an external crystal with the internal oscillator; providing that internal serial resistance of the crystal is less than 40Ω. However, higher frequencies can be applied with an external clock source on pin XTAL1, but in this case, the input clock signal must reach the defined levels  $V_{IL}$  and  $V_{IH2}$ .

#### 20.5.4 - Prescaler Operation

When pins P0.15-13 (P0H.7-5) equal '001' during reset, the CPU clock is derived from the internal oscillator (input clock signal) by a 2:1 prescaler. The frequency of  $f_{CPU}$  is half the frequency of  $f_{XTAL}$  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  $f_{XTAL}$ .

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

Note that if the bit OWDDIS in SYSCON register is cleared, the PLL runs on its free-running frequency and delivers the clock signal for the Oscillator Watchdog. If bit OWDDIS is set, then the PLL is switched off.

#### 20.5.5 - Direct Drive

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

The frequency of  $f_{CPU}$  directly follows the frequency of  $f_{XTAL}$  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  $f_{XTAL}$ .

Therefore, the timings given in this chapter refer to the minimum TCL. This minimum value can be calculated by the following formula:

$$TCL_{min} = 1/f_{XTAL} \times DC_{min}$$

DC = duty cycle

For two consecutive TCLs, the deviation caused by the duty cycle of  $f_{XTAL}$  is compensated, so the duration of 2TCL is always  $1/f_{XTAL}$ . The minimum value  $TCL_{min}$  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:

$$2TCL = 1/f_{XTAL}$$

Note: The address float timings in Multiplexed bus mode ( $t_{11}$  and  $t_{45}$ ) use the maximum duration of TCL ( $TCL_{max} = 1/f_{XTAL} \times DC_{max}$ ) instead of  $TCL_{min}$ .

If bit OWDDIS in the SYSCON register is cleared, the PLL runs on its free-running frequency and delivers the clock signal for the Oscillator Watchdog. If bit OWDDIS is set, then the PLL is switched off.

#### 20.5.6 - Oscillator Watchdog (OWD)

When the clock option selected is direct drive or direct drive with prescaler, in order to provide a fail safe mechanism in case of a loss of the external clock, an oscillator watchdog is implemented as an additional functionality of the PLL circuitry. This oscillator watchdog operates as follows :

After a reset, the Oscillator Watchdog is enabled by default. To disable the OWD, the bit OWDDIS (bit 4 of SYSCON register) must be set.

When the OWD is enabled, the PLL runs on its free-running frequency, and increments the Oscillator Watchdog counter. On each transition of XTAL1 pin, the Oscillator Watchdog is cleared. If an external clock failure occurs, then the Oscillator Watchdog counter overflows (after 16 PLL clock cycles). The CPU clock signal will be switched to the PLL free-running clock signal, and the Oscillator Watchdog Interrupt Request (XP3INT) is flagged. The CPU clock will not switch back to the external clock even if a valid external clock exists on XTAL1 pin. Only a hardware reset can switch the CPU clock source back to direct clock input.

When the OWD is disabled, the CPU clock is always fed from the oscillator input and the PLL is switched off to decrease power supply current.

#### 20.5.7 - Phase Locked Loop

For all other combinations of pins P0.15-13 (P0H.7-5) during reset the on-chip phase locked loop is enabled and provides the CPU clock (see Table 23).

The PLL multiplies the input frequency by the factor F which is selected via the combination of pins P0.15-13 (i.e.  $f_{CPU} = f_{XTAL} \times F$ ). With every F'th transition of  $f_{XTAL}$  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  $f_{XTAL}$ . The slight variation causes a jitter of  $f_{CPU}$  which also effects the duration of individual TCL.

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

The real minimum value for TCL depends on the jitter of the PLL. The PLL tunes  $f_{CPU}$  to keep it locked on  $f_{XTAL}$ . The relative deviation of TCL is the maximum when it is referred to one TCL period. It decreases according to the formula and to the Figure 19 given below. For  $N$  periods of TCL the minimum value is computed using the corresponding deviation  $D_N$ :

$$TCL_{MIN} = TCL_{NOM} \times \left( 1 - \frac{[D_N]}{100} \right)$$

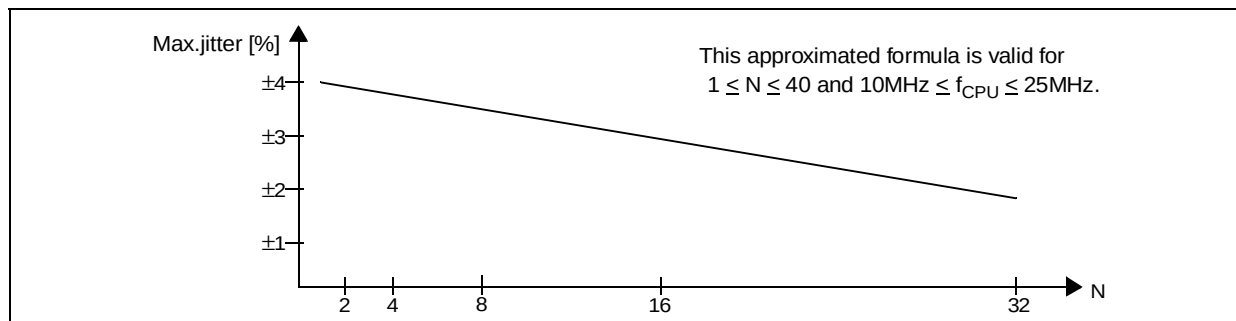
$$D_N = \pm(4 - N/15)[\%]$$

where  $N$  = number of consecutive TCL periods and  $1 \leq N \leq 40$ . So for a period of 3 TCL periods ( $N = 3$ ):

$$\begin{aligned} D_3 &= 4 - 3/15 = 3.8\% \\ 3TCL_{min} &= 3TCL_{NOM} \times (1 - 3.8/100) \\ &= 3TCL_{NOM} \times 0.962 \\ 3TCL_{min} &= (57.72\text{ns at } f_{CPU} = 25\text{MHz}) \end{aligned}$$

This is especially important for bus cycles using wait states 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 Baud rates, etc.) the deviation caused by the PLL jitter is negligible (see Figure 19).

**Figure 19** : Approximated maximum PLL jitter



### 20.5.8 - External Clock Drive XTAL1

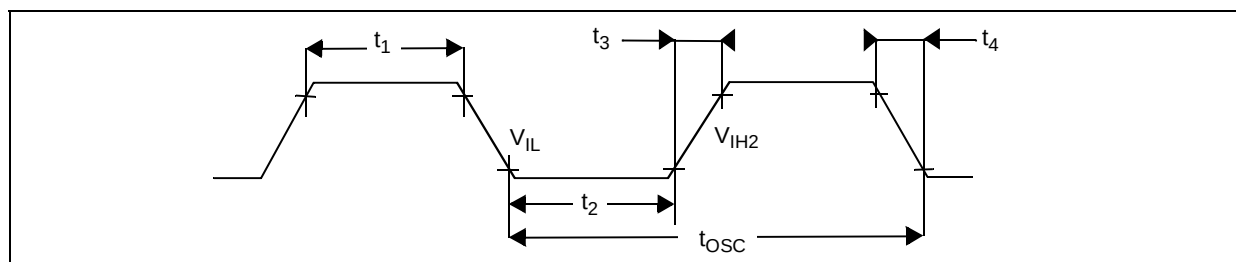
$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , for Q6 version :  $T_A = -40, +85^\circ\text{C}$  and for Q3 version  $T_A = -40, +125^\circ\text{C}$ , unless otherwise specified.

| Symbol    | SR | Parameter         | $f_{CPU} = f_{XTAL}$ |                 | $f_{CPU} = f_{XTAL} / 2$ |                | $f_{CPU} = f_{XTAL} \times N$<br>$N = 1.5 / 2 / 2.5 / 3 / 4 / 5$ |                 | Unit |
|-----------|----|-------------------|----------------------|-----------------|--------------------------|----------------|------------------------------------------------------------------|-----------------|------|
|           |    |                   | Min.                 | Max.            | Min.                     | Max.           | Min.                                                             | Max.            |      |
| $t_{OSC}$ | SR | Oscillator period | 40 <sup>1</sup>      | 1000            | 20                       | 500            | 40 x N                                                           | 100 x N         | ns   |
| $t_1$     | SR | High time         | 18 <sup>2</sup>      | —               | 6 <sup>2</sup>           | —              | 10 <sup>2</sup>                                                  | —               | ns   |
| $t_2$     | SR | Low time          | 18 <sup>2</sup>      | —               | 6 <sup>2</sup>           | —              | 10 <sup>2</sup>                                                  | —               | ns   |
| $t_3$     | SR | Rise time         | —                    | 10 <sup>2</sup> | —                        | 6 <sup>3</sup> | —                                                                | 10 <sup>2</sup> | ns   |
| $t_4$     | SR | Fall time         | —                    | 10 <sup>2</sup> | —                        | 6 <sup>2</sup> | —                                                                | 10 <sup>2</sup> | ns   |

Notes: 1. Theoretical minimum. The real minimum value depends on the duty cycle of the input clock signal.

2. The input clock signal must reach the defined levels  $V_{IL}$  and  $V_{IH2}$ .

**Figure 20** : External clock drive XTAL1



### 20.5.9 - Memory Cycle Variables

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

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

### 20.5.10 - Multiplexed Bus

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , for Q6 version :  $T_A = -40, +85^\circ C$  and for Q3 version  $T_A = -40, +125^\circ C$ ,  $C_L = 100pF$ , ALE cycle time =  $6 TCL + 2t_A + t_C + t_F$  (120ns at 25MHz CPU clock without wait states), unless otherwise specified.

