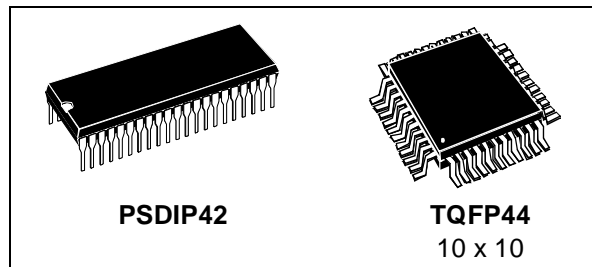




# ST72774/ST72754/ST72734

8-BIT USB MCU FOR MONITORS, WITH UP TO 60K OTP, 1K RAM, ADC, TIMER, SYNC, TMU, PWM/BRM, H/W DDC & I<sup>2</sup>C

- User ROM/OTP/EPROM: up to 60 Kbytes
- Data RAM: up to 1 Kbytes (256 bytes stack)
- 8 MHz Internal Clock Frequency in fast mode, 4 MHz in normal mode
- Run and Wait CPU modes
- System protection against illegal address jumps and illegal opcode execution
- Sync Processor for Mode Recognition, power management and composite video blanking, clamping and free-running frequency generation
  - Corrector mode
  - Analyzer mode
- USB (Universal Serial Bus) for monitor function <sup>1</sup>
  - Three endpoints
  - Integrated 3.3V voltage regulator
  - Transceiver
  - Suspend and Resume operations
- Timing Measurement Unit (TMU) for autoposition and autosize <sup>1</sup>
- Fast I<sup>2</sup>C Single Master Interface
- DDC Bus Interface with:
  - DDC1/2B protocol implemented in hardware
  - Programmable DDC CI modes
  - Enhanced DDC (EDDC) address decoding
- 31 I/O lines



- 2 lines programmable as interrupt inputs
- 16-bit timer with 2 input captures and 2 output compare functions
- 8-bit Analog to Digital Converter with 4 channels on port B
- 8 10-bit PWM/BRM Digital to Analog outputs
- Master Reset and Low Voltage Detector (LVD) reset
- Programmable Watchdog for system reliability
- Fully static operation
- 63 basic instructions / 17 main addressing modes
- 8x8 unsigned multiply instruction
- True bit manipulation
- Complete development support on PC/DOS-Windows: Real-Time Emulator, EPROM Programming Board and Gang Programmer
- Full software package (assembler, linker, C-compiler, source level debugger)

## Device Summary

| Features               | ST72(T/E)774(J/S)9                                                                    | ST72(T)754(J/S)9 | ST72774(J/S)7 | ST72754(J/S)7 | ST72(T/E)734J6                                                                   |
|------------------------|---------------------------------------------------------------------------------------|------------------|---------------|---------------|----------------------------------------------------------------------------------|
| Program Memory - Bytes | 60K                                                                                   |                  | 48K           |               | 32K                                                                              |
| RAM (stack) - Bytes    | 1K (256)                                                                              |                  |               |               | 512 (256)                                                                        |
| Peripherals            | USB                                                                                   | No USB           | USB           | No USB        | No USB                                                                           |
|                        | ADC <sup>3</sup> , 16-bit timer, I <sup>2</sup> C, DDC, TMU, Sync, PWM, LVD, Watchdog |                  |               |               | ADC <sup>4</sup> , I <sup>2</sup> C, LVD, DDC, Sync, 16-bit timer, PWM, Watchdog |
| Operating Supply       | 4.0V to 5.5V supply operating range                                                   |                  |               |               |                                                                                  |
| Oscillator Frequency   | 12 or 24 MHz                                                                          |                  |               |               |                                                                                  |
| Operating Temperature  | 0 to +70°C                                                                            |                  |               |               |                                                                                  |
| Package                | CSDIP42 or PSDIP42 or TQFP44                                                          |                  |               |               | PSDIP42<br>CSDIP42                                                               |

(1) On some devices only, refer to Device Summary; (2) Contact Sales office for availability  
 (3) 8-bit ±2 LSB A/D converter ; (4) 8-bit ±4 LSB A/D converter.

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## Revision follow-up

### Changes applied since version 4.0

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Version 4.0 | <p>March 2001</p> <p>Page 1: Addition of 72T774 (32KOTP).<br/>Addition of 60K/48K ROM for ST72754<br/>Deletion of table " device summary", replaced with cross reference to table 36 on page 147.<br/>page 13 - addition of section 1.4. external connections</p>                                                                                                                                                                                                                                                                                                          |
| Version 4.1 | <p>July 2001</p> <p>Initial format reapplied, text and related figures in the same page.<br/>Table "Device summary" reinserted in cover page and updated.<br/>Update of table 36: ordering information (p143)</p>                                                                                                                                                                                                                                                                                                                                                          |
| Version 4.2 | <p>July 2001</p> <p>Cover - addition of feature about system protection added,<br/>table for device summary: addition of stack values<br/>page 9 - figure 3: replaced 1KByte with 512 Bytes + notes about opcode fetch and HALT mode<br/>page 10 - table: CR replaced by WDGCR<br/>TIM replaced with Timer and WDG replaced with Watchdog<br/>page 115 - EDF register: addition of "read from RAM", EDE: few changes<br/>page 135 - Note 1 replaced, note 2 added SUSpend mode limitation..<br/>Whole document: all mentions of HALT mode either deleted or rewritten.</p> |
| Version 4.3 | <p>October 2001</p> <p>p140, chapter 8, section 8.1-<br/>code for unused bytes ( FFh) replaced with 9Dh (opcode for NOP)<br/>page 141- update of table 36 "Ordering information"<br/>page 142 - list of available devices updated<br/>page 114 - DDC DCR register: bit 5 = 1, text "or read from RAM" deleted</p>                                                                                                                                                                                                                                                          |
| Version 4.3 | <p>November 2001</p> <p>page 10, one address corrected in the figure 3 "memory map": 0400h<br/>page 14: addition of mandatory 1K resistor (text and figure)</p>                                                                                                                                                                                                                                                                                                                                                                                                            |

# 1 GENERAL DESCRIPTION

## 1.1 INTRODUCTION

The ST72774, ST72754 and ST72734 are HCMOS microcontroller units (MCU) from the ST727x4 family with dedicated peripherals for Monitor applications.

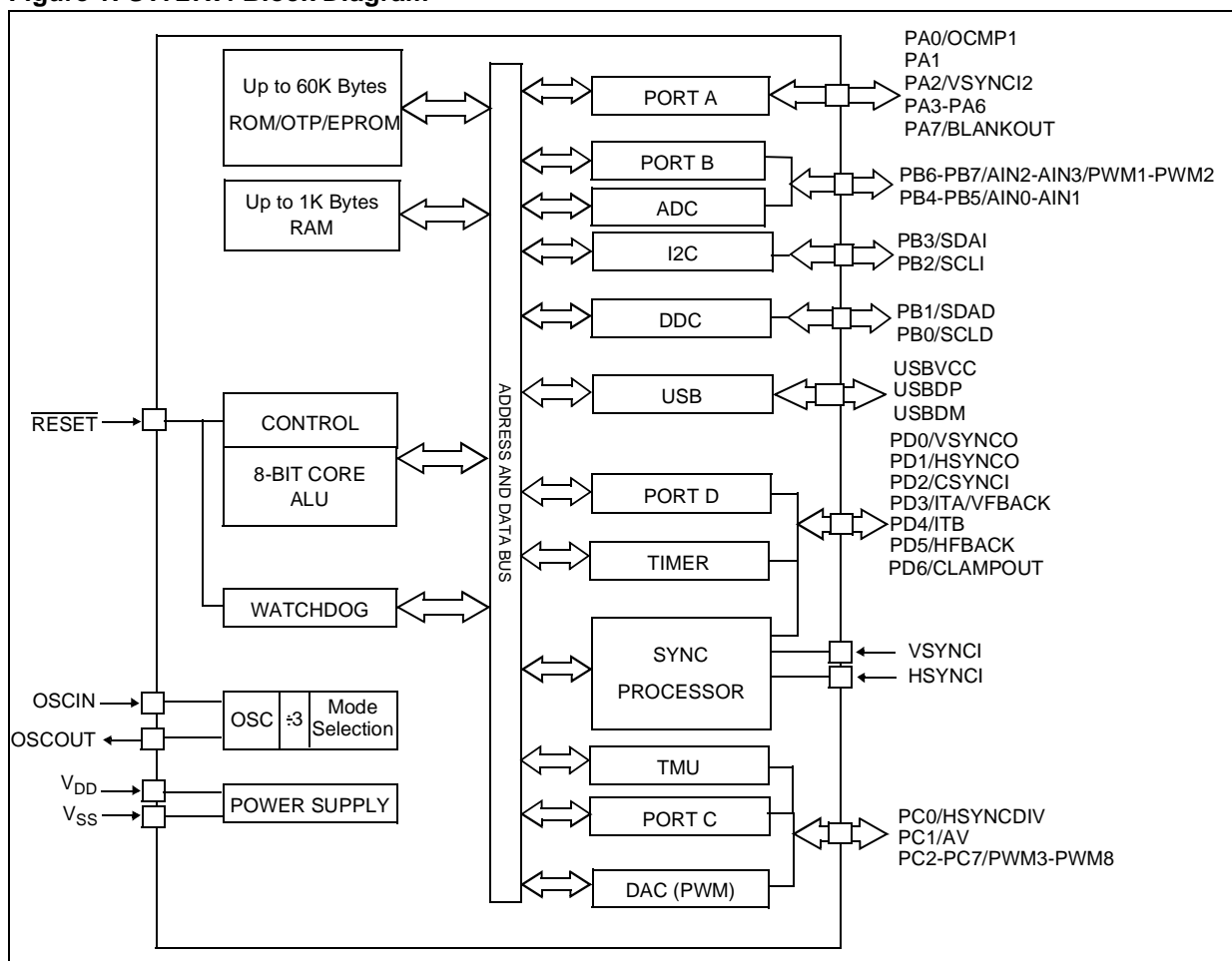
They are based around an industry standard 8-bit core and offer an enhanced instruction set. The processor runs with an external clock at 12 or 24 MHz with a 5V supply. Due to the fully static design of this device, operation down to DC is possible. Under software control the ST727x4 can be placed in WAIT mode thus reducing power consumption. The HALT mode is no longer available.

The enhanced instruction set and addressing modes afford real programming potential. Illegal opcodes are patched and lead to a reset.

In addition to standard 8-bit data management the ST7 features true bit manipulation, 8x8 unsigned multiplication and indirect addressing modes.

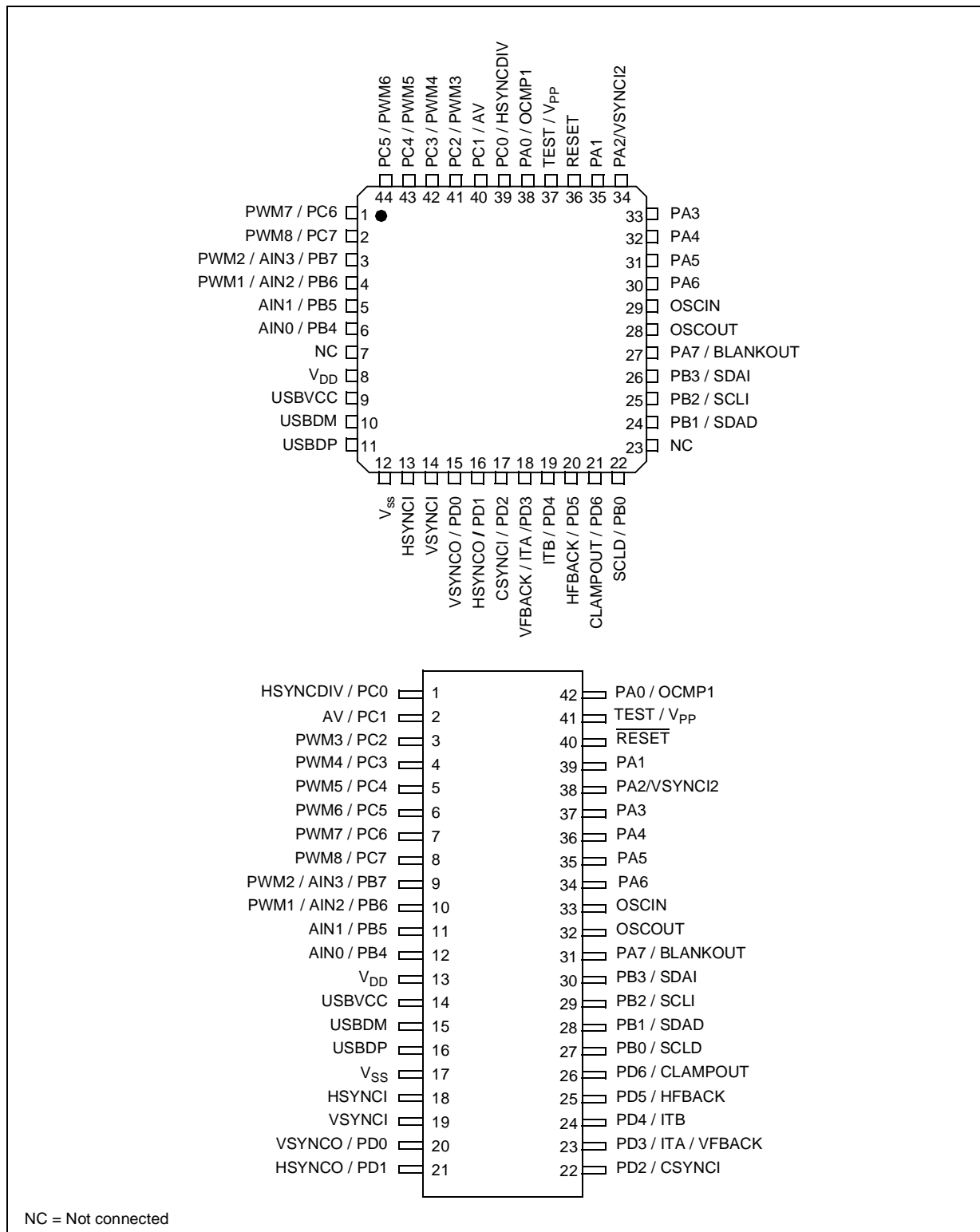
The device includes an on-chip oscillator, CPU, System protection against illegal address jumps, Sync Processor for video timing & Vfbck analysis, up to 60K Program Memory, up to 1K RAM, USB/DMA, a Timing Measurement Unit, I/O, a timer with 2 input captures and 2 output compares, a 4-channel Analog to Digital Converter, DDC, I<sup>2</sup>C Single Master, Watchdog Reset, and eight 10-bit PWM/BRM outputs for analog DC control of external functions.

Figure 1. ST727x4 Block Diagram



1.2 PIN DESCRIPTION

Figure 2. 44-pin TQFP and 42-Pin SDIP Package Pinouts



## ST72774/ST727754/ST72734

### PIN DESCRIPTION (Cont'd)

**RESET:** Bidirectional. This active low signal forces the initialization of the MCU. This event is the top priority non maskable interrupt. This pin is switched low when the Watchdog has triggered or  $V_{DD}$  is low. It can be used to reset external peripherals.

**OSCIN/OSCO:** Input/Output Oscillator pin. These pins connect a parallel-resonant crystal, or an external source to the on-chip oscillator.

**TEST/V<sub>PP</sub>:** Input. EPROM programming voltage. This pin must be held low during normal operating modes.

**V<sub>DD</sub>:** Power supply voltage (4.0V-5.5V)

**V<sub>SS</sub>:** Digital Ground.

**Alternate Functions:** several pins of the I/O ports assume software programmable alternate functions as shown in the pin description

Table 1. ST727x4 Pin Description

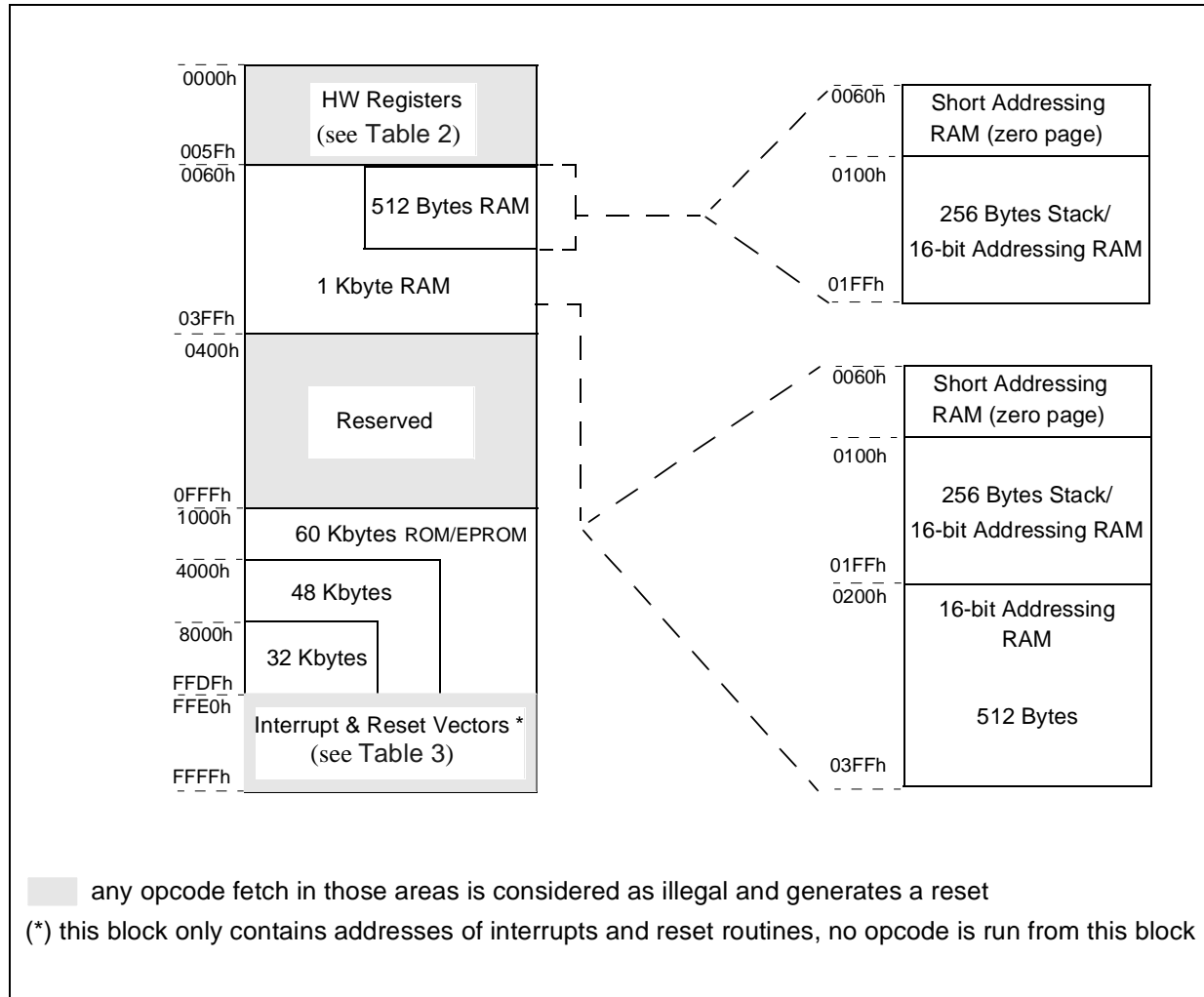
| Pin No. |        | Pin Name        | Type | Description                                              | Remarks                                                   |
|---------|--------|-----------------|------|----------------------------------------------------------|-----------------------------------------------------------|
| TQFP44  | SDIP42 |                 |      |                                                          |                                                           |
| 39      | 1      | PC0/HSYNCDIV    | I/O  | Port C0 or HSYNCDIV output (HSYNCO divided by 2)         |                                                           |
| 40      | 2      | PC1/AV          | I/O  | Port C1 or "Active Video" input                          |                                                           |
| 41      | 3      | PC2/PWM3        | I/O  | Port C2 or 10-bit PWM/BRM output 3                       | For analog controls, after external filtering             |
| 42      | 4      | PC3/PWM4        | I/O  | Port C3 or 10-bit PWM/BRM output 4                       |                                                           |
| 43      | 5      | PC4/PWM5        | I/O  | Port C4 or 10-bit PWM/BRM output5                        |                                                           |
| 44      | 6      | PC5/PWM6        | I/O  | Port C5 or 10-bit PWM/BRM output 6                       |                                                           |
| 1       | 7      | PC6/PWM7        | I/O  | Port C6 or 10-bit PWM/BRM output 7                       |                                                           |
| 2       | 8      | PC7/PWM8        | I/O  | Port C7 or 10-bit PWM/BRM output 8                       |                                                           |
| 3       | 9      | PB7/AIN3/PWM2   | I/O  | Port B7 or ADC analog input 3 or 10-bit PWM/BRM output 2 |                                                           |
| 4       | 10     | PB6/AIN2/PWM1   | I/O  | Port B6 or ADC analog input 2 or 10-bit PWM/BRM output 1 |                                                           |
| 5       | 11     | PB5/AIN1        | I/O  | Port B5 or ADC analog input 1                            |                                                           |
| 6       | 12     | PB4/AIN0        | I/O  | Port B4 or ADC analog input 0                            |                                                           |
| 8       | 13     | V <sub>DD</sub> | S    | Supply (4.0V - 5.5V)                                     |                                                           |
| 9       | 14     | USBVCC          | S    | USB power supply (output 3.3V +/- 10%)                   |                                                           |
| 10      | 15     | USBDM           | I/O  | USB bidirectional data                                   | Must be tied to ground for devices without USB peripheral |
| 11      | 16     | USBDP           | I/O  | USB bidirectional data                                   |                                                           |
| 12      | 17     | V <sub>SS</sub> | S    | Ground 0V                                                |                                                           |
| 13      | 18     | HSYNCI          | I    | SYNC horizontal synchronisation input                    | TTL levels<br>Refer to Figure 16                          |
| 14      | 19     | VSYNCI          | I    | SYNC vertical synchronisation input                      |                                                           |
| 15      | 20     | PD0/VSYNCO      | I/O  | Port D0 or SYNC vertical synchronisation output          |                                                           |
| 16      | 21     | PD1/HSYNCO      | I/O  | Port D1 or SYNC horizontal synchronisation output        |                                                           |
| 17      | 22     | PD2/CSYNCI      | I/O  | Port D2 or SYNC composite synchronisation input          | TTL levels with pull-up (SYNC input)                      |



| Pin No. |        | Pin Name                  | Type | Description                                                                           | Remarks                                            |
|---------|--------|---------------------------|------|---------------------------------------------------------------------------------------|----------------------------------------------------|
| TQFP44  | SDIP42 |                           |      |                                                                                       |                                                    |
| 18      | 23     | PD3/VFBACK/ITA            | I/O  | Port D3 or SYNC Vertical flyback input or interrupt falling edge detector input A     | Refer to Figure 16 and Table 11 Port D Description |
| 19      | 24     | PD4/ITB                   | I/O  | Port D4 or Interrupt falling edge detector input B                                    | Refer to Table 11 Port D Description               |
| 20      | 25     | PD5/HFBACK                | I/O  | Port D5 or SYNC horizontal flyback input                                              | TTL levels with pull-up (SYNC input)               |
| 21      | 26     | PD6/CLAMPOUT              | I/O  | Port D6 or SYNC clamping/ MOIRE output                                                |                                                    |
| 22      | 27     | PB0/SCLD                  | I/O  | Port B0 or DDC serial clock                                                           |                                                    |
| 24      | 28     | PB1/SDAD                  | I/O  | Port B1 or DDC serial data                                                            |                                                    |
| 25      | 29     | PB2/SCLI                  | I/O  | Port B2 or I2C serial clock                                                           |                                                    |
| 26      | 30     | PB3/SDAI                  | I/O  | Port B3 or I2C serial data                                                            |                                                    |
| 27      | 31     | PA7/BLANKOUT              | I/O  | Port A7 or SYNC blanking output                                                       |                                                    |
| 28      | 32     | OSCOUT                    | O    | Oscillator output                                                                     |                                                    |
| 29      | 33     | OSCIN                     | I    | Oscillator input                                                                      |                                                    |
| 30      | 34     | PA6                       | I/O  | Port A6                                                                               |                                                    |
| 31      | 35     | PA5                       | I/O  | Port A5                                                                               |                                                    |
| 32      | 36     | PA4                       | I/O  | Port A4                                                                               |                                                    |
| 33      | 37     | PA3                       | I/O  | Port A3                                                                               |                                                    |
| 34      | 38     | PA2/VSINCI2               | I/O  | Port A2 or SYNC vertical synchronisation input 2                                      | DDC1 only                                          |
| 35      | 39     | PA1                       | I/O  | Port A1                                                                               |                                                    |
| 36      | 40     | $\overline{\text{RESET}}$ | I/O  | Reset pin                                                                             | Active low                                         |
| 37      | 41     | TEST/V <sub>PP</sub>      | S    | Test mode pin or EPROM programming voltage. This pin should be tied low in user mode. |                                                    |
| 38      | 42     | PA0/OCMP1                 | I/O  | Port A0 or TIMER output compare 1                                                     |                                                    |

1.3 MEMORY MAP

Figure 3. Memory Map



## MEMORY MAP (Cont'd)

Table 2. Hardware Register Memory Map

| Address              | Block    | Register Label          | Register Name                         | Reset Status | Remarks   |
|----------------------|----------|-------------------------|---------------------------------------|--------------|-----------|
| 0000h                |          | PADR                    | Port A Data Register                  | 00h          | R/W       |
| 0001h                |          | PADDR                   | Port A Data Direction Register        | 00h          | R/W       |
| 0002h                |          | PBDR                    | Port B Data Register                  | 00h          | R/W       |
| 0003h                |          | PBDDR                   | Port B Data Direction Register        | 00h          | R/W       |
| 0004h                |          | PCDR                    | Port C Data Register                  | 00h          | R/W       |
| 0005h                |          | PCDDR                   | Port C Data Direction Register        | 00h          | R/W       |
| 0006h                |          | PDDR                    | Port D Data Register                  | 00h          | R/W       |
| 0007h                |          | PDDDR                   | Port D Data Direction Register        | 00h          | R/W       |
| 0008h                | Watchdog | WDGCR                   | Watchdog Control Register             | 7Fh          | R/W       |
| 0009h                |          | MISCR                   | Miscellaneous Register                | 10h          | R/W       |
| 000Ah                | ADC      | ADCDR                   | ADC Data Register                     | 00h          | Read only |
| 000Bh                |          | ADCCSR                  | ADC Control Status register           | 00h          | R/W       |
| 000Ch                | DDC1/2B  | DDCDCR                  | DDC1/2B Control Register              | 00h          | R/W       |
| 000Dh                |          | DDCAHR                  | DDC1/2B Address Pointer High Register | xxh          | R/W       |
| 000Eh                | TMU      | TMUCSR                  | TMU control status register           | FC           | R/W       |
| 000Fh                |          | TMUT1CR                 | TMU T1 counter register               | FFh          | Read only |
| 00010h               |          | TMUT2CR                 | TMU T2 counter register               | FFh          | Read only |
| 0011h                | Timer    | TIMCR2                  | Timer Control Register 2              | 00h          | R/W       |
| 0012h                |          | TIMCR1                  | Timer Control Register 1              | 00h          | R/W       |
| 0013h                |          | TIMSR                   | Timer Status Register                 | 00h          | Read only |
| 0014h                |          | TIMIC1HR                | Timer Input Capture 1 High Register   | xxh          | Read only |
| 0015h                |          | TIMIC1LR                | Timer Input Capture 1 Low Register    | xxh          | Read only |
| 0016h                |          | TIMOC1HR                | Timer Output Compare 1 High Register  | 80h          | R/W       |
| 0017h                |          | TIMOC1LR                | Timer Output Compare 1 Low Register   | 00h          | R/W       |
| 0018h                |          | TIMCHR                  | Timer Counter High Register           | FFh          | Read only |
| 0019h                |          | TIMCLR                  | Timer Counter Low Register            | FC           | R/W       |
| 001Ah                |          | TIMACHR                 | Timer Alternate Counter High Register | FFh          | Read only |
| 001Bh                |          | TIMACL                  | Timer Alternate Counter Low Register  | FC           | R/W       |
| 001Ch                |          | TIMIC2HR                | Timer Input Capture 2 High Register   | xxh          | Read only |
| 001Dh                |          | TIMIC2LR                | Timer Input Capture 2 Low Register    | xxh          | Read only |
| 001Eh                |          | TIMOC2HR                | Timer Output Compare 2 High Register  | 80h          | R/W       |
| 001Fh                |          | TIMOC2LR                | Timer Output Compare 2 Low Register   | 00h          | R/W       |
| 0020h<br>to<br>0024h |          | Reserved Area (5 bytes) |                                       |              |           |

**ST72774/ST727754/ST72734**

| Address              | Block                   | Register Label | Register Name                  | Reset Status               | Remarks   |
|----------------------|-------------------------|----------------|--------------------------------|----------------------------|-----------|
| 0025h                | USB                     | USBPIDR        | USB PID Register               | XXh                        | Read only |
| 0026h                |                         | USBDMAR        | USB DMA address Register       | XXh                        | R/W       |
| 0027h                |                         | USBIDR         | USB Interrupt/DMA Register     | XXh                        | R/W       |
| 0028h                |                         | USBISTR        | USB Interrupt Status Register  | 00h                        | R/W       |
| 0029h                |                         | USBIMR         | USB Interrupt Mask Register    | 00h                        | R/W       |
| 002Ah                |                         | USBCTLR        | USB Control Register           | xxxx 0110                  | R/W       |
| 002Bh                |                         | USBDADDR       | USB Device Address Register    | 00h                        | R/W       |
| 002Ch                |                         | USBEP0RA       | USB Endpoint 0 Register A      | 0000 xxxx                  | R/W       |
| 002Dh                |                         | USBEP0RB       | USB Endpoint 0 Register B      | 80h                        | R/W       |
| 002Eh                |                         | USBEP1RA       | USB Endpoint 1 Register A      | 0000 xxxx                  | R/W       |
| 002Fh                |                         | USBEP1RB       | USB Endpoint 1 Register B      | 0000                       | R/W       |
| 0030h                |                         | USBEP2RA       | USB Endpoint 2 Register A      | xxxx0000                   | R/W       |
| 0031h                |                         | USBEP2RB       | USB Endpoint2 Register B       | 0000                       | R/W       |
|                      |                         |                |                                |                            | xxxx0000  |
| 0032h                | PWM                     | PWM1           | 10 BIT PWM / BRM               | 80h                        | R/W       |
| 0033h                |                         | BRM21          |                                | 00h                        | R/W       |
| 0034h                |                         | PWM2           |                                | 80h                        | R/W       |
| 0035h                |                         | PWM3           |                                | 80h                        | R/W       |
| 0036h                |                         | BRM43          |                                | 00h                        | R/W       |
| 0037h                |                         | PWM4           |                                | 80h                        | R/W       |
| 0038h                |                         | PWM5           |                                | 80h                        | R/W       |
| 0039h                |                         | BRM65          |                                | 00h                        | R/W       |
| 003Ah                |                         | PWM6           |                                | 80h                        | R/W       |
| 003Bh                |                         | PWM7           |                                | 80h                        | R/W       |
| 003Ch                |                         | BRM87          |                                | 00h                        | R/W       |
| 003Dh                |                         | PWM8           |                                | 80h                        | R/W       |
| 003Eh                |                         | PWMCR          |                                | PWM output enable register | 00h       |
| 003Fh                | Reserved Area (1 byte)  |                |                                |                            |           |
| 0040h                | SYNC                    | SYNCCFGR       | SYNC Configuration Register    | 00h                        | R/W       |
| 0041h                |                         | SYNCMCR        | SYNC Multiplexer Register      | 20h                        | R/W       |
| 0042h                |                         | SYNCCCR        | SYNC Counter Register          | 00h                        | R/W       |
| 0043h                |                         | SYNCPOLR       | SYNC Polarity Register         | 08h                        | R/W       |
| 0044h                |                         | SYNCLATR       | SYNC Latch Register            | 00h                        | R/W       |
| 0045h                |                         | SYNCHGENR      | SYNC H Sync Generator Register | 00h                        | R/W       |
| 0046h                |                         | SYNCGENR       | SYNC V Sync Generator Register | 00h                        | R/W       |
| 0047h                |                         | SYNCENR        | SYNC Processor Enable Register | C3h                        | R/W       |
| 0048h<br>to<br>004Fh | Reserved Area (8 bytes) |                |                                |                            |           |