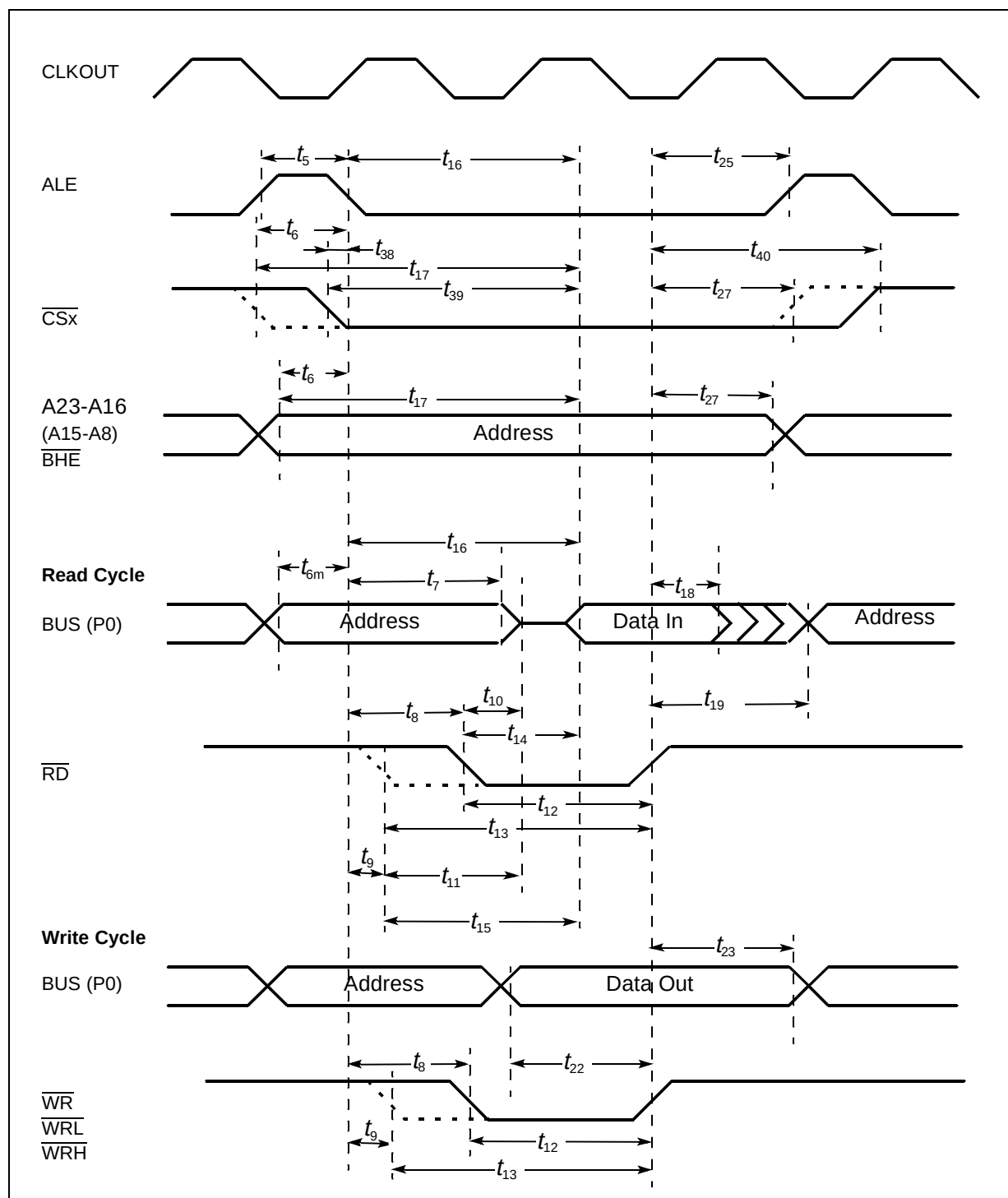
**Table 24** : Multiplexed bus characteristics

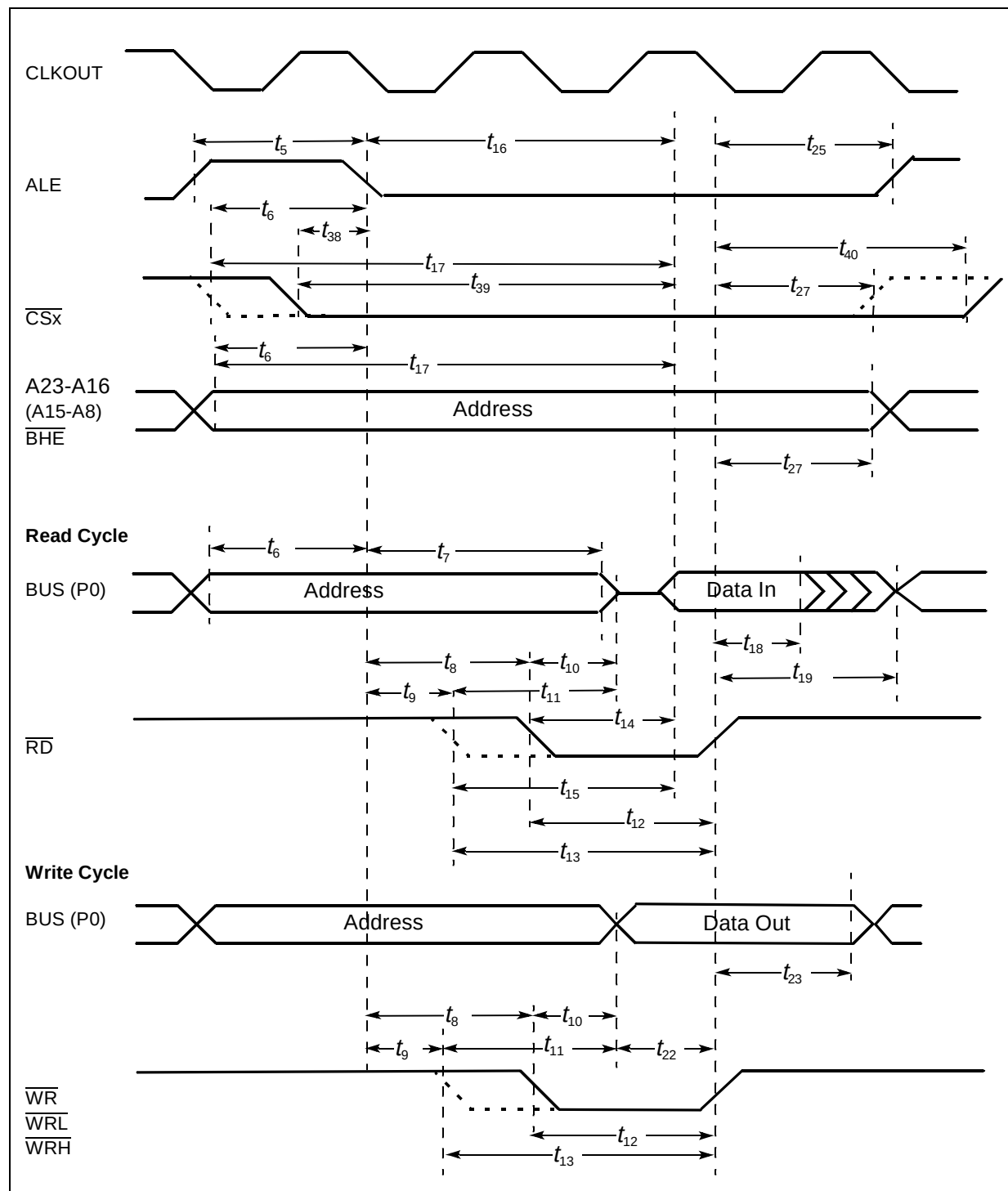
| Symbol      | Parameter                                                                             | Maximum CPU Clock<br>25MHz |                   | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |                          | Unit |
|-------------|---------------------------------------------------------------------------------------|----------------------------|-------------------|--------------------------------------------|--------------------------|------|
|             |                                                                                       | Minimum                    | Maximum           | Minimum                                    | Maximum                  |      |
| $t_5$ CC    | ALE high time                                                                         | $10 + t_A$                 | —                 | $TCL - 10 + t_A$                           | —                        | ns   |
| $t_6$ CC    | Address setup to ALE                                                                  | $4 + t_A$                  | —                 | $TCL - 16 + t_A$                           | —                        | ns   |
| $t_7$ CC    | Address hold after ALE                                                                | $10 + t_A$                 | —                 | $TCL - 10 + t_A$                           | —                        | ns   |
| $t_8$ CC    | ALE falling edge to $\overline{RD}$ , $\overline{WR}$<br>(with RW-delay)              | $10 + t_A$                 | —                 | $TCL - 10 + t_A$                           | —                        | ns   |
| $t_9$ CC    | ALE falling edge to $\overline{RD}$ , $\overline{WR}$<br>(no RW-delay)                | $-10 + t_A$                | —                 | $-10 + t_A$                                | —                        | ns   |
| $t_{10}$ CC | Address float after $\overline{RD}$ , $\overline{WR}$ <sup>1</sup><br>(with RW-delay) | —                          | 6                 | —                                          | 6                        | ns   |
| $t_{11}$ CC | Address float after $\overline{RD}$ , $\overline{WR}$ <sup>1</sup><br>(no RW-delay)   | —                          | 26                | —                                          | $TCL + 6$                | ns   |
| $t_{12}$ CC | $\overline{RD}$ , $\overline{WR}$ low time (with RW-delay)                            | $30 + t_C$                 | —                 | $2TCL - 10 + t_C$                          | —                        | ns   |
| $t_{13}$ CC | $\overline{RD}$ , $\overline{WR}$ low time (no RW-delay)                              | $50 + t_C$                 | —                 | $3TCL - 10 + t_C$                          | —                        | ns   |
| $t_{14}$ SR | $\overline{RD}$ to valid data in (with RW-delay)                                      | —                          | $20 + t_C$        | —                                          | $2TCL - 20 + t_C$        | ns   |
| $t_{15}$ SR | $\overline{RD}$ to valid data in (no RW-delay)                                        | —                          | $40 + t_C$        | —                                          | $3TCL - 20 + t_C$        | ns   |
| $t_{16}$ SR | ALE low to valid data in                                                              | —                          | $40 + t_A + t_C$  | —                                          | $3TCL - 20 + t_A + t_C$  | ns   |
| $t_{17}$ SR | Address / Unlatched $\overline{CS}$ to valid data in                                  | —                          | $50 + 2t_A + t_C$ | —                                          | $4TCL - 30 + 2t_A + t_C$ | ns   |
| $t_{18}$ SR | Data hold after $\overline{RD}$ rising edge                                           | 0                          | —                 | 0                                          | —                        | ns   |
| $t_{19}$ SR | Data float after $\overline{RD}$ <sup>1</sup>                                         | —                          | $26 + t_F$        | —                                          | $2TCL - 14 + t_F$        | ns   |
| $t_{22}$ CC | Data valid to $\overline{WR}$                                                         | $20 + t_C$                 | —                 | $2TCL - 20 + t_C$                          | —                        | ns   |

Table 24 : Multiplexed bus characteristics (continued)

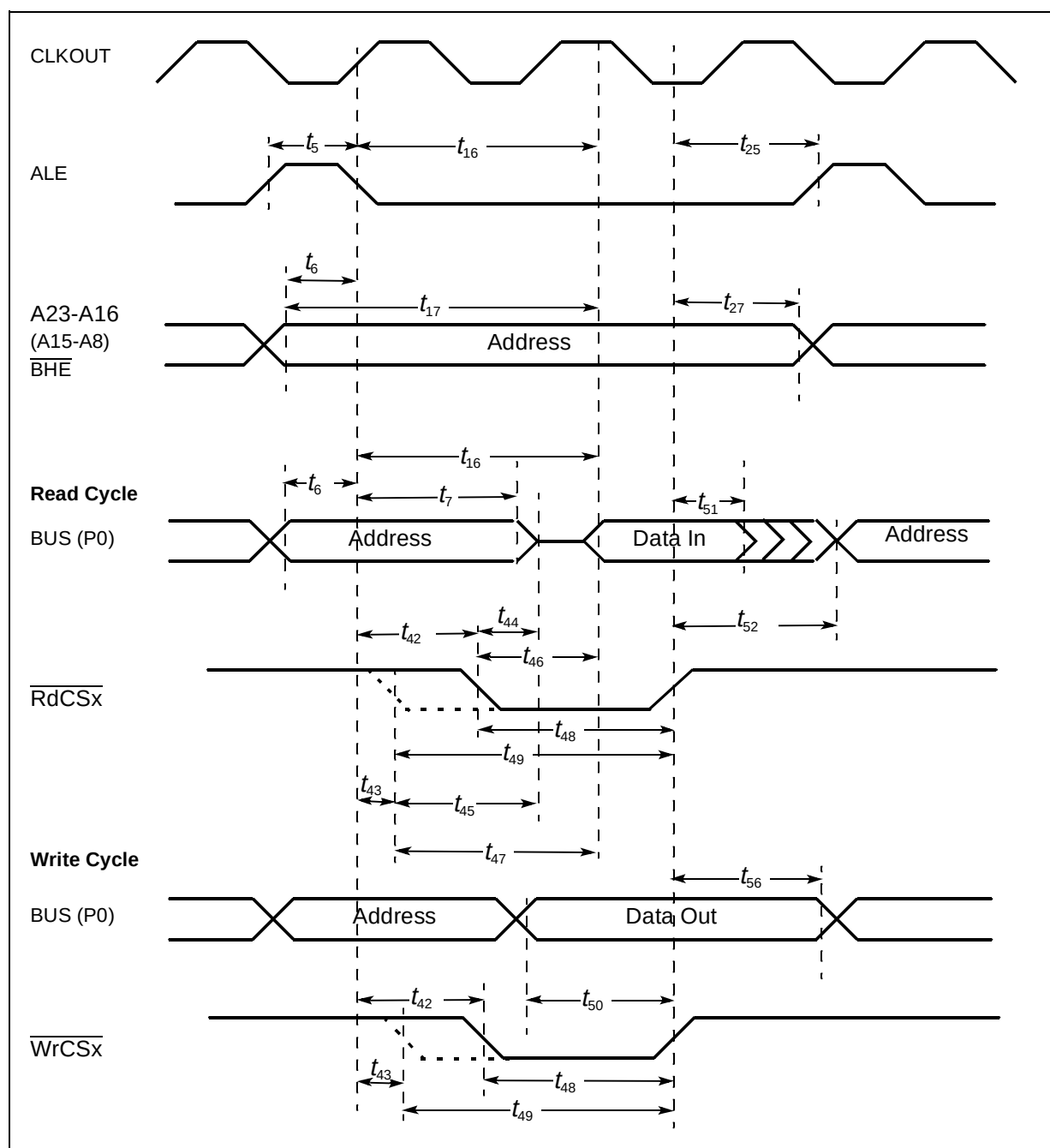
| Symbol             | Parameter                                                                              | Maximum CPU Clock<br>25MHz |                                       | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |                                              | Unit |
|--------------------|----------------------------------------------------------------------------------------|----------------------------|---------------------------------------|--------------------------------------------|----------------------------------------------|------|
|                    |                                                                                        | Minimum                    | Maximum                               | Minimum                                    | Maximum                                      |      |
| t <sub>23</sub> CC | Data hold after $\overline{WR}$                                                        | 26 + t <sub>F</sub>        | –                                     | 2TCL - 14 + t <sub>F</sub>                 | –                                            | ns   |
| t <sub>25</sub> CC | ALE rising edge after $\overline{RD}$ , $\overline{WR}$                                | 26 + t <sub>F</sub>        | –                                     | 2TCL - 14 + t <sub>F</sub>                 | –                                            | ns   |
| t <sub>27</sub> CC | Address / Unlatched $\overline{CS}$ hold after $\overline{RD}$ , $\overline{WR}$       | 26 + t <sub>F</sub>        | –                                     | 2TCL - 14 + t <sub>F</sub>                 | –                                            | ns   |
| t <sub>38</sub> CC | ALE falling edge to Latched $\overline{CS}$                                            | -4 - t <sub>A</sub>        | 10 - t <sub>A</sub>                   | -4 - t <sub>A</sub>                        | 10 - t <sub>A</sub>                          | ns   |
| t <sub>39</sub> SR | Latched $\overline{CS}$ low to Valid Data In                                           | –                          | 40 + t <sub>C</sub> + 2t <sub>A</sub> | –                                          | 3TCL - 20 + t <sub>C</sub> + 2t <sub>A</sub> | ns   |
| t <sub>40</sub> CC | Latched $\overline{CS}$ hold after $\overline{RD}$ , $\overline{WR}$                   | 46 + t <sub>F</sub>        | –                                     | 3TCL - 14 + t <sub>F</sub>                 | –                                            | ns   |
| t <sub>42</sub> CC | ALE fall. edge to $\overline{RdCS}$ , $\overline{WrCS}$ (with RW delay)                | 16 + t <sub>A</sub>        | –                                     | TCL - 4 + t <sub>A</sub>                   | –                                            | ns   |
| t <sub>43</sub> CC | ALE fall. edge to $\overline{RdCS}$ , $\overline{WrCS}$ (no RW delay)                  | -4 + t <sub>A</sub>        | –                                     | -4 + t <sub>A</sub>                        | –                                            | ns   |
| t <sub>44</sub> CC | Address float after $\overline{RdCS}$ , $\overline{WrCS}$ <sup>1</sup> (with RW delay) | –                          | 0                                     | –                                          | 0                                            | ns   |
| t <sub>45</sub> CC | Address float after $\overline{RdCS}$ , $\overline{WrCS}$ <sup>1</sup> (no RW delay)   | –                          | 20                                    | –                                          | TCL                                          | ns   |
| t <sub>46</sub> SR | $\overline{RdCS}$ to Valid Data In (with RW delay)                                     | –                          | 16 + t <sub>C</sub>                   | –                                          | 2TCL - 24 + t <sub>C</sub>                   | ns   |
| t <sub>47</sub> SR | $\overline{RdCS}$ to Valid Data In (no RW delay)                                       | –                          | 36 + t <sub>C</sub>                   | –                                          | 3TCL - 24 + t <sub>C</sub>                   | ns   |
| t <sub>48</sub> CC | $\overline{RdCS}$ , $\overline{WrCS}$ Low Time (with RW delay)                         | 30 + t <sub>C</sub>        | –                                     | 2TCL - 10 + t <sub>C</sub>                 | –                                            | ns   |
| t <sub>49</sub> CC | $\overline{RdCS}$ , $\overline{WrCS}$ Low Time (no RW delay)                           | 50 + t <sub>C</sub>        | –                                     | 3TCL - 10 + t <sub>C</sub>                 | –                                            | ns   |
| t <sub>50</sub> CC | Data valid to $\overline{WrCS}$                                                        | 26 + t <sub>C</sub>        | –                                     | 2TCL - 14 + t <sub>C</sub>                 | –                                            | ns   |
| t <sub>51</sub> SR | Data hold after $\overline{RdCS}$                                                      | 0                          | –                                     | 0                                          | –                                            | ns   |
| t <sub>52</sub> SR | Data float after $\overline{RdCS}$ <sup>1</sup>                                        | –                          | 20 + t <sub>F</sub>                   | –                                          | 2TCL - 20 + t <sub>F</sub>                   | ns   |
| t <sub>54</sub> CC | Address hold after $\overline{RdCS}$ , $\overline{WrCS}$                               | 20 + t <sub>F</sub>        | –                                     | 2TCL - 20 + t <sub>F</sub>                 | –                                            | ns   |
| t <sub>56</sub> CC | Data hold after $\overline{WrCS}$                                                      | 20 + t <sub>F</sub>        | –                                     | 2TCL - 20 + t <sub>F</sub>                 | –                                            | ns   |

Note: 1. Partially tested, guaranteed by design characterization.