| Address | Block                   | Register Label | Register Name                           | Reset Status | Remarks   |
|---------|-------------------------|----------------|-----------------------------------------|--------------|-----------|
| 0050h   | DDC/CI                  | DDCCR          | DDC/CI Control Register                 | 00h          | R/W       |
| 0051h   |                         | DDCSR1         | DDC/CI Status Register 1                | 00h          | Read only |
| 0052h   |                         | DDCSR2         | DDC/CI Status Register 2                | 00h          | Read only |
| 0053h   |                         |                | Reserved                                |              |           |
| 0054h   |                         | DDCOAR         | DDC/CI (7 Bits) Slave address Register  | 00h          | R/W       |
| 0055h   |                         |                | Reserved                                |              |           |
| 0056h   |                         | DDCDR          | DDC/CI Data Register                    | 00h          | R/W       |
| 0057h   | Reserved Area (2 bytes) |                |                                         |              |           |
| 0058h   |                         |                |                                         |              |           |
| 0059h   | I2C                     | I2CDR          | I2C Data Register                       | 00h          | R/W       |
| 005Ah   |                         |                | Reserved                                |              |           |
| 005Bh   |                         |                | Reserved                                |              |           |
| 005Ch   |                         | I2CCCR         | I <sup>2</sup> C Clock Control Register | 00h          | R/W       |
| 005Dh   |                         | I2CSR2         | I <sup>2</sup> C Status Register 2      | 00h          | Read only |
| 005Eh   |                         | I2CSR1         | I <sup>2</sup> C Status Register 1      | 00h          | Read only |
| 005Fh   |                         | I2CCR          | I <sup>2</sup> C Control Register       | 00h          | R/W       |

Table 3. Interrupt Vector Map

| Vector Address | Description                           | Remarks             |
|----------------|---------------------------------------|---------------------|
| FFE0-FFE1h     | Not used                              | Internal Interrupts |
| FFE2-FFE3h     | Not used                              |                     |
| FFE4-FFE5h     | Not used                              |                     |
| FFE6-FFE7h     | USB interrupt vector                  |                     |
| FFE8-FFE9h     | Not used                              |                     |
| FFEA-FFEBh     | I2C interrupt vector                  |                     |
| FFEC-FFEDh     | Timer Overflow interrupt vector       |                     |
| FFEE-FFEFh     | Timer Output Compare interrupt vector |                     |
| FFF0-FFF1h     | Timer Input Capture interrupt vector  |                     |
| FFF2-FFF3h     | ITA falling edge interrupt vector     |                     |
| FFF4-FFF5h     | ITB falling edge interrupt vector     |                     |
| FFF6-FFF7h     | DDC1/2B interrupt vector              | Internal Interrupt  |
| FFF8-FFF9h     | DDC/CI interrupt vector               |                     |
| FFFA-FFFBh     | USB End Suspend interrupt vector      | CPU Interrupt       |
| FFFC-FFFDh     | TRAP (software) interrupt vector      |                     |
| FFFE-FFFFh     | RESET vector                          |                     |

1.4 External connections

The following figure shows the recommended external connections for the device.

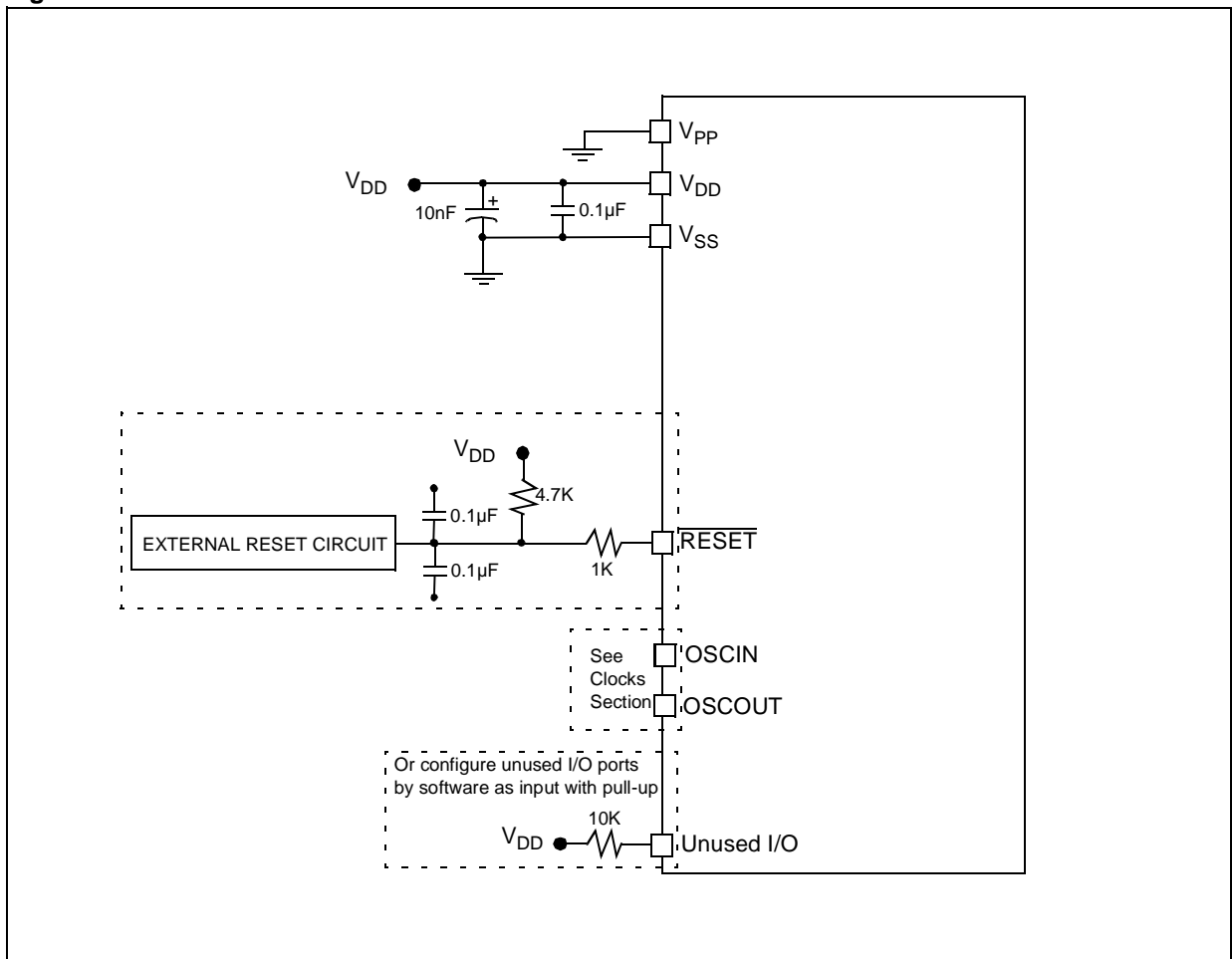
The  $V_{PP}$  pin is only used for programming OTP and EPROM devices and must be tied to ground in user mode.

The 10 nF and 0.1  $\mu$ F decoupling capacitors on the power supply lines are a suggested EMC performance/cost tradeoff.

The external reset network (including the mandatory 1K serial resistor) is intended to protect the device against parasitic resets, especially in noisy environments.

Unused I/Os should be tied high to avoid any unnecessary power consumption on floating lines. An alternative solution is to program the unused ports as inputs with pull-up.

Figure 4. Recommended External Connections



## 2 CENTRAL PROCESSING UNIT

### 2.1 INTRODUCTION

This CPU has a full 8-bit architecture and contains six internal registers allowing efficient 8-bit data manipulation.

### 2.2 MAIN FEATURES

- 63 basic instructions
- Fast 8-bit by 8-bit multiply
- 17 main addressing modes
- Two 8-bit index registers
- 16-bit stack pointer
- Low power modes
- Maskable hardware interrupts
- Non-maskable software interrupt

### 2.3 CPU REGISTERS

The 6 CPU registers shown in Figure 5 are not present in the memory mapping and are accessed by specific instructions.

#### Accumulator (A)

The Accumulator is an 8-bit general purpose register used to hold operands and the results of the arithmetic and logic calculations and to manipulate data.

#### Index Registers (X and Y)

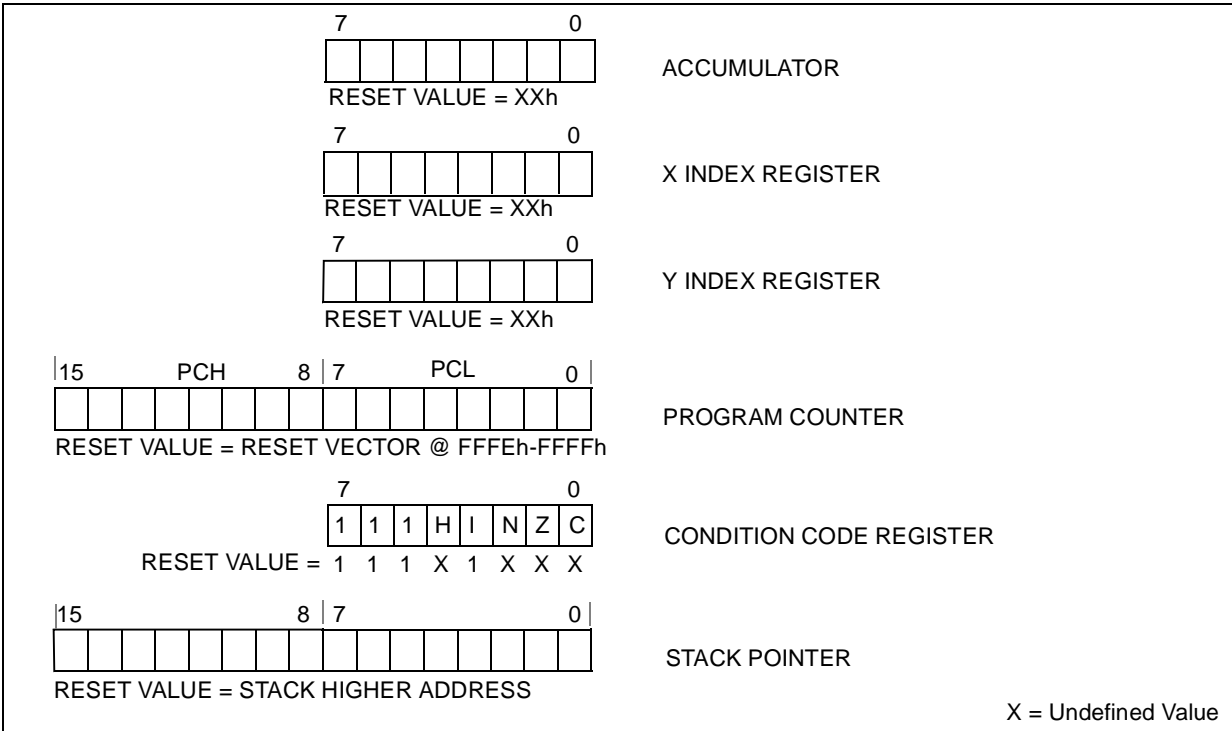
In indexed addressing modes, these 8-bit registers are used to create either effective addresses or temporary storage areas for data manipulation. (The Cross-Assembler generates a precede instruction (PRE) to indicate that the following instruction refers to the Y register.)

The Y register is not affected by the interrupt automatic procedures (not pushed to and popped from the stack).

#### Program Counter (PC)

The program counter is a 16-bit register containing the address of the next instruction to be executed by the CPU. It is made of two 8-bit registers PCL (Program Counter Low which is the LSB) and PCH (Program Counter High which is the MSB).

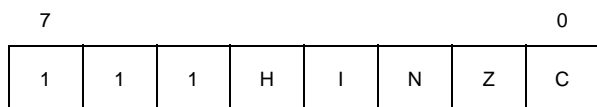
Figure 5. CPU Registers



**CPU REGISTERS (Cont'd)**  
**CONDITION CODE REGISTER (CC)**

Read/Write

Reset Value: 111x1xxx



The 8-bit Condition Code register contains the interrupt mask and four flags representative of the result of the instruction just executed. This register can also be handled by the PUSH and POP instructions.

These bits can be individually tested and/or controlled by specific instructions.

**Bit 4 = H Half carry.**

This bit is set by hardware when a carry occurs between bits 3 and 4 of the ALU during an ADD or ADC instruction. It is reset by hardware during the same instructions.

- 0: No half carry has occurred.
- 1: A half carry has occurred.

This bit is tested using the JRH or JRNH instruction. The H bit is useful in BCD arithmetic subroutines.

**Bit 3 = I Interrupt mask.**

This bit is set by hardware when entering in interrupt or by software to disable all interrupts except the TRAP software interrupt. This bit is cleared by software.

- 0: Interrupts are enabled.
- 1: Interrupts are disabled.

This bit is controlled by the RIM, SIM and IRET instructions and is tested by the JRM and JRNM instructions.

**Note:** Interrupts requested while I is set are latched and can be processed when I is cleared. By default an interrupt routine is not interruptable because the I bit is set by hardware when you

enter it and reset by the IRET instruction at the end of the interrupt routine. If the I bit is cleared by software in the interrupt routine, pending interrupts are serviced regardless of the priority level of the current interrupt routine.

**Bit 2 = N Negative.**

This bit is set and cleared by hardware. It is representative of the result sign of the last arithmetic, logical or data manipulation. It is a copy of the 7<sup>th</sup> bit of the result.

- 0: The result of the last operation is positive or null.
- 1: The result of the last operation is negative (i.e. the most significant bit is a logic 1).

This bit is accessed by the JRMI and JRPL instructions.

**Bit 1 = Z Zero.**

This bit is set and cleared by hardware. This bit indicates that the result of the last arithmetic, logical or data manipulation is zero.

- 0: The result of the last operation is different from zero.
- 1: The result of the last operation is zero.

This bit is accessed by the JREQ and JRNE test instructions.

**Bit 0 = C Carry/borrow.**

This bit is set and cleared by hardware and software. It indicates an overflow or an underflow has occurred during the last arithmetic operation.

- 0: No overflow or underflow has occurred.
- 1: An overflow or underflow has occurred.

This bit is driven by the SCF and RCF instructions and tested by the JRC and JRNC instructions. It is also affected by the "bit test and branch", shift and rotate instructions.