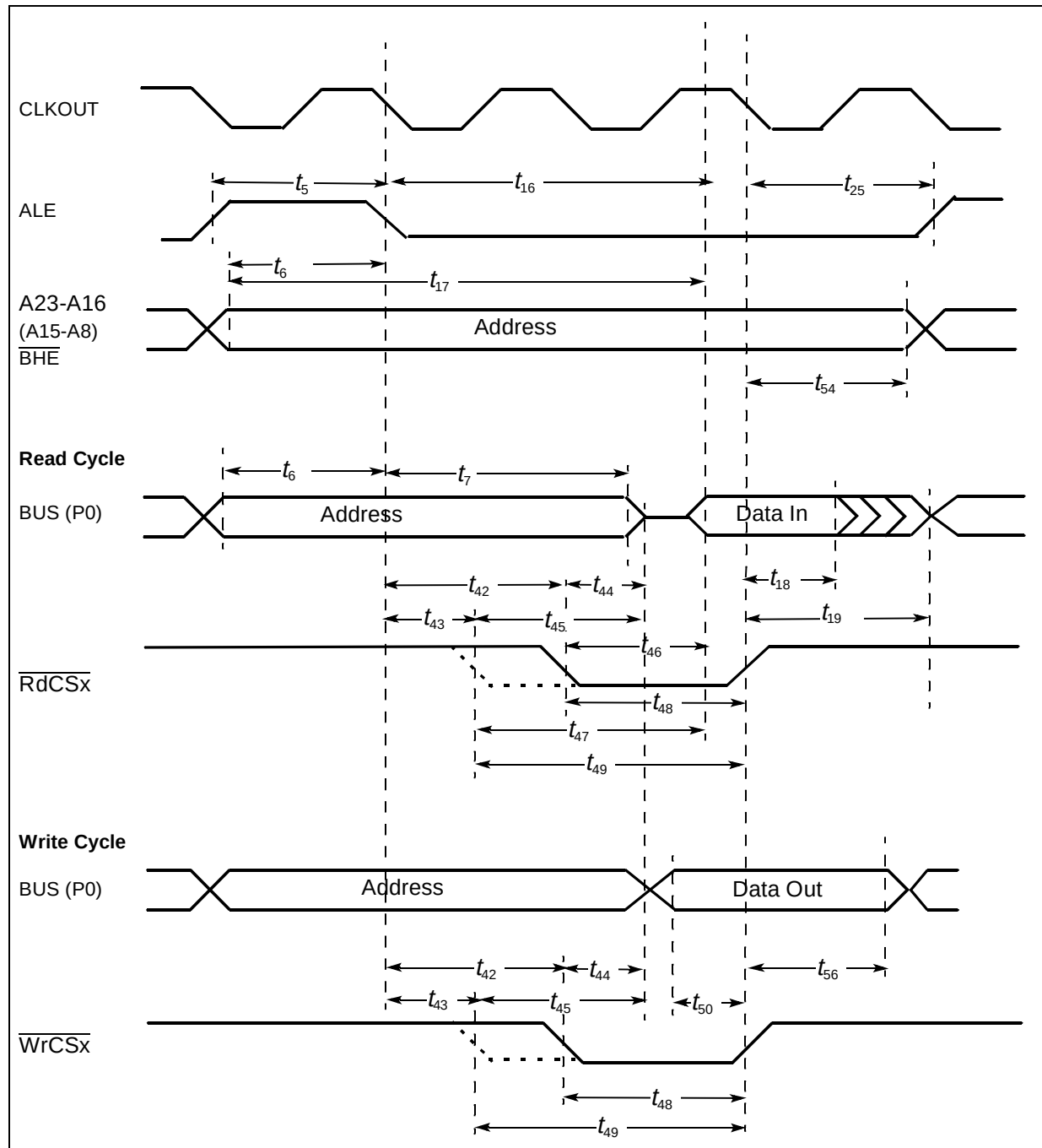
**Figure 21** : External Memory Cycle : multiplexed bus, with / without read/write delay, normal ALE

**Figure 22** : External Memory Cycle: multiplexed bus, with / without read/write delay, extended ALE

**Figure 23** : External Memory Cycle: multiplexed bus, with / without read/write delay, normal ALE, read/write chip select



**Figure 24 :** External Memory Cycle: multiplexed bus, with / without read/write delay, extended ALE, read/write chip select



### 20.5.11 - Demultiplexed Bus

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , for Q6 version :  $T_A = -40, +85^\circ C$  and for Q3 version  $T_A = -40, +125^\circ C$ ,  $C_L = 100pF$ , ALE cycle time =  $4 \text{ TCL} + 2t_A + t_C + t_F$  (80ns at 25MHz CPU clock without wait states), unless otherwise specified.

**Table 25** : Demultiplexed bus characteristics

| Symbol       | Parameter                                                                                      | Maximum<br>CPU Clock = 25MHz              |                   | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |                            | Unit |
|--------------|------------------------------------------------------------------------------------------------|-------------------------------------------|-------------------|--------------------------------------------|----------------------------|------|
|              |                                                                                                | Minimum                                   | Maximum           | Minimum                                    | Maximum                    |      |
| $t_5$ CC     | ALE high time                                                                                  | $10 + t_A$                                | –                 | $TCL - 10 + t_A$                           | –                          | ns   |
| $t_6$ CC     | Address setup to ALE                                                                           | $4 + t_A$                                 | –                 | $TCL - 16 + t_A$                           | –                          | ns   |
| $t_{80}$ CC  | Address / Unlatched $\overline{CS}$ setup to $\overline{RD}$ , $\overline{WR}$ (with RW-delay) | $30 + 2t_A$                               | –                 | $2TCL - 10 + 2t_A$                         | –                          | ns   |
| $t_{81}$ CC  | Address / Unlatched $\overline{CS}$ setup to $\overline{RD}$ , $\overline{WR}$ (no RW-delay)   | $10 + 2t_A$                               | –                 | $TCL - 10 + 2t_A$                          | –                          | ns   |
| $t_{12}$ CC  | $\overline{RD}$ , $\overline{WR}$ low time (with RW-delay)                                     | $30 + t_C$                                | –                 | $2TCL - 10 + t_C$                          | –                          | ns   |
| $t_{13}$ CC  | $\overline{RD}$ , $\overline{WR}$ low time (no RW-delay)                                       | $50 + t_C$                                | –                 | $3TCL - 10 + t_C$                          | –                          | ns   |
| $t_{14}$ SR  | $\overline{RD}$ to valid data in (with RW-delay)                                               | –                                         | $20 + t_C$        | –                                          | $2TCL - 20 + t_C$          | ns   |
| $t_{15}$ SR  | $\overline{RD}$ to valid data in (no RW-delay)                                                 | –                                         | $40 + t_C$        | –                                          | $3TCL - 20 + t_C$          | ns   |
| $t_{16}$ SR  | ALE low to valid data in                                                                       | –                                         | $40 + t_A + t_C$  | –                                          | $3TCL - 20 + t_A + t_C$    | ns   |
| $t_{17}$ SR  | Address / Unlatched $\overline{CS}$ to valid data in                                           | –                                         | $50 + 2t_A + t_C$ | –                                          | $4TCL - 30 + 2t_A + t_C$   | ns   |
| $t_{18}$ SR  | Data hold after $\overline{RD}$ rising edge                                                    | 0                                         | –                 | 0                                          | –                          | ns   |
| $t_{20}$ SR  | Data float after $\overline{RD}$ rising edge (with RW-delay) <sup>1 2</sup>                    | –                                         | $26 + t_F$        | –                                          | $2TCL - 14 + t_F + 2t_A^1$ | ns   |
| $t_{21}$ SR  | Data float after $\overline{RD}$ rising edge (no RW-delay) <sup>1 2</sup>                      | –                                         | $10 + t_F$        | –                                          | $TCL - 10 + t_F + 2t_A^1$  | ns   |
| $t_{22}$ CC  | Data valid to $\overline{WR}$                                                                  | $20 + t_C$                                | –                 | $2TCL - 20 + t_C$                          | –                          | ns   |
| $t_{24}$ CC  | Data hold after $\overline{WR}$                                                                | $10 + t_F$                                | –                 | $TCL - 10 + t_F$                           | –                          | ns   |
| $t_{26}$ CC  | ALE rising edge after $\overline{RD}$ , $\overline{WR}$                                        | $-10 + t_F$                               | –                 | $-10 + t_F$                                | –                          | ns   |
| $t_{28}$ CC  | Address / Unlatched $\overline{CS}$ hold after $\overline{RD}$ , $\overline{WR}$ <sup>3</sup>  | 0 (no $t_F$ )<br>$-5 + t_F$ ( $t_F > 0$ ) | –                 | 0 (no $t_F$ )<br>$-5 + t_F$ ( $t_F > 0$ )  | –                          | ns   |
| $t_{28h}$ CC | Address / Unlatched $\overline{CS}$ hold after $\overline{WRH}$                                | $-5 + t_F$                                | –                 | $-5 + t_F$                                 | –                          | ns   |
| $t_{38}$ CC  | ALE falling edge to Latched $\overline{CS}$                                                    | $-4 - t_A$                                | $10 - t_A$        | $-4 - t_A$                                 | $10 - t_A$                 | ns   |