### 3 CLOCKS, RESET, INTERRUPTS & LOW POWER MODES

#### 3.1 CLOCK SYSTEM

##### 3.1.1 General Description

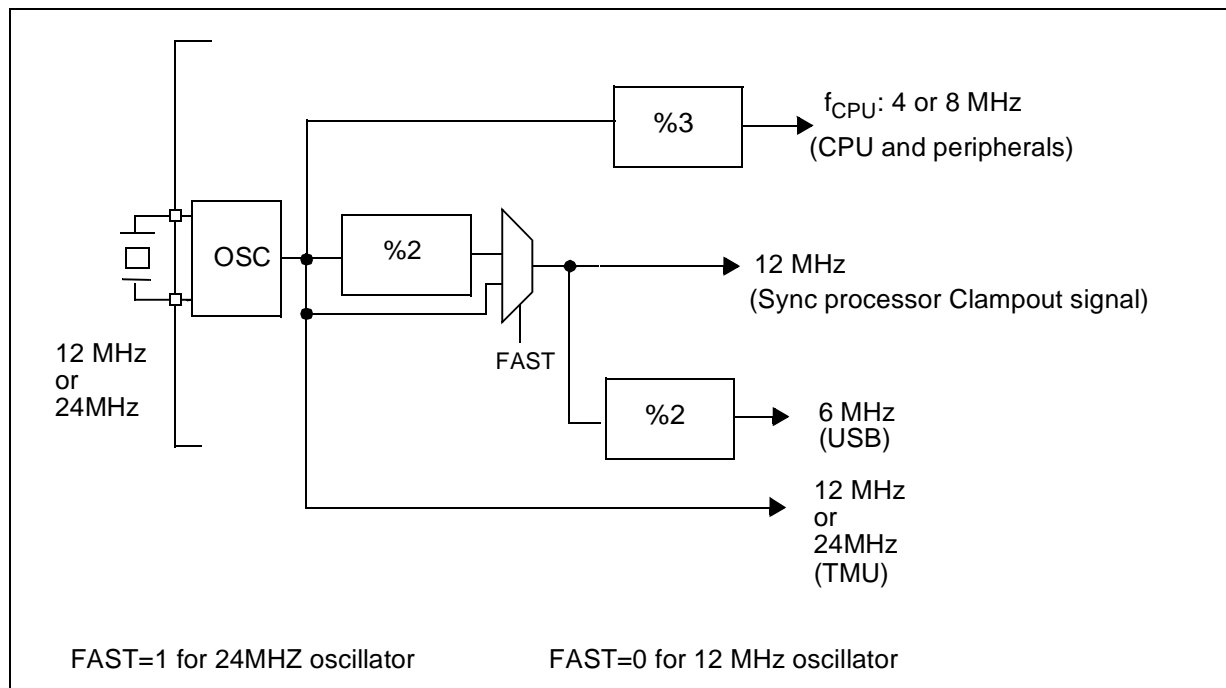
The MCU accepts either a crystal or an external clock signal to drive the internal oscillator. The internal clock (CPU CLK running at  $f_{CPU}$ ) is derived from the external oscillator frequency ( $f_{OSC}$ ), which is divided by 3. Depending on the external quartz or clock frequency, a division factor of 2 is optionally added to generate the 12 MHz clock for the Sync Processor (clamp function) as

shown in Figure 7 and a second divider by 2 for the 6MHz USB clock.

The CPU clock is used also as clock for the ST727x4 peripherals.

**Note:** In the Sync processor, an additional divider by two is added in fast mode (same external timing for this peripheral).

Figure 7. Clock divider chain

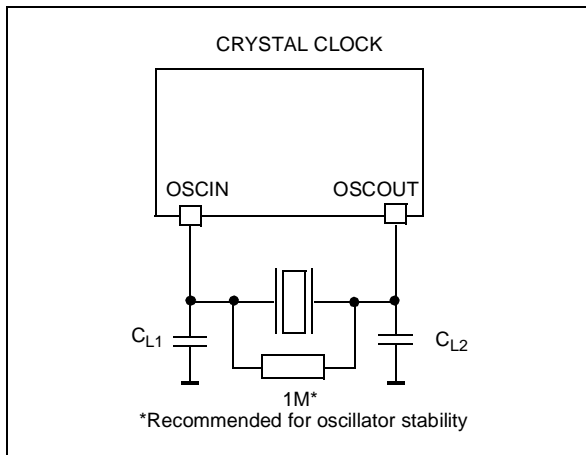


**CLOCK SYSTEM (Cont'd)**

**3.1.2 Crystal Resonator**

The internal oscillator is designed to operate with an AT-cut parallel resonant quartz crystal resonator in the frequency range specified for  $f_{OSC}$ . The circuit shown in Figure 8 is recommended when using a crystal, and Table 4, “. Recommended Crystal Values,” on page 19 lists the recommended capacitance and feedback resistance values. The crystal and associated components should be mounted as close as possible to the input pins in order to minimize output distortion and start-up stabilization time.

**Figure 8. Crystal/Ceramic Resonator**



**Table 4. Recommended Crystal Values**

| 24 Mhz     |    |    |    | Unit |
|------------|----|----|----|------|
| $R_{SMAX}$ | 70 | 25 | 20 | Ohms |
| $C_{L1}$   | 22 | 47 | 56 | pf   |
| $C_{L2}$   | 22 | 47 | 56 | pf   |

**Legend:**

$C_{L1}$ ,  $C_{L2}$  = Maximum total capacitance on pins OSCIN and OSCOUT (the value includes the external capacitance tied to the pin plus the parasitic capacitance of the board and of the device).

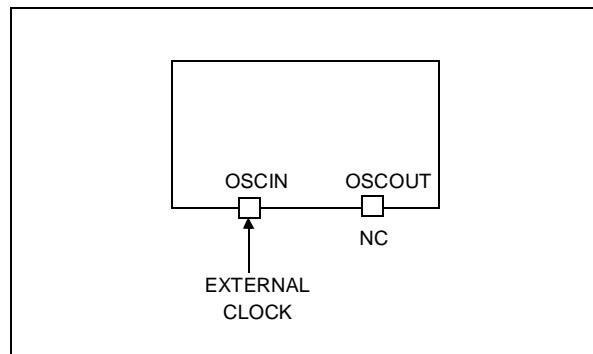
$R_{SMAX}$  = Maximum series parasitic resistance of the quartz allowed.

**Note:** The tables are relative to the quartz crystal only (not ceramic resonator).

**3.1.3 External Clock**

An external clock should be applied to the OSCIN input with the OSCOUT pin not connected as shown in Figure 9. The Crystal clock specifications do not apply when using an external clock input. The equivalent specification of the external clock source should be used.

**Figure 9. External Clock Source Connections**



### 3.2 RESET

The Reset procedure is used to provide an orderly software start-up or to quit low power modes.

Five conditions generate a reset:

- LVD,
- watchdog,
- external pulse at the  $\overline{\text{RESET}}$  pin,
- illegal address,
- illegal opcode.

A reset causes the reset vector to be fetched from addresses FFFEh and FFFFh in order to be loaded into the PC and with program execution starting from this point.

An internal circuitry provides a 4096 CPU clock cycle delay from the time that the oscillator becomes active.

#### 3.2.1 LVD and Watchdog Reset

The Low Voltage Detector (LVD) generates a reset when  $V_{DD}$  is below  $V_{TRH}$  when  $V_{DD}$  is rising or  $V_{TRL}$  when  $V_{DD}$  is falling (refer to Figure 11). This circuitry is active only when  $V_{DD}$  is above  $V_{TRM}$ .

During LVD Reset, the  $\overline{\text{RESET}}$  pin is held low, thus permitting the MCU to reset other devices.

When a watchdog reset occurs, the  $\overline{\text{RESET}}$  pin is pulled low permitting the MCU to reset other devices as when Power on/off (Figure 10).

#### 3.2.2 External Reset

The external reset is an active low input signal applied to the RESET pin of the MCU.

As shown in Figure 12, the  $\overline{\text{RESET}}$  signal must remain low for 1000ns.

An internal Schmitt trigger at the  $\overline{\text{RESET}}$  pin is provided to improve noise immunity.

#### 3.2.3 Illegal Address Detection

An opcode fetch from an illegal address (refer to Figure 3) generates an illegal address reset. Program execution at those addresses is forbidden (especially to protect page 0 registers against spurious accesses).

#### 3.2.4 Illegal Opcode Detection

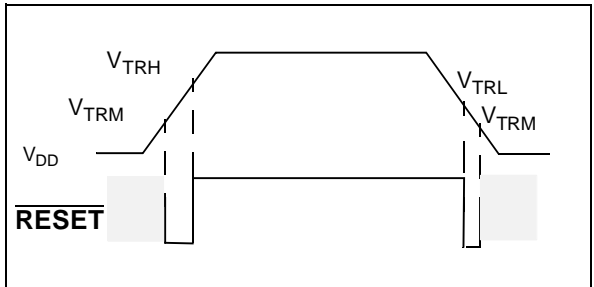
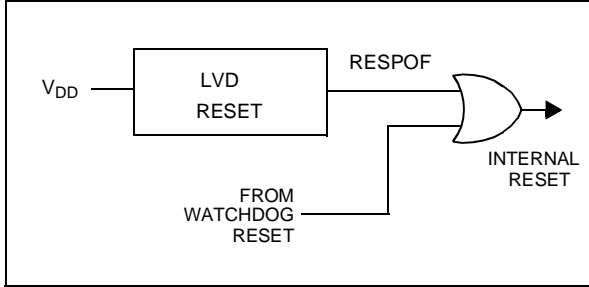
Illegal instructions corresponding to no valid opcode generate a reset. Refer to ST7 Programming Manual.

**Table 5. List of sections affected by RESET and WAIT (Refer to 3.6 for Wait Mode)**

| Section                                                                      | RESET | WAIT |
|------------------------------------------------------------------------------|-------|------|
| Fast bit of the miscellaneous register set to one (24 MHz as external clock) | X     |      |
| Timer Prescaler reset to zero                                                | X     |      |
| Timer Counter set to FFFCh                                                   | X     |      |
| All Timer enable bits set to 0 (disabled)                                    | X     |      |
| Data Direction Registers set to 0 (as Inputs)                                | X     |      |
| Set Stack Pointer to 01FFh                                                   | X     |      |
| Force Internal Address Bus to restart vector FFFEh, FFFFh                    | X     |      |
| Set Interrupt Mask Bit (I-Bit, CC) to 1 (Interrupt disable)                  | X     |      |
| Set Interrupt Mask Bit (I-Bit, CC) to 0 (Interrupt enable)                   |       | X    |
| Reset WAIT latch                                                             | X     |      |
| Disable Oscillator (for 4096 cycles)                                         | X     |      |
| Set Timer Clock to 0                                                         | X     |      |
| Watchdog counter reset                                                       | X     |      |
| Watchdog register reset                                                      | X     |      |
| Port data registers reset                                                    | X     |      |
| Other on-chip peripherals: registers reset                                   | X     |      |

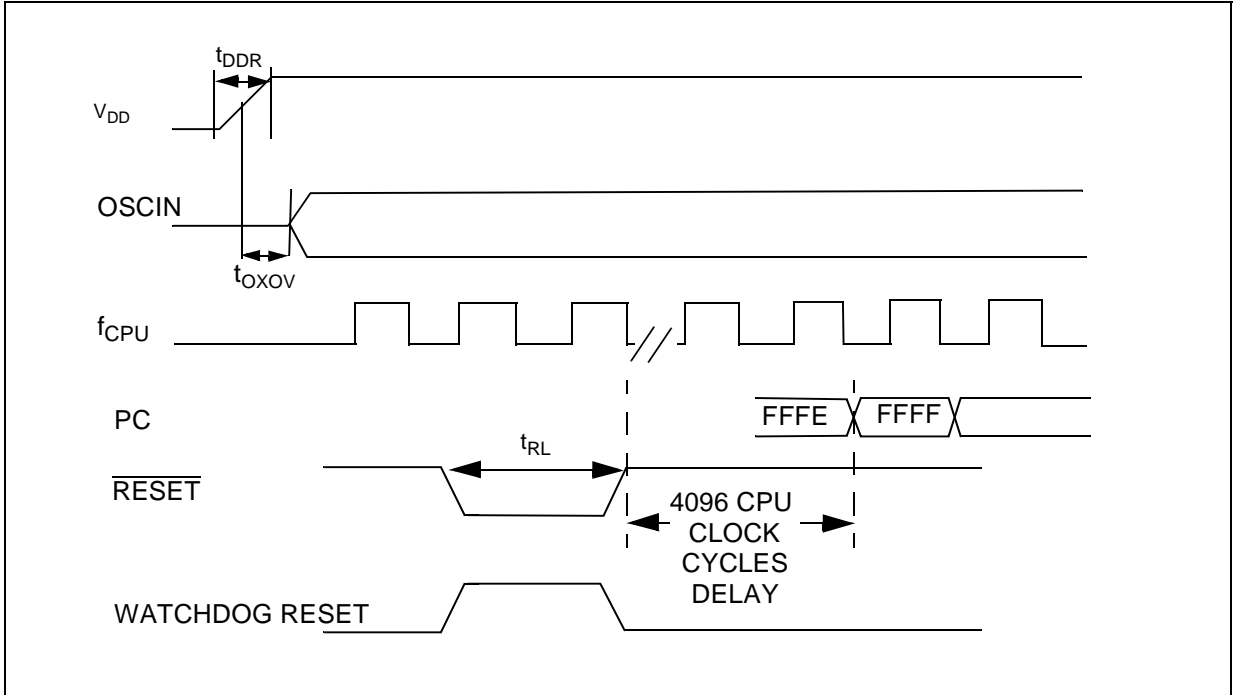
RESET (Cont'd)

Figure 10. Low Voltage Detector Functional Diagram Figure 11. LVD Reset Signal Output



Note: See electrical characteristics section for values of  $V_{TRH}$ ,  $V_{TRL}$  and  $V_{TRM}$

Figure 12. Reset Timing Diagram



Note: Refer to Electrical Characteristics for values of  $t_{DDR}$ ,  $t_{OXOV}$  and  $t_{RL}$

### 3.3 INTERRUPTS

The ST727x4 may be interrupted by one of two different methods: maskable hardware interrupts as listed in Table 6 and a non-maskable software interrupt (TRAP). The Interrupt processing flowchart is shown in Figure 13.

The maskable interrupts must be enabled in order to be serviced. However, disabled interrupts can be latched and processed when they are enabled. When an interrupt has to be serviced, the PC, X, A and CC registers are saved onto the stack and the interrupt mask (I bit of the Condition Code Register) is set to prevent additional interrupts. The Y register is not automatically saved.

The PC is then loaded with the interrupt vector of the interrupt to service and the interrupt service routine runs (refer to Table 6, "Interrupt Mapping," on page 24 for vector addresses). The interrupt service routine should finish with the IRET instruction which causes the contents of the registers to be recovered from the stack and normal processing to resume. Note that the I bit is then cleared if and only if the corresponding bit stored in the stack is zero.

Though many interrupts can be simultaneously pending, a priority order is defined (see Table 6, "Interrupt Mapping," on page 24). The RESET pin has the highest priority.

If the I bit is set, only the TRAP interrupt is enabled. All interrupts allow the processor to leave the WAIT low power mode.

**Software Interrupt.** The software interrupt is the executable instruction TRAP. The interrupt is recognized when the TRAP instruction is executed, regardless of the state of the I bit. When the interrupt is recognized, it is serviced according to the flowchart on Figure 13.

**ITA, ITB interrupts.** The ITA (PD3), ITB (PD4), pins can generate an interrupt when a falling edge occurs on these pins, if these interrupts are enabled with the ITAITE, ITBITE bits respectively in the miscellaneous register and the I bit of the CC register is reset. When an enabled interrupt occurs, normal processing is suspended at the end of the current instruction execution. It is then serviced according to the flowchart on Figure 13. Software in the ITA or ITB service routine must reset the cause of this interrupt by clearing the ITALAT, ITBLAT or ITAITE, ITBITE bits in the miscellaneous register.