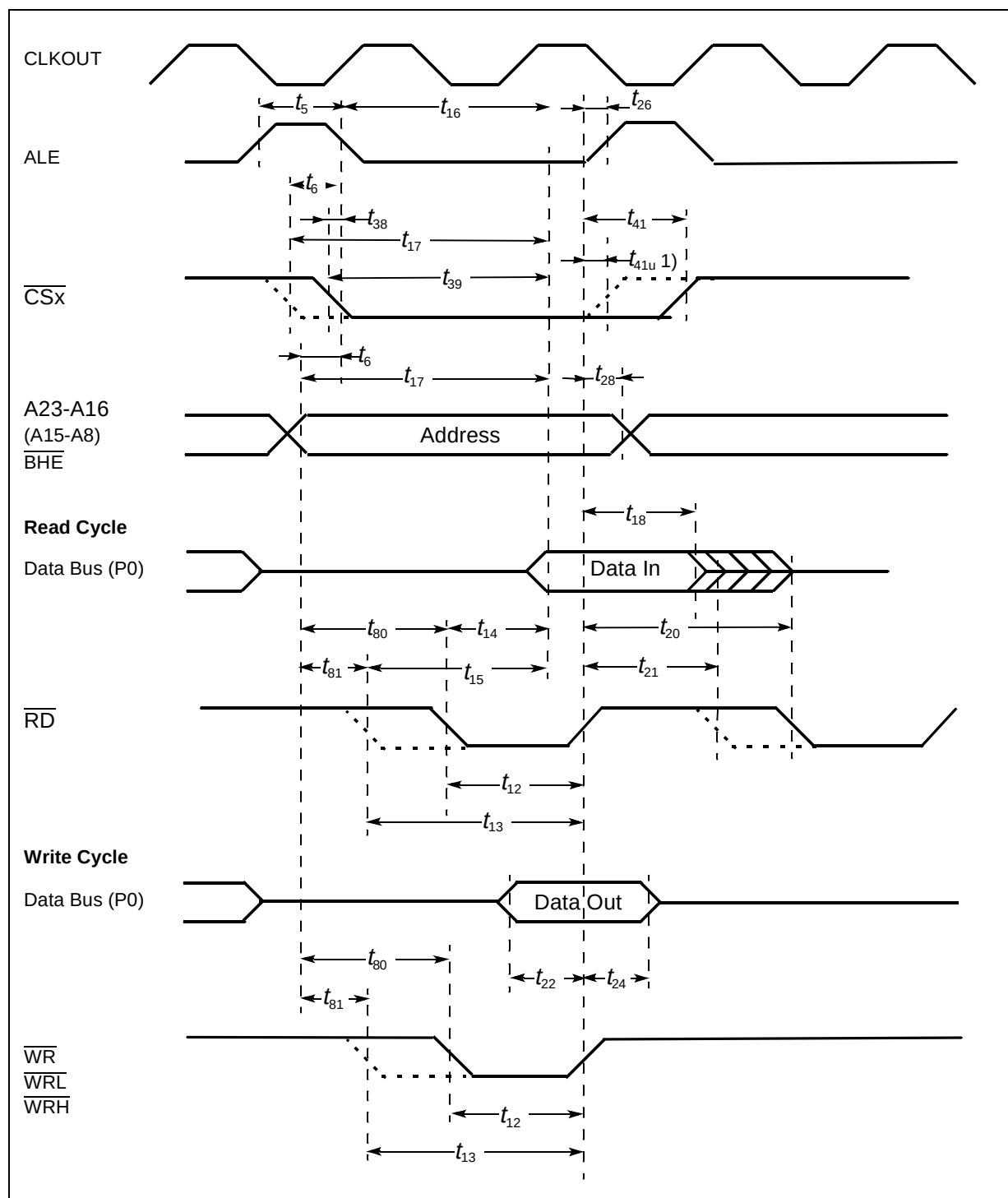
Table 25 : Demultiplexed bus characteristics (continued)

| Symbol             | Parameter                                                              | Maximum<br>CPU Clock = 25MHz |                   | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |                          | Unit |
|--------------------|------------------------------------------------------------------------|------------------------------|-------------------|--------------------------------------------|--------------------------|------|
|                    |                                                                        | Minimum                      | Maximum           | Minimum                                    | Maximum                  |      |
| t <sub>39</sub> SR | Latched $\overline{CS}$ low to Valid Data In                           | –                            | $40 + t_C + 2t_A$ | –                                          | $3TCL - 20 + t_C + 2t_A$ | ns   |
| t <sub>41</sub> CC | Latched $\overline{CS}$ hold after $\overline{RD}$ , $\overline{WR}$   | $6 + t_F$                    | –                 | $TCL - 14 + t_F$                           | –                        | ns   |
| t <sub>82</sub> CC | Address setup to $\overline{RdCS}$ , $\overline{WrCS}$ (with RW-delay) | $26 + 2t_A$                  | –                 | $2TCL - 14 + 2t_A$                         | –                        | ns   |
| t <sub>83</sub> CC | Address setup to $\overline{RdCS}$ , $\overline{WrCS}$ (no RW-delay)   | $6 + 2t_A$                   | –                 | $TCL - 14 + 2t_A$                          | –                        | ns   |
| t <sub>46</sub> SR | $\overline{RdCS}$ to Valid Data In (with RW-delay)                     | –                            | $16 + t_C$        | –                                          | $2TCL - 24 + t_C$        | ns   |
| t <sub>47</sub> SR | $\overline{RdCS}$ to Valid Data In (no RW-delay)                       | –                            | $36 + t_C$        | –                                          | $3TCL - 24 + t_C$        | ns   |
| t <sub>48</sub> CC | $\overline{RdCS}$ , $\overline{WrCS}$ Low Time (with RW-delay)         | $30 + t_C$                   | –                 | $2TCL - 10 + t_C$                          | –                        | ns   |
| t <sub>49</sub> CC | $\overline{RdCS}$ , $\overline{WrCS}$ Low Time (no RW-delay)           | $50 + t_C$                   | –                 | $3TCL - 10 + t_C$                          | –                        | ns   |
| t <sub>50</sub> CC | Data valid to $\overline{WrCS}$                                        | $26 + t_C$                   | –                 | $2TCL - 14 + t_C$                          | –                        | ns   |
| t <sub>51</sub> SR | Data hold after $\overline{RdCS}$                                      | 0                            | –                 | 0                                          | –                        | ns   |
| t <sub>53</sub> SR | Data float after $\overline{RdCS}$ (with RW-delay) <sup>2</sup>        | –                            | $20 + t_F$        | –                                          | $2TCL - 20 + t_F$        | ns   |
| t <sub>68</sub> SR | Data float after $\overline{RdCS}$ (no RW-delay) <sup>2</sup>          | –                            | $0 + t_F$         | –                                          | $TCL - 20 + t_F$         | ns   |
| t <sub>55</sub> CC | Address hold after $\overline{RdCS}$ , $\overline{WrCS}$               | $-10 + t_F$                  | –                 | $-10 + t_F$                                | –                        | ns   |
| t <sub>57</sub> CC | Data hold after $\overline{WrCS}$                                      | $6 + t_F$                    | –                 | $TCL - 14 + t_F$                           | –                        | ns   |

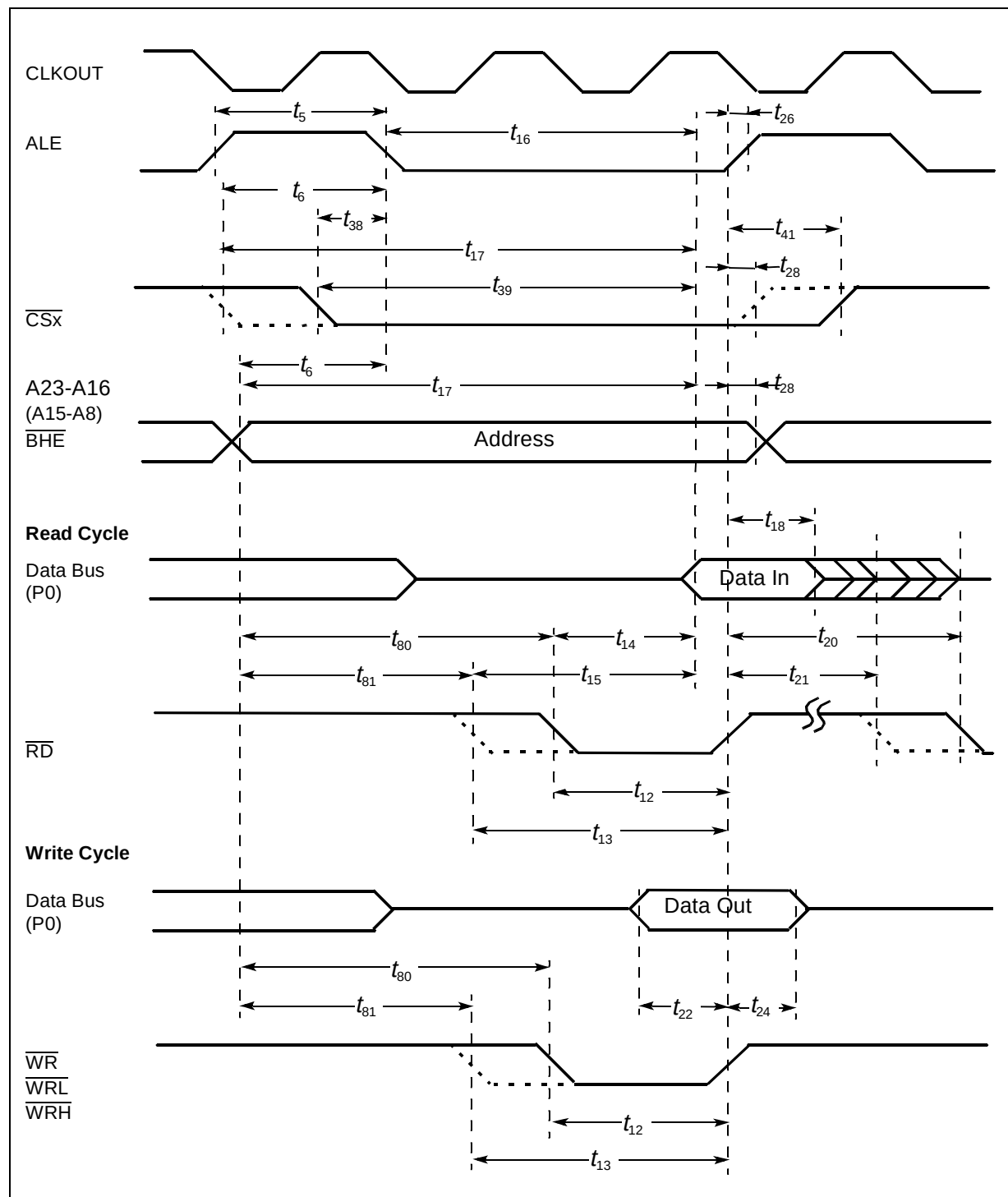
Notes: 1. RW-delay and  $t_A$  refer to the following bus cycle.

2. Partially tested, guaranteed by design characterization.

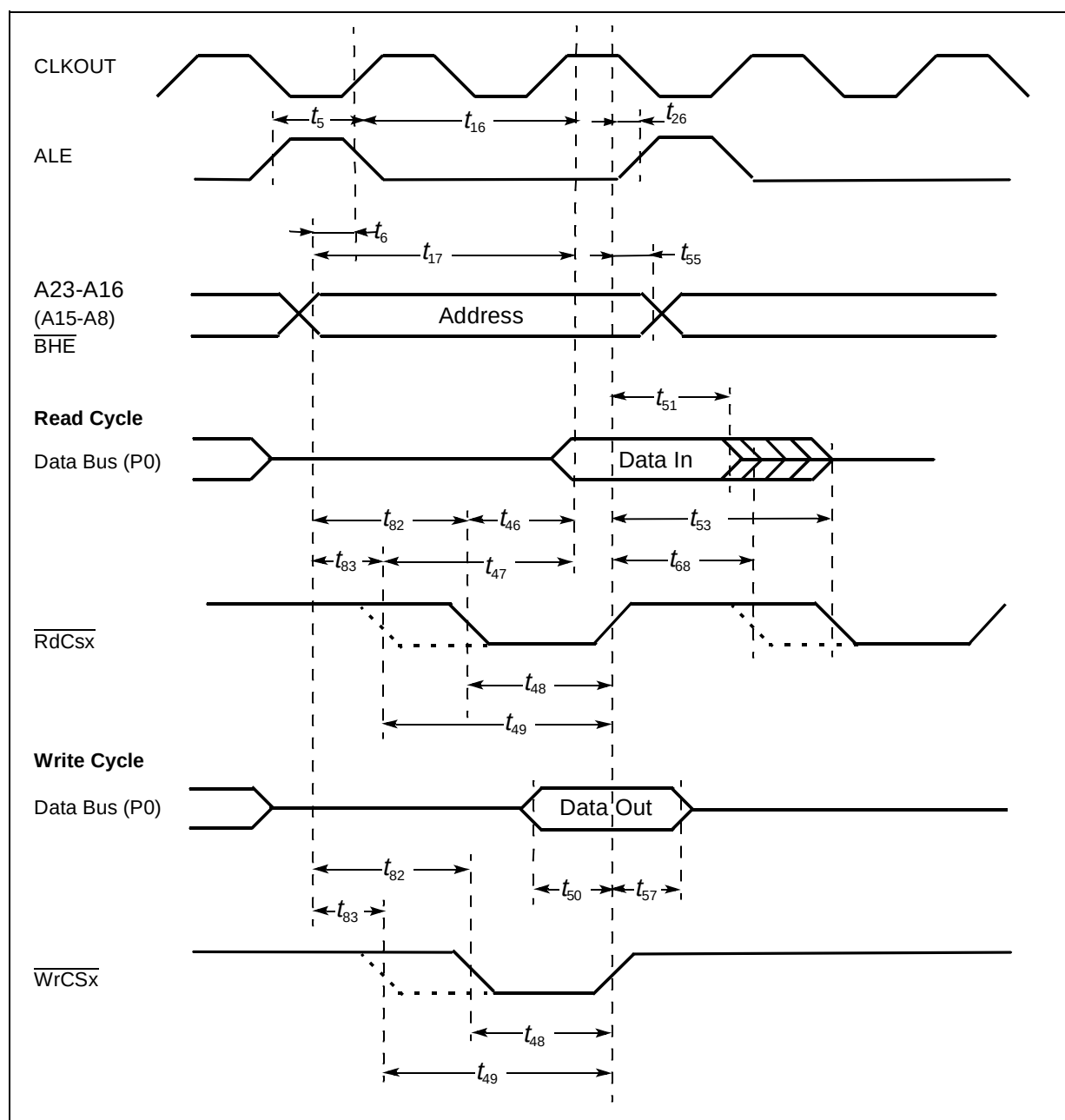
3. Read data is latched with the same clock edge that triggers the address change and the rising  $\overline{RD}$  edge. Therefore address changes before the end of  $\overline{RD}$  have no impact on read cycles.

**Figure 25** : External Memory Cycle: demultiplexed bus, with / without read/write delay, normal ALE

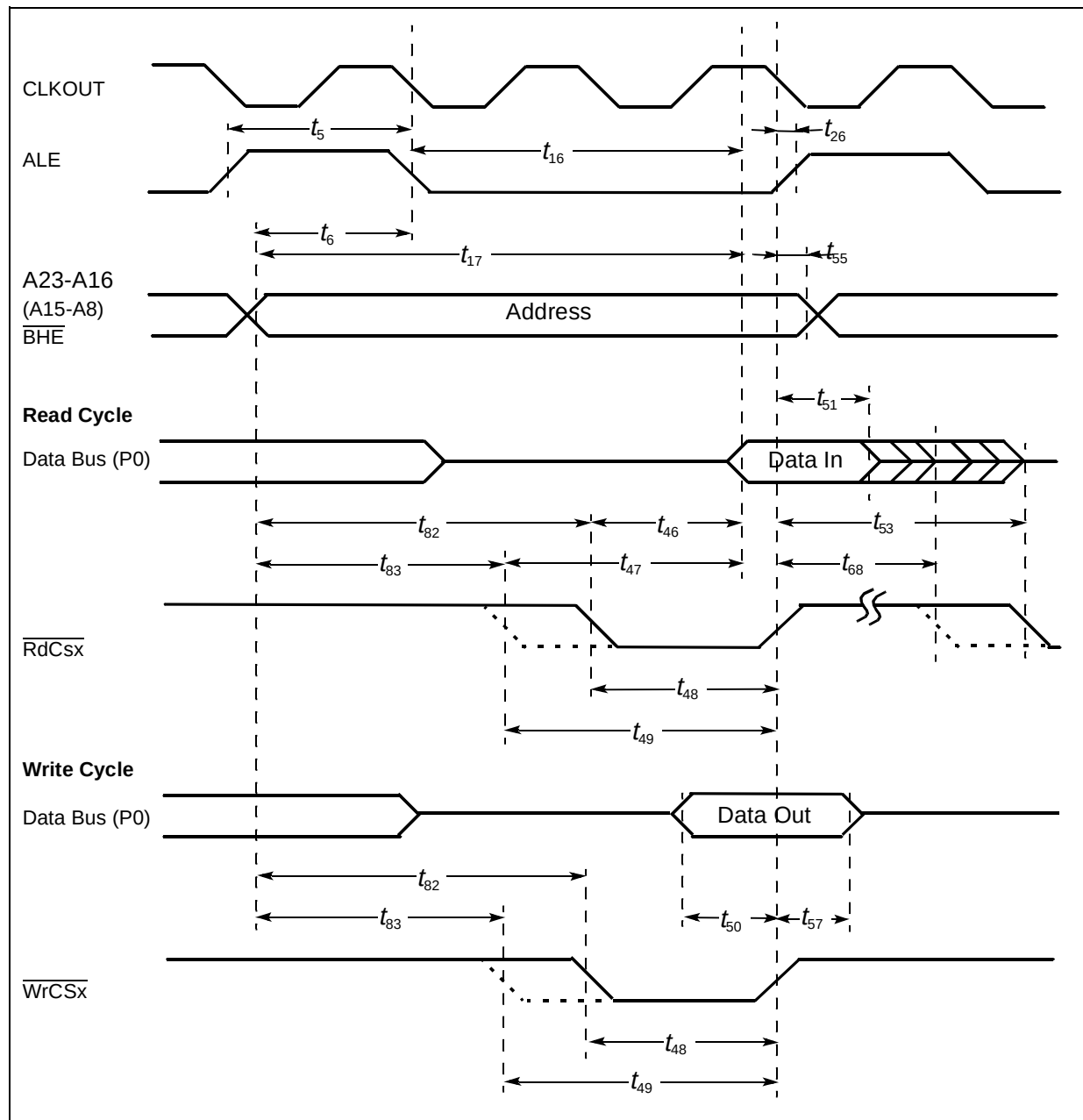
Note: 1. Un-latched CSx =  $t_{41u} = t_{41} - TCL = -14 + t_F$

**Figure 26** : External Memory Cycle: demultiplexed bus, with / without read/write delay, extended ALE

**Figure 27** : External Memory Cycle: demultiplexed bus, with / without read/write delay, normal ALE, read/write chip select



**Figure 28** : External Memory Cycle: demultiplexed bus, no read/write delay, extended ALE, read/write chip select



**20.5.12 - CLKOUT and  $\overline{\text{READY}}$** 

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , for Q6 version :  $T_A = -40, +85^\circ\text{C}$  and for Q3 version  $T_A = -40, +125^\circ\text{C}$ ,  $C_L = 100\text{pF}$ , unless otherwise specified