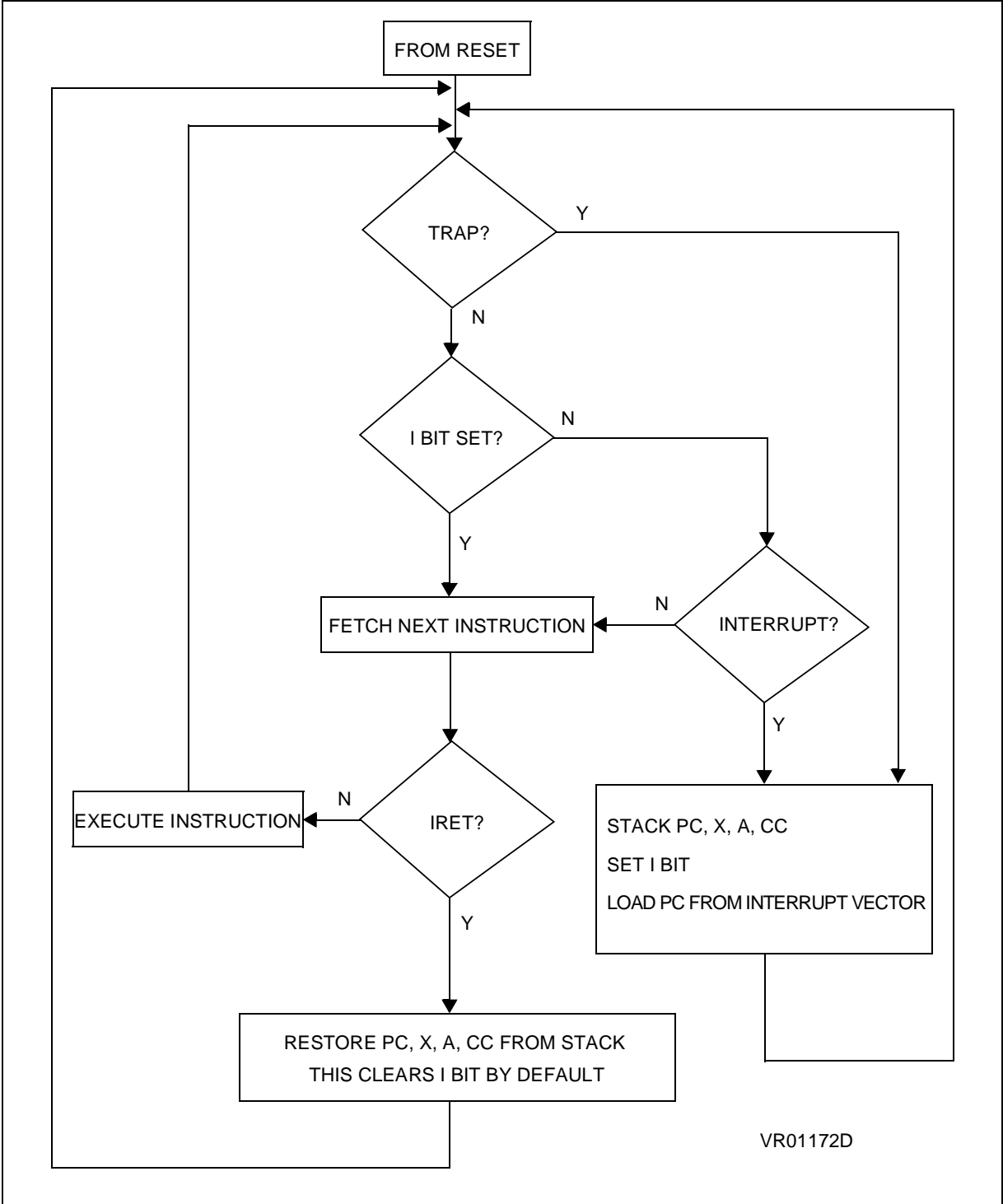
**Peripheral Interrupts.** Different peripheral interrupt flags are able to cause an interrupt when they are active if both the I bit of the CC register is reset and if the corresponding enable bit is set. If either of these conditions is false, the interrupt is latched and thus remains pending.

The interrupt flags are located in the status register. The Enable bits are in the control register. When an enabled interrupt occurs, normal processing is suspended at the end of the current instruction execution. It is then serviced according to the flowchart on Figure 13.

The general sequence for clearing an interrupt is an access to the status register while the flag is set followed by a read or write of an associated register. Note that the clearing sequence resets the internal latch. A pending interrupt (i.e. waiting for being enabled) will therefore be lost if the clear sequence is executed.

INTERRUPTS (Cont'd)


Figure 13. Interrupt Processing Flowchart



VR01172D

INTERRUPTS (Cont'd)

Table 6. Interrupt Mapping

| Source Block | Description               | Register Label   | Flag   | Maskable by I-bit | Vector Address | Priority Order                                                                                                             |
|--------------|---------------------------|------------------|--------|-------------------|----------------|----------------------------------------------------------------------------------------------------------------------------|
| RESET        | Reset                     | N/A              | N/A    | no                | FFFEh-FFFFh    | Highest Priority<br><br>Lowest Priority |
| TRAP         | Software                  | N/A              | N/A    | no                | FFFCh-FFFDh    |                                                                                                                            |
| USB          | End Suspend Interrupt     | USBISTR          | ESUSP  | yes               | FFFAh-FFFBh    |                                                                                                                            |
| DDC/CI       | DDC/CI Interrupt          | DDCSR1<br>DDCSR2 | **     | yes               | FFF8h-FFF9h    |                                                                                                                            |
| DDC1/2B      | DDC1/2B Interrupt         | DDCDCR           | EDF    | yes               | FFF6h-FFF7h    |                                                                                                                            |
| Port D bit 4 | External Interrupt ITB    | MISCR            | ITBLAT | yes               | FFF4h-FFF5h    |                                                                                                                            |
| Port D bit 3 | External Interrupt ITA    |                  | ITALAT | yes               | FFF2h-FFF3h    |                                                                                                                            |
| TIM          | Input Capture 1           | TIMSR            | ICF1   | yes               | FFF0h-FFF1h    |                                                                                                                            |
|              | Input Capture 2           |                  | ICF2   |                   |                |                                                                                                                            |
|              | Output Compare 1          |                  | OCF1   | yes               |                |                                                                                                                            |
|              | Output Compare 2          |                  | OCF2   |                   |                |                                                                                                                            |
|              | Timer Overflow            |                  | TOF    | yes               |                |                                                                                                                            |
| I2C          | I2C Peripheral Interrupts | I2CSR1<br>I2CSR2 | **     | yes               | FFEAh-FFEBh    |                                                                                                                            |
| USB          | USB Interrupt             | USBISTR          | **     | yes               | FFE6h-FFE7h    |                                                                                                                            |

\*\* Many flags can cause an interrupt, see peripheral interrupt status register description.



### 3.4 POWER SAVING MODES

#### 3.4.1 WAIT Mode

This mode is a low power consumption mode. The WFI instruction places the MCU in WAIT mode: The internal clock remains active but all CPU processing is stopped; however, all other peripherals are still running.

**Note:** In WAIT mode, DMA accesses (DDC, USB) are possible.

During WAIT mode, the I bit in the condition code register is cleared to enable all interrupts, which causes the MCU to exit WAIT mode, causes the corresponding interrupt vector to be fetched, the interrupt routine to be executed and normal processing to resume. A reset causes the program counter to fetch the reset vector and processing starts as for a normal reset.

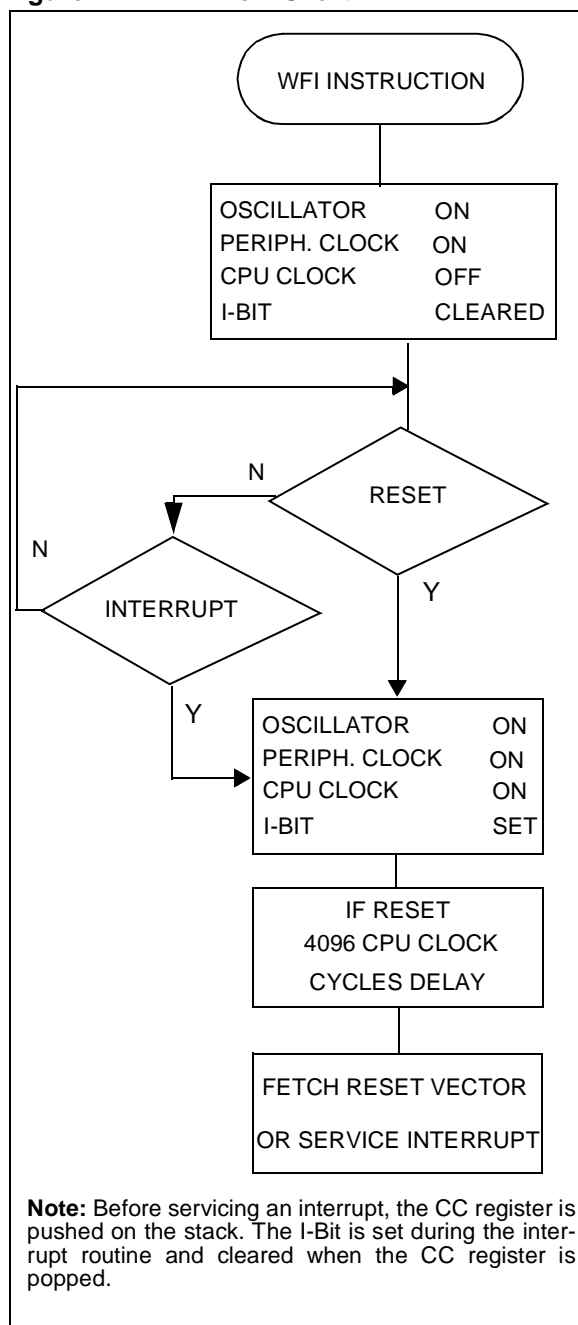
Table 5 gives a list of the different sections affected by the low power modes. For detailed information on a particular device, please refer to the corresponding part.

#### 3.4.2 HALT Mode

The HALT mode is the MCU lowest power consumption mode. Meanwhile, the HALT mode also stops the oscillator stage completely which is the most critical condition in CRT monitors.

For this reason, the HALT mode has been disabled and its associated HALT instruction is now considered as illegal and will generate a reset.

Figure 14. WAIT Flow Chart



3.5 MISCELLANEOUS REGISTER

MISCELLANEOUS REGISTER (MISCR)  
 Address: 0009h — Read/Write  
 Reset Value: 0001 0000 (10h)

|              |             |                |      |        |        |        |        |
|--------------|-------------|----------------|------|--------|--------|--------|--------|
| 7            |             |                |      |        |        |        | 0      |
| VSYNC<br>SEL | FLY_S<br>YN | HSYNC<br>DIVEN | FAST | ITBLAT | ITALAT | ITBITE | ITAITE |

Bit 7= **VSYNCESEL** DDC1 VSYNC Selection.

This bit is set and cleared by software. It is used to choose the VSYNC signal in DDC1 mode.

- 0: VSYNCI1 selected
- 1: VSYNCI2 selected

**Note:** VSYNCI 2 is only available for the DDC cell, not for the SYNC processor cell.

Bit 6= **FLY\_SYN** Flyback or Synchro Switch.

This bit is set and cleared by software. It is used to choose the signals the Timing Measurement Unit (TMU) will analyse.

- 0: horizontal and vertical synchro outputs analysis
- 1: horizontal and vertical Flyback inputs analysis

Bit 5= **HSYNCDIVEN** HSYNCDIV Enable.

This bit is set and cleared by software. It is used to enable the output of the HSYNCO output on PC0.

- 0: HSYNCDIV disabled
- 1: HSYNCDIV enabled

Bit 4= **FAST** Fast Mode.

This bit is set and cleared by software. It is used to select the external clock frequency. If the external clock frequency is 12 MHz, this bit must be at 0, else if the external frequency is 24 MHz, this bit must be at 1.

Bit 3= **ITBLAT** Falling Edge Detector Latch.

This bit is set by hardware when a falling edge occurs on pin ITB/PD4 in Port D. An interrupt is generated if ITBITE=1 and the I bit in the CC register = 0. It is cleared by software.

- 0: No falling edge detected on ITB
- 1: Falling edge detected on ITB

Bit 2= **ITALAT** Falling Edge Detector Latch.

This bit is set by hardware when a falling edge occurs on pin ITA/PD3 in Port D. An interrupt is generated if ITAITE=1 and the I bit in the CC register = 0. It is cleared by software.

- 0: No falling edge detected on ITA
- 1: Falling edge detected on ITA

Bit 1= **ITBITE** ITB Interrupt Enable.

This bit is set and cleared by software.

- 0: ITB interrupt disabled
- 1: ITB interrupt enabled

Bit 0= **ITAITE** ITA Interrupt Enable.

This bit is set and cleared by software.

- 0: ITA interrupt disabled
- 1: ITA interrupt enabled

### 4 ON-CHIP PERIPHERALS

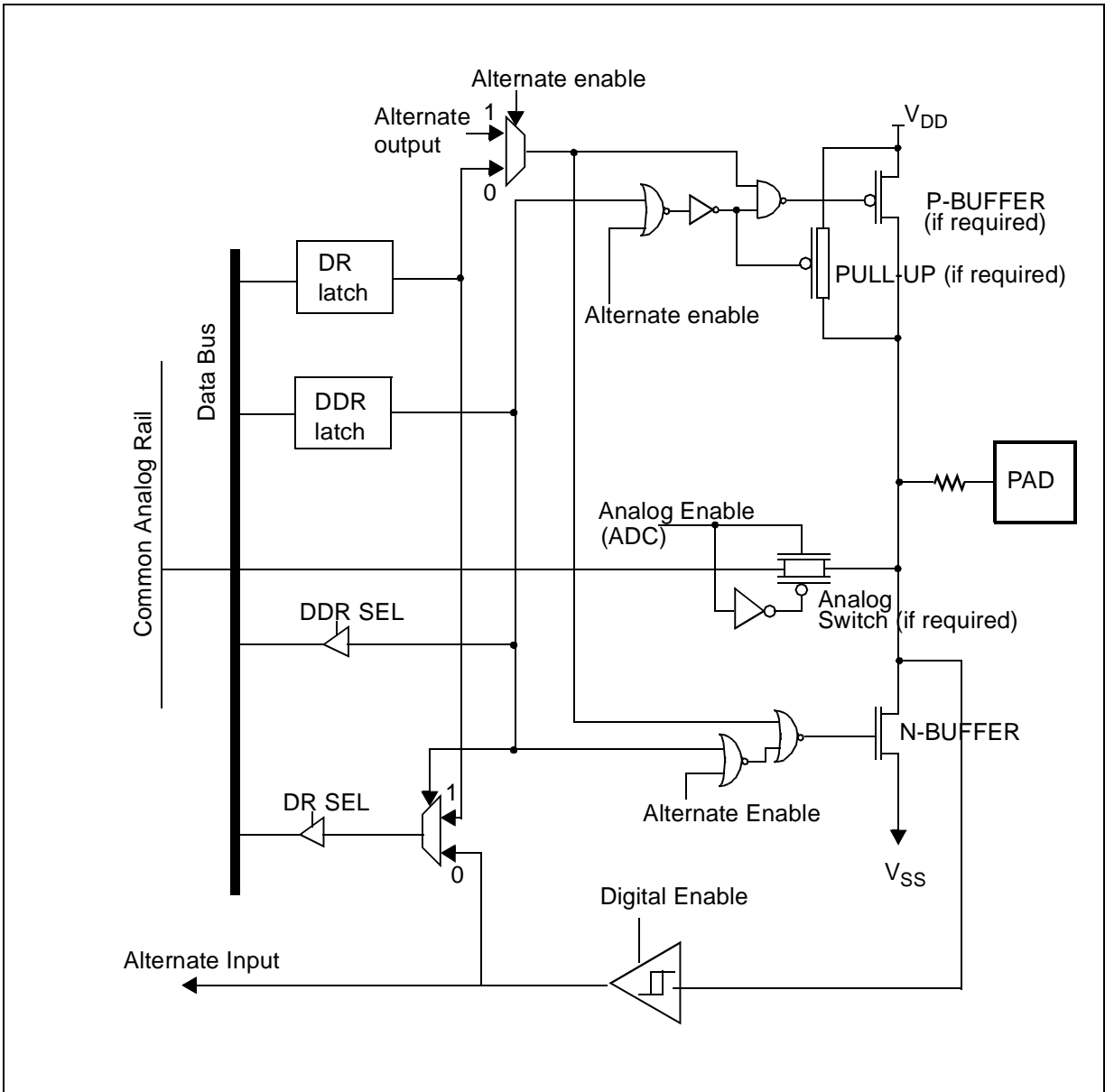
#### 4.1 I/O PORTS

##### 4.1.1 Introduction

The I/O ports allow the transfer of data through digital inputs and outputs, and, for specific pins, the input of analog signals or the Input/Output of alternate signals for on-chip peripherals (DDC, TIMER...).