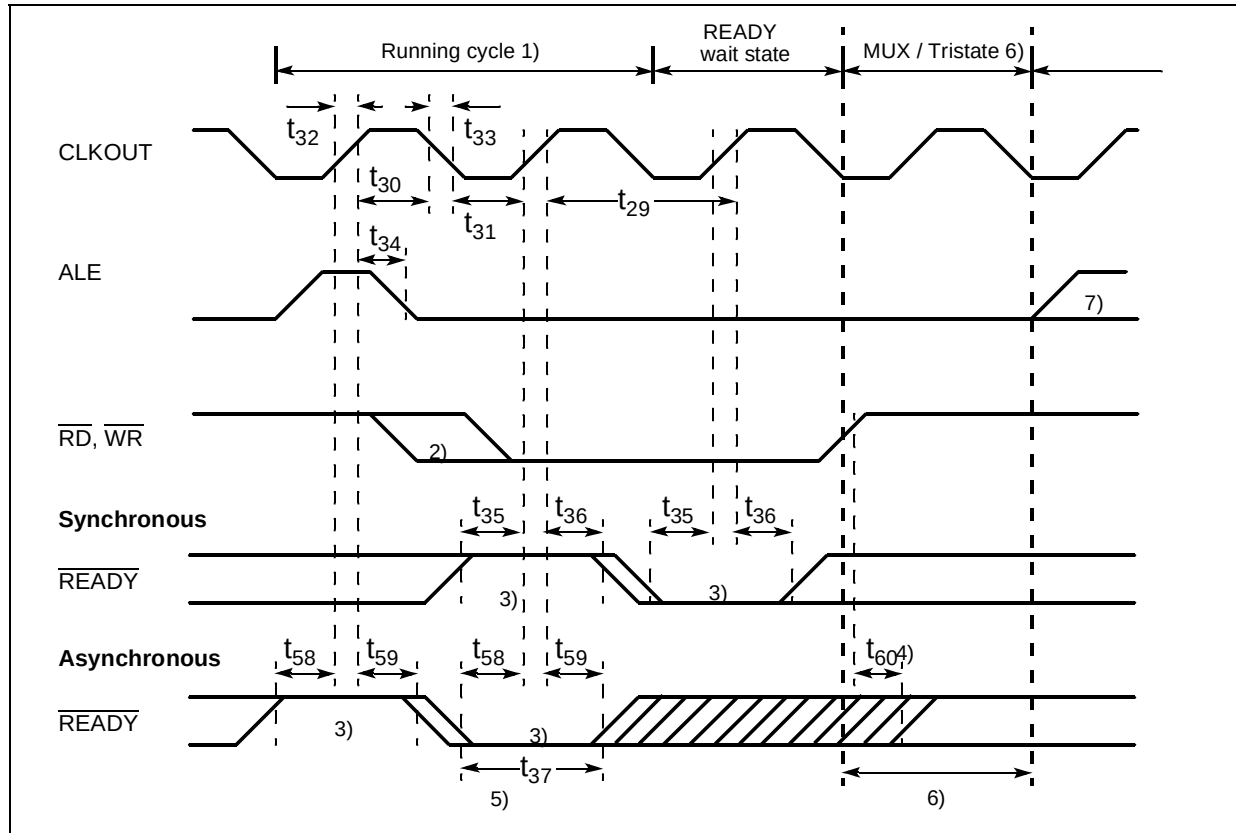
**Table 26 : CLKOUT and  $\overline{\text{READY}}$  characteristics**

| Symbol             | Parameter                                                                                                                              | Max. CPU Clock<br>25MHz |                                                                       | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |                                                                              | Unit |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------------------------------------------------|--------------------------------------------|------------------------------------------------------------------------------|------|
|                    |                                                                                                                                        | Minimum                 | Maximum                                                               | Minimum                                    | Maximum                                                                      |      |
| t <sub>29</sub> CC | CLKOUT cycle time                                                                                                                      | 40                      | 40                                                                    | 2TCL                                       | 2TCL                                                                         | ns   |
| t <sub>30</sub> CC | CLKOUT high time                                                                                                                       | 14                      | –                                                                     | TCL – 6                                    | –                                                                            | ns   |
| t <sub>31</sub> CC | CLKOUT low time                                                                                                                        | 10                      | –                                                                     | TCL – 10                                   | –                                                                            | ns   |
| t <sub>32</sub> CC | CLKOUT rise time                                                                                                                       | –                       | 4                                                                     | –                                          | 4                                                                            | ns   |
| t <sub>33</sub> CC | CLKOUT fall time                                                                                                                       | –                       | 4                                                                     | –                                          | 4                                                                            | ns   |
| t <sub>34</sub> CC | CLKOUT rising edge to ALE falling edge                                                                                                 | -3 + t <sub>A</sub>     | +7 + t <sub>A</sub>                                                   | -3 + t <sub>A</sub>                        | 7 + t <sub>A</sub>                                                           | ns   |
| t <sub>35</sub> SR | Synchronous $\overline{\text{READY}}$ setup time to CLKOUT                                                                             | 14                      | –                                                                     | 14                                         | –                                                                            | ns   |
| t <sub>36</sub> SR | Synchronous $\overline{\text{READY}}$ hold time after CLKOUT                                                                           | 4                       | –                                                                     | 4                                          | –                                                                            | ns   |
| t <sub>37</sub> SR | Asynchronous $\overline{\text{READY}}$ low time                                                                                        | 54                      | –                                                                     | 2TCL + 14                                  | –                                                                            | ns   |
| t <sub>58</sub> SR | Asynchronous $\overline{\text{READY}}$ setup time <sup>1</sup>                                                                         | 14                      | –                                                                     | 14                                         | –                                                                            | ns   |
| t <sub>59</sub> SR | Asynchronous $\overline{\text{READY}}$ hold time <sup>1</sup>                                                                          | 4                       | –                                                                     | 4                                          | –                                                                            | ns   |
| t <sub>60</sub> SR | Async. $\overline{\text{READY}}$ hold time after $\overline{\text{RD}}$ , $\overline{\text{WR}}$ high (Demultiplexed Bus) <sup>2</sup> | 0                       | 0 + 2t <sub>A</sub><br>+ t <sub>C</sub> + t <sub>F</sub> <sup>2</sup> | 0                                          | TCL - 20<br>+ 2t <sub>A</sub> + t <sub>C</sub> + t <sub>F</sub> <sup>2</sup> | ns   |

Notes: 1. These timings are given for test purposes only, in order to assure recognition at a specific clock edge.

2. Demultiplexed bus is the worst case. For multiplexed bus 2TCL are to be added to the maximum values. This adds even more time for deactivating  $\overline{\text{READY}}$ .

The 2t<sub>A</sub> and t<sub>C</sub> refer to the next following bus cycle, t<sub>F</sub> refers to the current bus cycle.

Figure 29 : CLKOUT and  $\overline{\text{READY}}$ 

Notes: 1. Cycle as programmed, including MCTC wait states (Example shows 0 MCTC WS).

2. The leading edge of the respective command depends on RW-delay.

3.  $\overline{\text{READY}}$  sampled HIGH at this sampling point generates a  $\overline{\text{READY}}$  controlled wait state,  $\overline{\text{READY}}$  sampled LOW at this sampling point terminates the currently running bus cycle.

4.  $\overline{\text{READY}}$  may be deactivated in response to the trailing (rising) edge of the corresponding command ( $\overline{\text{RD}}$  or  $\overline{\text{WR}}$ ).

5. If the Asynchronous  $\overline{\text{READY}}$  signal does not fulfill the indicated setup and hold times with respect to CLKOUT (e.g. because CLKOUT is not enabled), it must fulfill  $t_{37}$  in order to be safely synchronized. This is guaranteed, if  $\overline{\text{READY}}$  is removed in response to the command (see Note 4)).

6. Multiplexed bus modes have a MUX wait state added after a bus cycle, and an additional MTTC wait state may be inserted here. For a multiplexed bus with MTTC wait state this delay is 2 CLKOUT cycles, for a demultiplexed bus without MTTC wait state this delay is zero.

7. The next external bus cycle may start here.

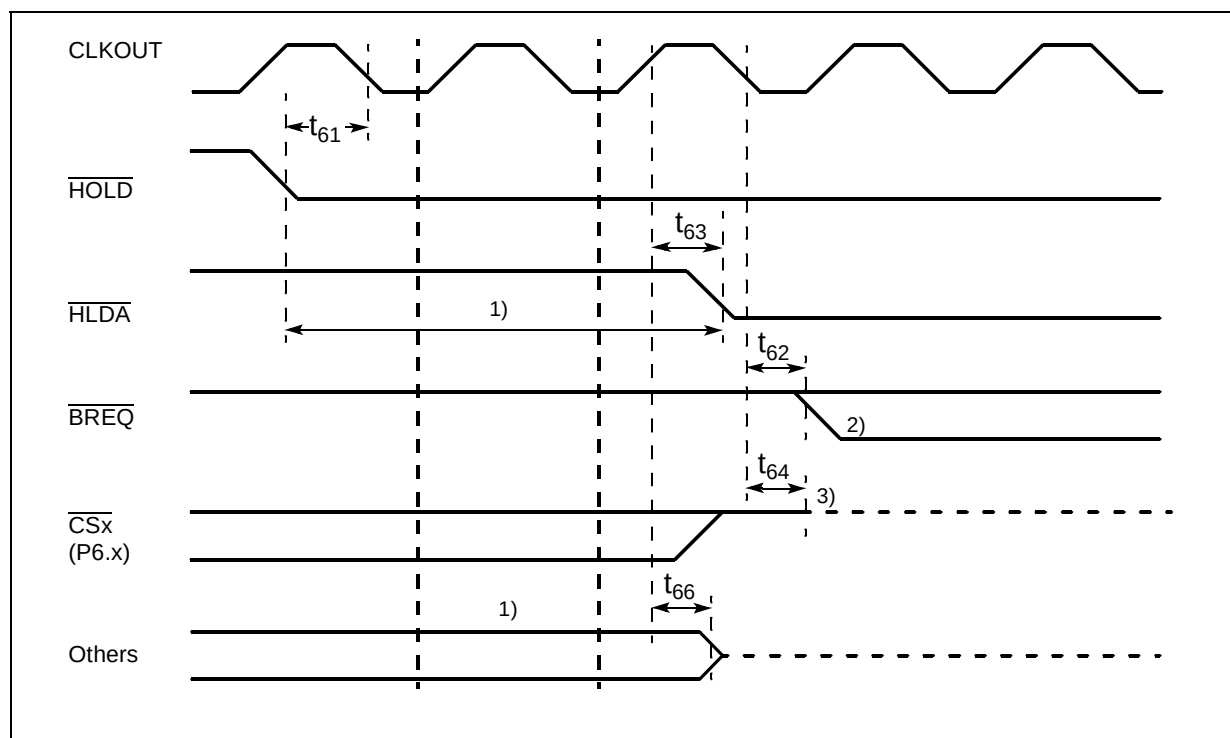
### 20.5.13 - External Bus Arbitration

$V_{DD} = 5V \pm 10\%$ ,  $V_{SS} = 0V$ , for Q6 version :  $T_A = -40, +85^\circ C$  and for Q3 version  $T_A = -40, +125^\circ C$ ,  $C_L = 100pF$ , unless otherwise specified.

| Symbol      | Parameter                                                       | Max. CPU Clock<br>25MHz |         | Variable CPU Clock<br>1/2 TCL = 1 to 25MHz |         | Unit |
|-------------|-----------------------------------------------------------------|-------------------------|---------|--------------------------------------------|---------|------|
|             |                                                                 | Minimum                 | Maximum | Minimum                                    | Maximum |      |
| $t_{61}$ SR | $\overline{HOLD}$ input setup time to CLKOUT                    | 20                      | –       | 20                                         | –       | ns   |
| $t_{62}$ CC | CLKOUT to $\overline{HLDA}$ high or $\overline{BREQ}$ low delay | –                       | 20      | –                                          | 20      | ns   |
| $t_{63}$ CC | CLKOUT to $\overline{HLDA}$ low or $\overline{BREQ}$ high delay | –                       | 20      | –                                          | 20      | ns   |
| $t_{64}$ CC | $\overline{CSx}$ release <sup>1</sup>                           | –                       | 20      | –                                          | 20      | ns   |
| $t_{65}$ CC | $\overline{CSx}$ drive                                          | -4                      | 24      | -4                                         | 24      | ns   |
| $t_{66}$ CC | Other signals release <sup>1</sup>                              | –                       | 20      | –                                          | 20      | ns   |
| $t_{67}$ CC | Other signals drive                                             | -4                      | 24      | -4                                         | 24      | ns   |

Note: 1. Partially tested, guaranted by design characterization.