Each pin can be programmed independently as digital input or digital output. Each pin can be an analog input when an analog switch is connected to the Analog to Digital Converter (ADC).

Figure 15. I/O Pin Typical Circuit



**Note:** This is the typical I/O pin configuration. For cost optimization, each port is customized with a specific configuration.

I/O PORTS (Cont'd)

Table 7. I/O Pin Functions

| DDR | MODE   |
|-----|--------|
| 0   | Input  |
| 1   | Output |

**4.1.2 Common Functional Description**

Each port pin of the I/O Ports can be individually configured under software control as either input or output.

Each bit of a Data Direction Register (DDR) corresponds to an I/O pin of the associated port. This corresponding bit must be set to configure its associated pin as output and must be cleared to configure its associated pin as input (Table 7, “I/O Pin Functions,” on page 28). The Data Direction Registers can be read and written.

The typical I/O circuit is shown on Figure 15. Any write to an I/O port updates the port data register even if it is configured as input. Any read of an I/O port returns either the data latched in the port data register (pins configured as output) or the value of the I/O pins (pins configured as input).

**Remark:** when an I/O pin does not exist inside an I/O port, the returned value is a logic one (pin configured as input).

At reset, all DDR registers are cleared, which configures all port’s I/Os as inputs with or without pull-ups (see Table 8 to Table 12 I/O Ports Register Map). The Data Registers (DR) are also initialized at reset.

**4.1.2.1 Input mode**

When DDR=0, the corresponding I/O is configured in Input mode.

In this case, the output buffer is switched off, the state of the I/O is readable through the Data Register address, but the I/O state comes directly

from the CMOS Schmitt Trigger output and not from the Data Register output.

**4.1.2.2 Output mode**

When DDR=1, the corresponding I/O is configured in Output mode.

In this case, the output buffer is activated according to the Data Register’s content.

A read operation is directly performed from the Data Register output.

**4.1.2.3 Analog input**

Each I/O can be used as analog input by adding an analog switch driven by the ADC.

The I/O must be configured in Input before using it as analog input.

The CMOS Schmitt trigger is OFF and the analog value directly input through an analog switch to the Analog to Digital Converter, when the analog channel is selected by the ADC.

**4.1.2.4 Alternate mode**

A signal coming from a on-chip peripheral can be output on the I/O.

In this case, the I/O is automatically configured in output mode.

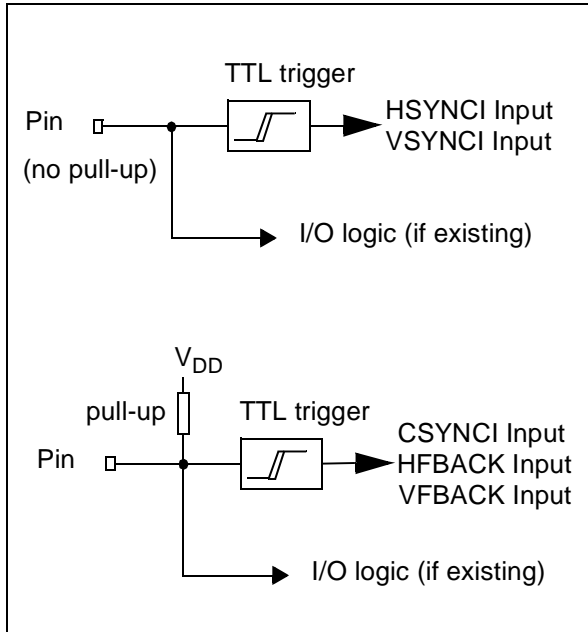
This must be controlled directly by the peripheral with a signal coming from the peripheral which enables the alternate signal to be output.

A signal coming from an I/O can be input in a on-chip peripheral.

Before using an I/O as Alternate Input, it must be configured in Input mode (DDR=0). So both Alternate Input configuration and I/O Input configuration are the same (with or without pull-up). The signal to be input in the peripheral is taken after the CMOS Schmitt trigger or TTL Schmitt trigger for SYNC.

The I/O state is readable as in Input mode by addressing the corresponding I/O Data Register.

**Figure 16. Input Structure for SYNC signals**



PA [6:3] can be defined as Input lines (without pull-up) or as Output Open drain lines.

PA7 and PA[2:0] can be defined as Input lines (with pull-up) or as Push-pull Outputs.

PA [6:3] can be defined as Input lines (without pull-up) or as Output Open drain lines.

**4.1.3 Port A**

PA7 and PA[2:0] can be defined as Input lines (with pull-up) or as Push-pull Outputs.

**Table 8. Port A Description**

| PORT A | I / O           |            | Alternate Function |                          |
|--------|-----------------|------------|--------------------|--------------------------|
|        | Input*          | Output     | Signal             | Condition                |
| PA0    | With pull-up    | push-pull  | OCMP1              | OC1E =1<br>(CR2[TIMER])  |
| PA1    | With pull-up    | push-pull  | -                  | -                        |
| PA2    | With pull-up    | push-pull  | VSYNCI2            | VSYNCSEL=1<br>(MISCR)    |
| PA3    | Without pull-up | open-drain | -                  | -                        |
| PA4    | Without pull-up | open-drain | -                  | -                        |
| PA5    | Without pull-up | open-drain | -                  | -                        |
| PA6    | Without pull-up | open-drain | -                  | -                        |
| PA7    | With pull-up    | push-pull  | BLANKOUT           | BLKEN = 1<br>(ENR[SYNC]) |

\*Reset State

I/O PORTS (Cont'd)

Figure 17. PA0 to PA2, PA7

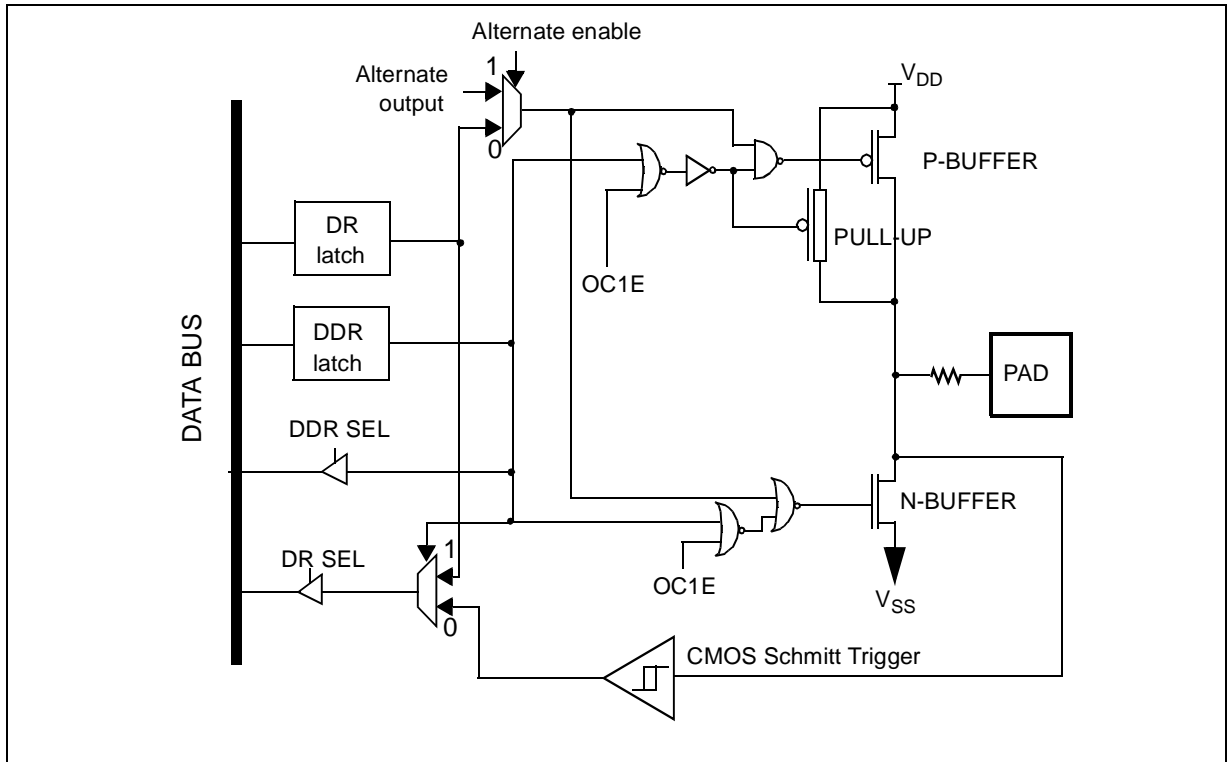
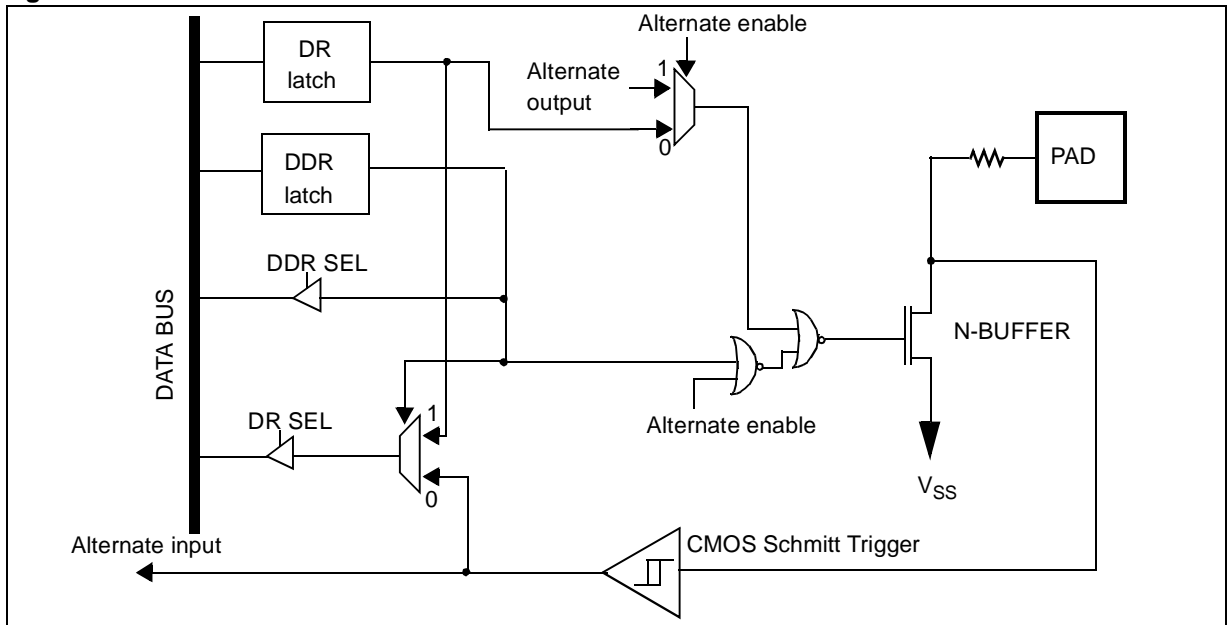


Figure 18. PA3 to PA6



**I/O PORTS** (Cont'd)**4.1.4 Port B**

The alternate functions are the I/O pins of the on-chip DDC SCLD & SCDAD for PB0:1, the I/O pins of the on-chip I2C SCLI & SDAI for PB2:3, and 4 bits of port B bit can be used as the Analog source to the Analog to Digital Converter.

Only one I/O line must be configured as an analog input at any time. The user must avoid any situation in which more than one I/O pin is selected as an analog input simultaneously to avoid device malfunction.

When the analog function is selected for an I/O pin, the pull-up of the respective pin of Port B is disconnected and the digital input is off.

All unused I/O lines should be tied to an appropriate logic level (either  $V_{DD}$  or  $V_{SS}$ )

Since the ADC is on the same chip as the microprocessor, the user should not switch heavily loaded signals during conversion, if high precision is required. Such switching will affect the supply voltages used as analog references. The accuracy of the conversion depends on the quality of the power supplies ( $V_{DD}$  and  $V_{SS}$ ). The user must take special care to ensure that a well regulated reference voltage is present on the  $V_{DD}$  and  $V_{SS}$  pins (power supply variations must be less than 5V/ms). This implies, in particular, that a suitable decoupling capacitor is used at the  $V_{DD}$  pin.

**Table 9. Port B Description**

| PORT B | I/O             |            | Alternate Function                                          |                      |
|--------|-----------------|------------|-------------------------------------------------------------|----------------------|
|        | Input*          | Output     | Signal                                                      | Condition            |
| PB0    | Without pull-up | Open-drain | SCLD (input with CMOS schmitt trigger or open drain output) | DDC enable           |
| PB1    | Without pull-up | Open-drain | SDAD (input with CMOS schmitt trigger or open drain output) | DDC enable           |
| PB2    | Without pull-up | Open-drain | SCLI (input with CMOS schmitt trigger or open drain output) | I2C enable           |
| PB3    | Without pull-up | Open-drain | SDAI (input with CMOS schmitt trigger or open drain output) | I2C enable           |
| PB4    | With pull-up    | Push-pull  | Analog input (ADC) (without pull-up)                        | CH[2:0]=000 (ADCCSR) |
| PB5    | With pull-up    | Push-pull  | Analog input (ADC) (without pull-up)                        | CH[2:0]=001 (ADCCSR) |
| PB6    | With pull-up    | Push-pull  | Analog input (ADC) (without pull-up)                        | CH[2:0]=010 (ADCCSR) |
|        |                 |            | 10-bit output 1 (PWM)                                       | OE0=1 (PWMOE)        |
| PB7    | With pull-up    | Push-pull  | Analog input (ADC) (without pull-up)                        | CH[2:0]=011 (ADCCSR) |
|        |                 |            | 10-bit output 2 (PWM)                                       | OE1=1 (PWMOE)        |

\*Reset state

I/O PORTS (Cont'd)