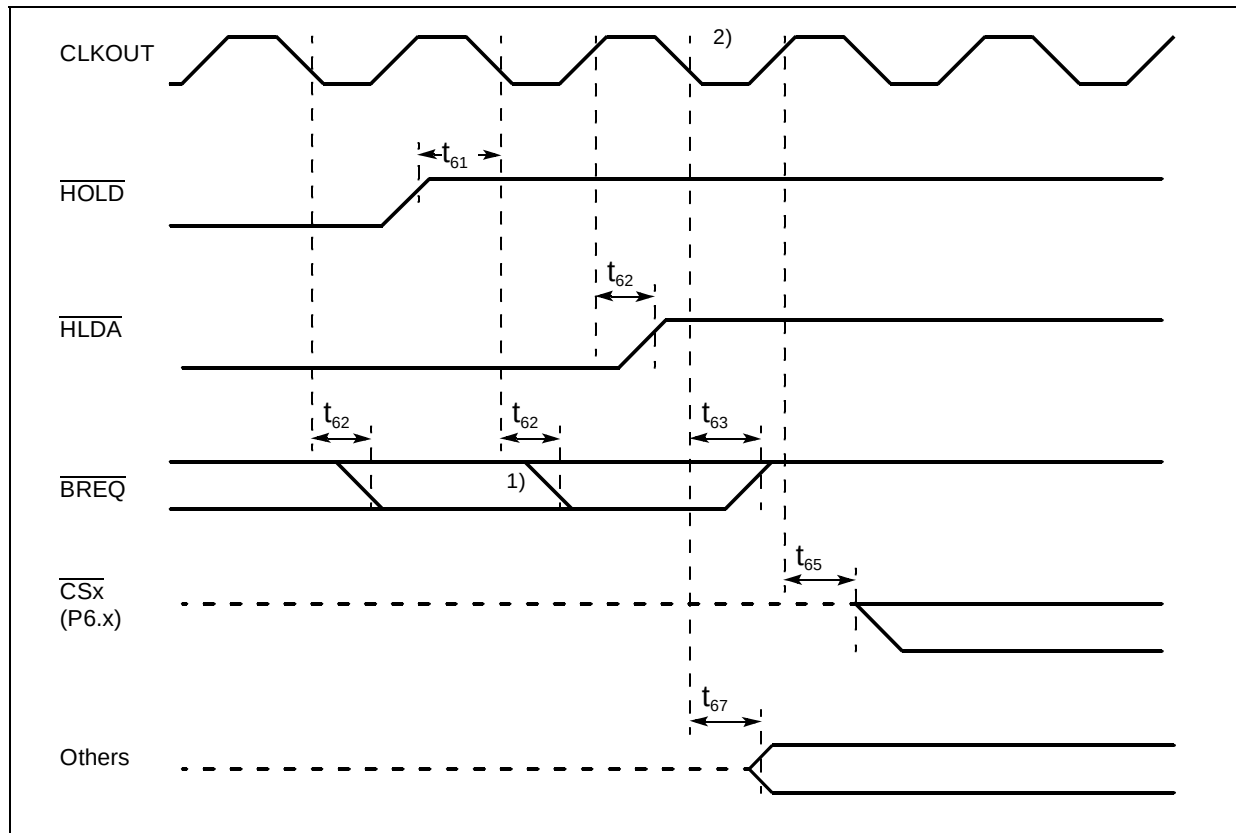
**Figure 30 : External bus arbitration, releasing the bus**



Notes: 1. The ST10F168 will complete the currently running bus cycle before granting bus access.

2. This is the first possibility for  $\overline{BREQ}$  to become active.

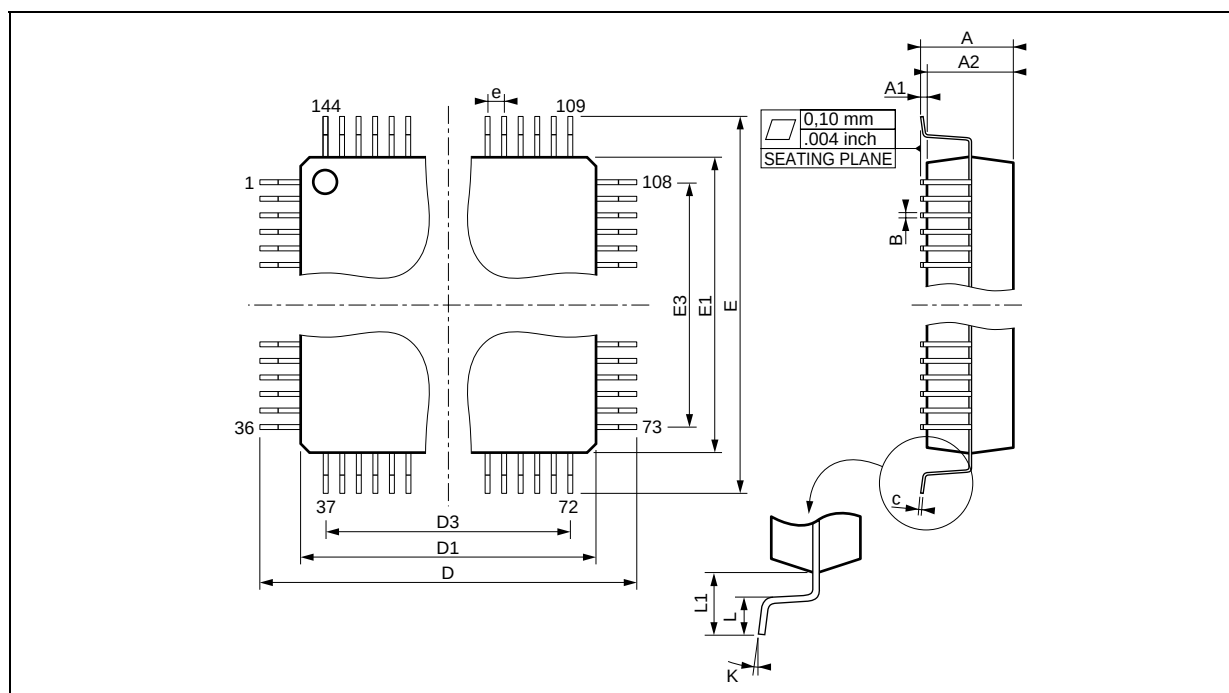
3. The  $\overline{CS}$  outputs will be resistive high (pullup) after  $t_{64}$ .

**Figure 31** : External bus arbitration, (regaining the bus)

Notes: 1. This is the last opportunity 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 ST10F168 requesting the bus.  
 2. The next ST10F168 driven bus cycle may start here.

## 21 - PACKAGE MECHANICAL DATA

Figure 32 : Package Outline PQFP144 (28 x 28mm)



| Dimensions | Millimeters <sup>1</sup> |         |         | Inches (approx) |         |         |
|------------|--------------------------|---------|---------|-----------------|---------|---------|
|            | Minimum                  | Typical | Maximum | Minimum         | Typical | Maximum |
| A          |                          |         | 4.07    |                 |         | 0.160   |
| A1         | 0.25                     |         |         | 0.010           |         |         |
| A2         | 3.17                     | 3.42    | 3.67    | 0.125           | 0.133   | 0.144   |
| B          | 0.22                     |         | 0.38    | 0.009           |         | 0.015   |
| c          | 0.13                     |         | 0.23    | 0.005           |         | 0.009   |
| D          | 30.95                    | 31.20   | 31.45   | 1.219           | 1.228   | 1.238   |
| D1         | 27.90                    | 28.00   | 28.10   | 1.098           | 1.102   | 1.106   |
| D3         |                          | 22.75   |         |                 | 0.896   |         |
| e          |                          | 0.65    |         |                 | 0.026   |         |
| E          | 30.95                    | 31.20   | 31.45   | 1.219           | 1.228   | 1.238   |
| E1         | 27.90                    | 28.00   | 28.10   | 1.098           | 1.102   | 1.106   |
| L          | 0.65                     | 0.80    | 0.95    | 0.026           | 0.031   | 0.037   |
| L1         |                          | 1.60    |         |                 | 0.063   |         |
| K          | 0° (Min.), 7° (Max.)     |         |         |                 |         |         |

Note: 1. Package dimensions are in mm. The dimensions quoted in inches are rounded.

## 22 - ORDERING INFORMATION

| Sales type  | Temperature range | Package             |
|-------------|-------------------|---------------------|
| ST10F168-Q6 | -40°C to 85°C     | PQFP144 (28 x 28mm) |
| ST10F168-Q3 | -40°C to 125°C    | PQFP144 (28 x 28mm) |

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