Figure 19. PB0 to PB3

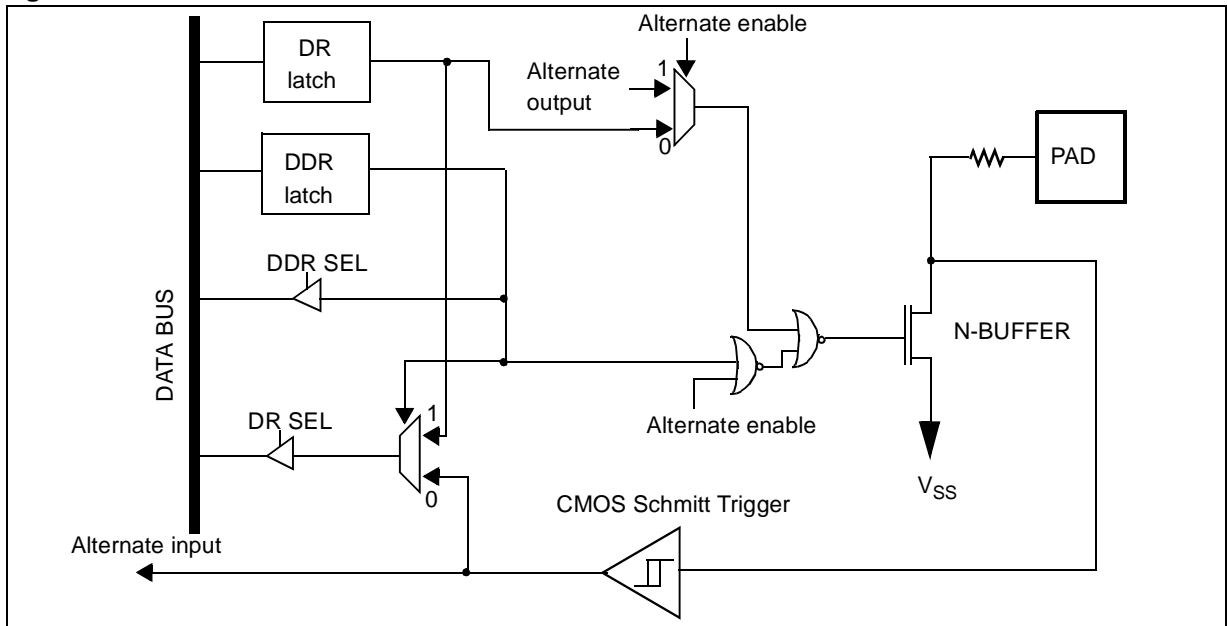
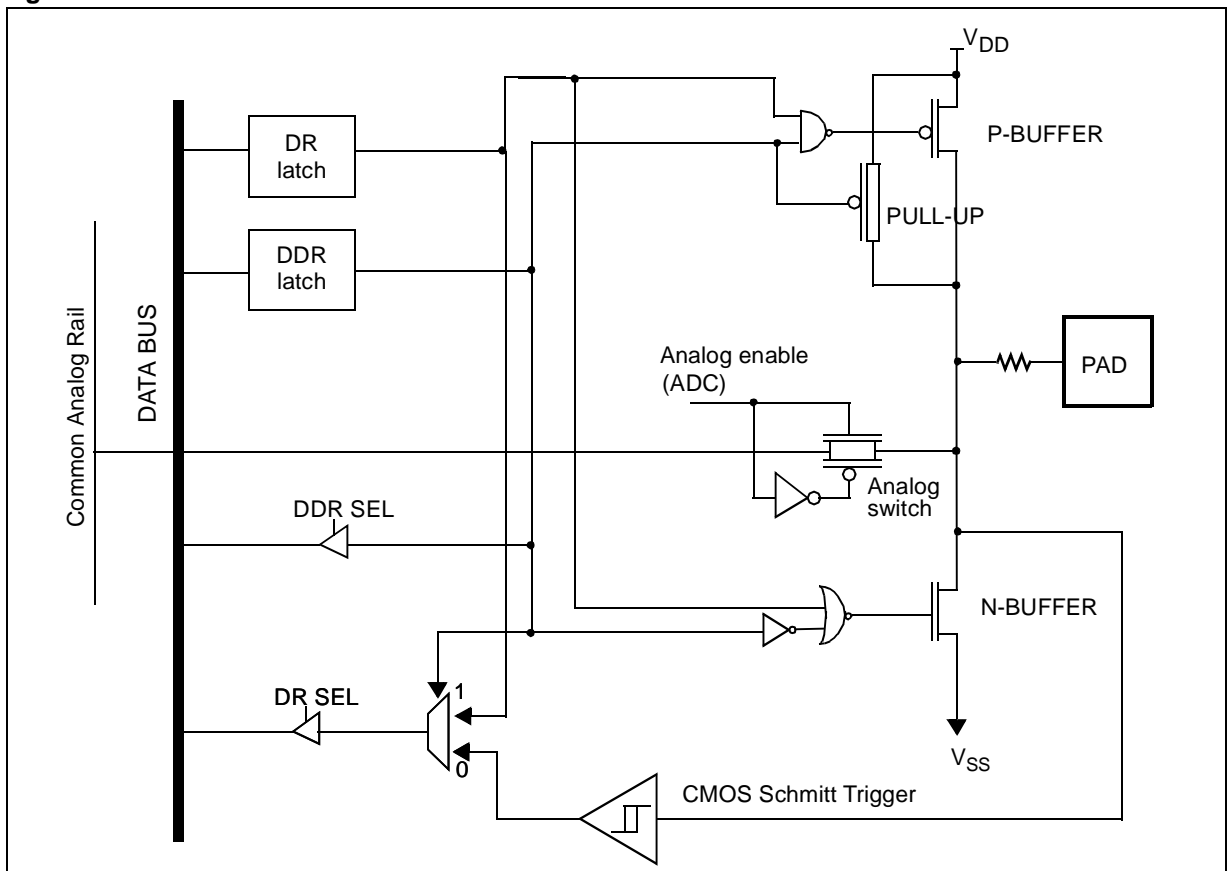


Figure 20. PB4 to PB7





**I/O PORTS** (Cont'd)**4.1.5 Port C**

The available port pins of port C may be used as general purpose I/O.

The alternate functions are the PWM outputs for PC2:7, HSYNCDIV (HSYNCO divided by 2) for PC0 and the TMU input for PC1.

**Table 10. Port C Description**

| PORT C | I/O          |           | Alternate Function            |                      |
|--------|--------------|-----------|-------------------------------|----------------------|
|        | Input*       | Output    | Signal                        | Condition            |
| PC0    | With pull-up | Push-pull | HSYNCDIV (push-pull)          | HSYNCDIVEN=1 (MISCR) |
| PC1    | With pull-up | Push-pull | AV (active video) input (TMU) | -                    |
| PC2    | With pull-up | Push-pull | 10-bit output 3 (PWM)         | OE2=1 (PWMOE)        |
| PC3    | With pull-up | Push-pull | 10-bit output 4 (PWM)         | OE3=1 (PWMOE)        |
| PC4    | With pull-up | Push-pull | 10-bit output 5 (PWM)         | OE4=1 (PWMOE)        |
| PC5    | With pull-up | Push-pull | 10-bit output 6 (PWM)         | OE5=1 (PWMOE)        |
| PC6    | With pull-up | Push-pull | 10-bit output 7 (PWM)         | OE6=1 (PWMOE)        |
| PC7    | With pull-up | Push-pull | 10-bit output 8 (PWM)         | OE7=1 (PWMOE)        |

\* Reset State

I/O PORTS (Cont'd)

Figure 21. PC0, PC2 to PC7

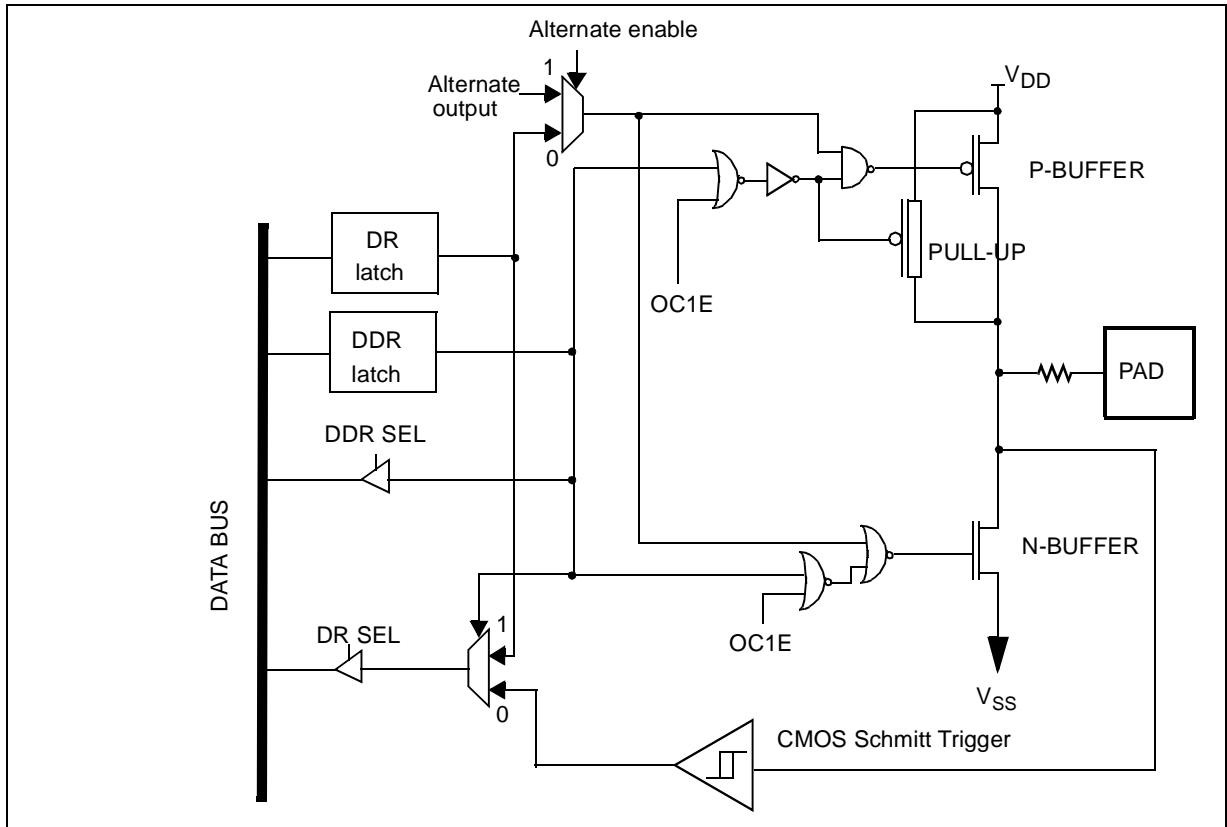
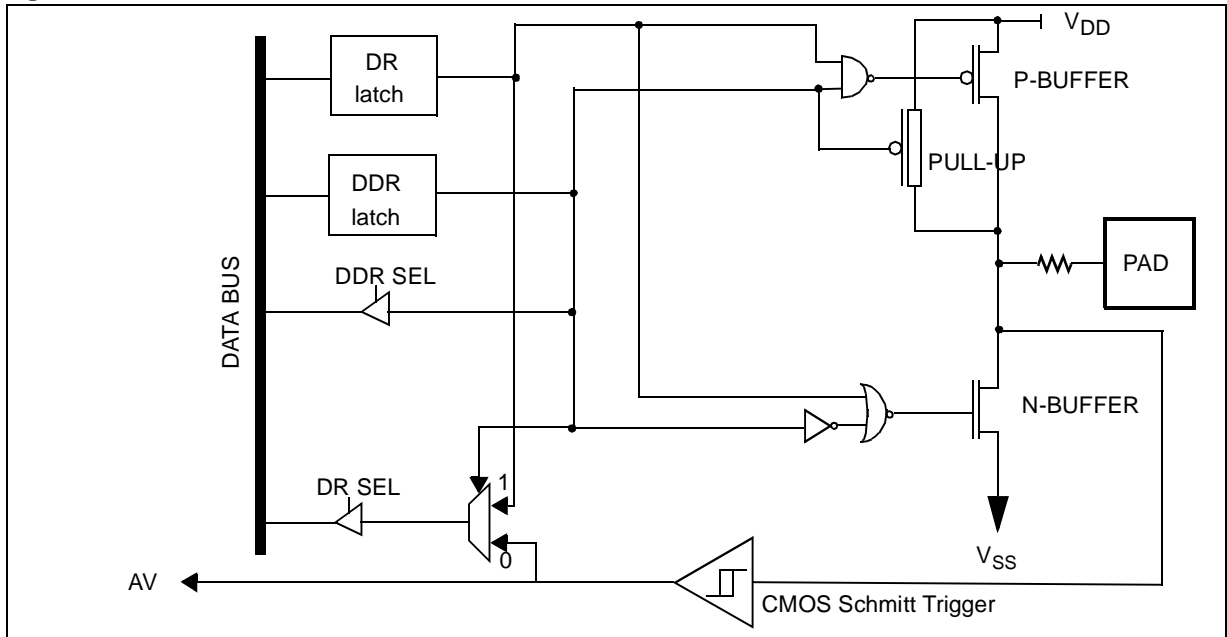


Figure 22. PC1



**I/O PORTS** (Cont'd)**4.1.6 Port D**

The Port D I/O pins are normally used for the input and output of video synchronization signals of the Sync Processor, but are set to I/O Input with pull-up upon reset. The I/O mode can be set individually for each port bit to Input with pull-up and output push-pull through the Port D DDR.

The configuration to support the Sync Processor requires that the SYNOP (bit7) and CLMPEN (bit6) of the ENR (Enable Register of SYNC) is reset. SYNOP enables port D bits 0,1 and CLMPEN enables Port D bit 6 to the sync outputs.

Port D, bit 4:3 are the alternate inputs ITA, ITB, (for the interrupt falling edge detector).

When a falling edge occurs on these inputs, an interrupt will be generated depending on the status of the INTX (ITAITE & ITBITE) bits in the MISCR Register.

Port D, bit 6 is switched to the alternate (CLAMPOUT) by resetting the CLMPEN bit of the ENR Register inside SYNC block.

If the SYNC function is selected, Port D bit 5 and 3 MUST be set as input to enable the HFBACK or VFBACK timing inputs.

**Note:** As these inputs are switched from normal I/O functionality, the video synchronization signals may also be monitored directly through the Port D Data Register for such tasks as checking for the presence of video signals or checking the polarity of Horizontal and Vertical synchronization signals (when the Sync Inputs are switched directly to the outputs using the multiplexers of the Sync Processor).

**Table 11. Port D Description**

| PORT D | I / O        |           | Alternate Function                                |                          |
|--------|--------------|-----------|---------------------------------------------------|--------------------------|
|        | Input*       | Output    | Signal                                            | Condition                |
| PD0    | With pull-up | Push-pull | VSYNCO<br>(push pull output)                      | SYNOP=0<br>(ENR [SYNC])  |
| PD1    | With pull-up | Push-pull | HSYNCO<br>(push pull output)                      | SYNOP=0<br>(ENR [SYNC])  |
| PD2    | With pull-up | Push-pull | CSYNCI (input with TTL Schmitt trigger & pull-up) | -                        |
| PD3    | With pull-up | Push-pull | ITA (input with CMOS Schmitt trigger & pull-up)   | -                        |
|        |              |           | VFBACK (input with TTL Schmitt trigger & pull-up) | -                        |
| PD4    | With pull-up | Push-pull | ITB (input with CMOS Schmitt trigger & pull-up)   | -                        |
| PD5    | With pull-up | Push-pull | HFBACK (input with TTL Schmitt trigger & pull-up) | -                        |
| PD6    | With pull-up | Push-pull | CLAMPOUT<br>(push pull output)                    | CLMPEN=0<br>(ENR [SYNC]) |

\* Reset state

I/O PORTS (Cont'd)

Figure 23. PD2 to PD5

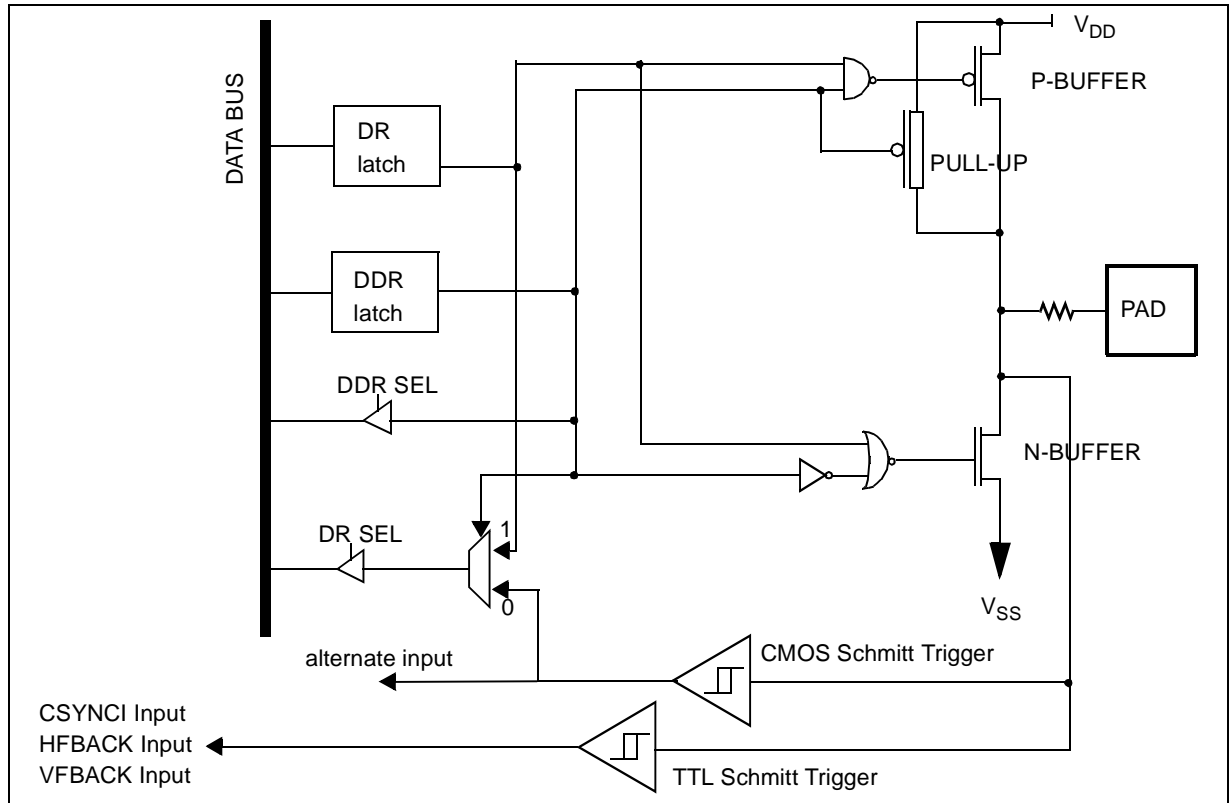
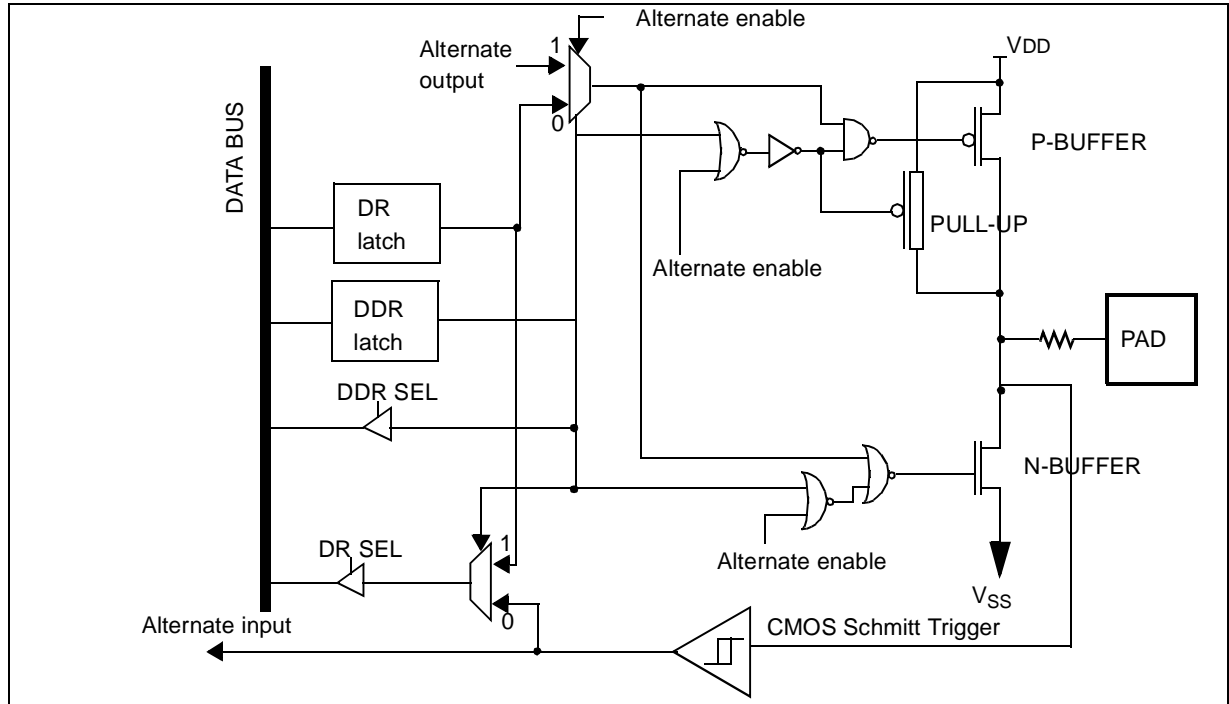
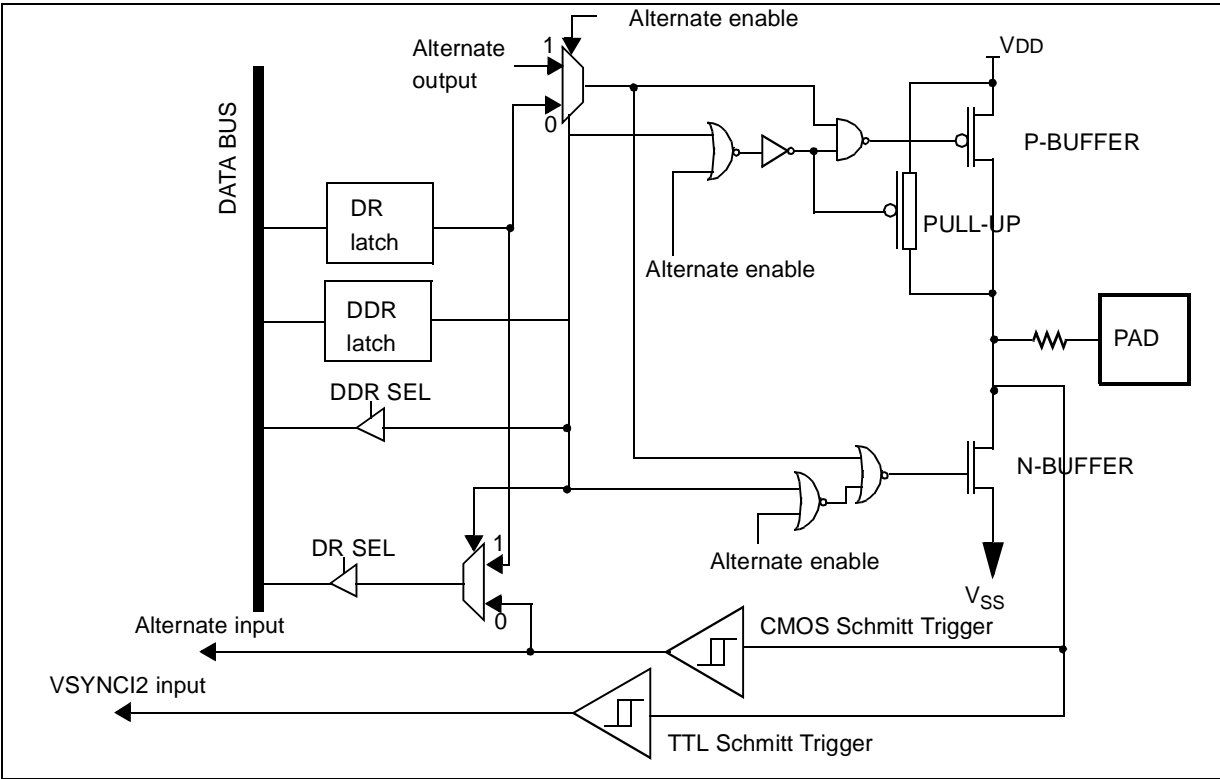


Figure 24. PD0 to PD1



I/O PORTS (Cont'd)

Figure 25. PD6

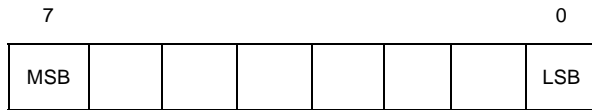


**ST72774/ST727754/ST72734**

**I/O PORTS (Cont'd)**

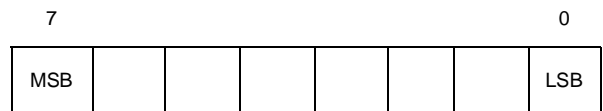
**4.1.7 Register Description**  
**Data Registers (PxDR)**

Read/Write  
 Reset Value: 0000 0000 (00h)



**Data Direction Registers (PxDDR)**

Read/Write  
 Reset Value: 0000 0000 (00h) (as inputs)



**Table 12. I/O Ports Register Map**

| Address (Hex.) | Register Name | 7   | 6 | 5 | 4 | 3 | 2 | 1 | 0   |
|----------------|---------------|-----|---|---|---|---|---|---|-----|
| 00             | PADR          | MSB |   |   |   |   |   |   | LSB |
| 01             | PADDR         | MSB |   |   |   |   |   |   | LSB |
| 02             | PBDR          | MSB |   |   |   |   |   |   | LSB |
| 03             | PBDDR         | MSB |   |   |   |   |   |   | LSB |
| 04             | PCDR          | MSB |   |   |   |   |   |   | LSB |
| 05             | PCDDR         | MSB |   |   |   |   |   |   | LSB |
| 06             | PDDR          | MSB |   |   |   |   |   |   | LSB |
| 07             | PDDDR         | MSB |   |   |   |   |   |   | LSB |

## 4.2 WATCHDOG TIMER (WDG)

### 4.2.1 Introduction

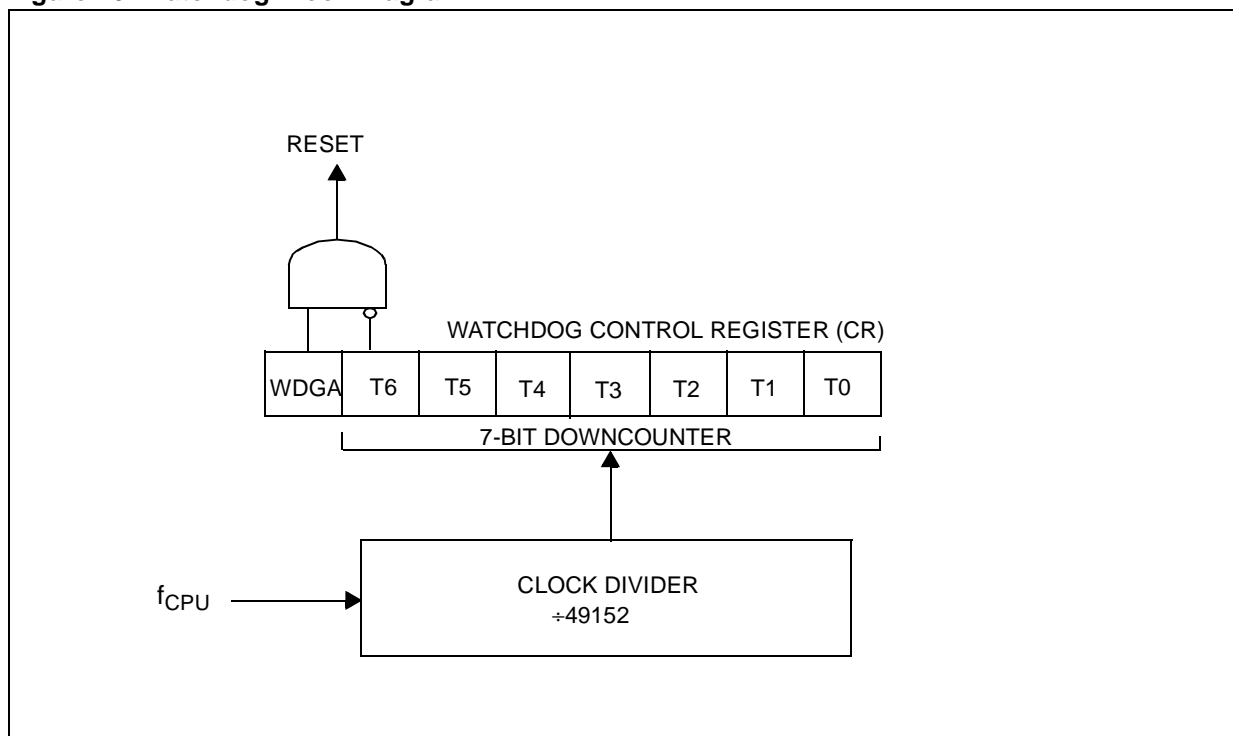
The Watchdog timer is used to detect the occurrence of a software fault, usually generated by external interference or by unforeseen logical conditions, which causes the application program to abandon its normal sequence. The Watchdog circuit generates an MCU reset on expiry of a programmed time period, unless the program

refreshes the counter's contents before the T6 bit becomes cleared.

### 4.2.2 Main Features

- Programmable timer (64 increments of 49152 CPU cycles)
- Programmable reset
- Reset (if watchdog activated) when the T6 bit reaches zero

Figure 26. Watchdog Block Diagram



### 4.2.3 Functional Description

The counter value stored in the CR register (bits T6:T0), is decremented every 49,152 machine cycles, and the length of the timeout period can be programmed by the user in 64 increments.

If the watchdog is activated (the WDGA bit is set) and when the 7-bit timer (bits T6:T0) rolls over from 40h to 3Fh (T6 becomes cleared), it initiates a reset cycle pulling low the reset pin for typically 500ns.

The application program must write in the CR register at regular intervals during normal

operation to prevent an MCU reset. The value to be stored in the CR register must be between FFh and C0h (see Table 13 . Watchdog Timing ( $f_{CPU} = 8$  MHz)):

- The WDGA bit is set (watchdog enabled)
- The T6 bit is set to prevent generating an immediate reset
- The T5:T0 bits contain the number of increments which represents the time delay before the watchdog produces a reset.

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**Table 13. Watchdog Timing ( $f_{CPU} = 8\text{ MHz}$ )**

|     | CR Register initial value | WDG timeout period (ms) |
|-----|---------------------------|-------------------------|
| Max | FFh                       | 393.216                 |
| Min | C0h                       | 6.144                   |

**Notes:** Following a reset, the watchdog is disabled. Once activated it cannot be disabled, except by a reset.

The T6 bit can be used to generate a software reset (the WDGA bit is set and the T6 bit is cleared).

### 4.2.4 Interrupts

None.

### 4.2.5 Register Description CONTROL REGISTER (CR)

Read/Write

Reset Value: 0111 1111 (7Fh)

|      |    |    |    |    |    |    |    |
|------|----|----|----|----|----|----|----|
| 7    |    |    |    |    |    |    | 0  |
| WDGA | T6 | T5 | T4 | T3 | T2 | T1 | T0 |

Bit 7 = **WDGA** Activation bit.

This bit is set by software and only cleared by hardware after a reset. When WDGA = 1, the watchdog can generate a reset.

0: Watchdog disabled

1: Watchdog enabled

Bit 6:0 = **T[6:0]** 7-bit timer (MSB to LSB).

These bits contain the decremented value. A reset is produced when it rolls over from 40h to 3Fh (T6 becomes cleared).

**Table 14. Watchdog Timer Register Map and Reset Values**

| Address (Hex.) | Register Label | 7    | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----------------|----------------|------|----|----|----|----|----|----|----|
| 08             | <b>WDGCR</b>   | WDGA | T6 | T5 | T4 | T3 | T2 | T1 | T0 |
|                | Reset Value    | 0    | 1  | 1  | 1  | 1  | 1  | 1  | 1  |



### 4.3 16-BIT TIMER (TIM)

#### 4.3.1 Introduction

The timer consists of a 16-bit free-running counter driven by a programmable prescaler.

It may be used for a variety of purposes, including pulse length measurement of up to two input signals (*input capture*) or generation of up to two output waveforms (*output compare* and *PWM*).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the CPU clock prescaler.

#### 4.3.2 Main Features

- Programmable prescaler:  $f_{\text{CPU}}$  divided by 2, 4 or 8.
- Overflow status flag and maskable interrupt
- External clock input (must be at least 4 times slower than the CPU clock speed) with the choice of active edge
- Output compare functions with
  - 2 dedicated 16-bit registers
  - 2 dedicated programmable signals
  - 2 dedicated status flags
  - 1 dedicated maskable interrupt
- Input capture functions with
  - 2 dedicated 16-bit registers
  - 2 dedicated active edge selection signals
  - 2 dedicated status flags
  - 1 dedicated maskable interrupt
- Pulse width modulation mode (PWM)
- One pulse mode
- 5 alternate functions on I/O ports\*

The Block Diagram is shown in Figure 27.

**Note:** Some external pins are not available on all devices. Refer to the device pin out description.

#### 4.3.3 Functional Description

##### 4.3.3.1 Counter

The principal block of the Programmable Timer is a 16-bit free running counter and its associated 16-bit registers:

Counter Registers

- Counter High Register (CHR) is the most significant byte (MSB).
- Counter Low Register (CLR) is the least significant byte (LSB).

Alternate Counter Registers

- Alternate Counter High Register (ACHR) is the most significant byte (MSB).
- Alternate Counter Low Register (ACLR) is the least significant byte (LSB).

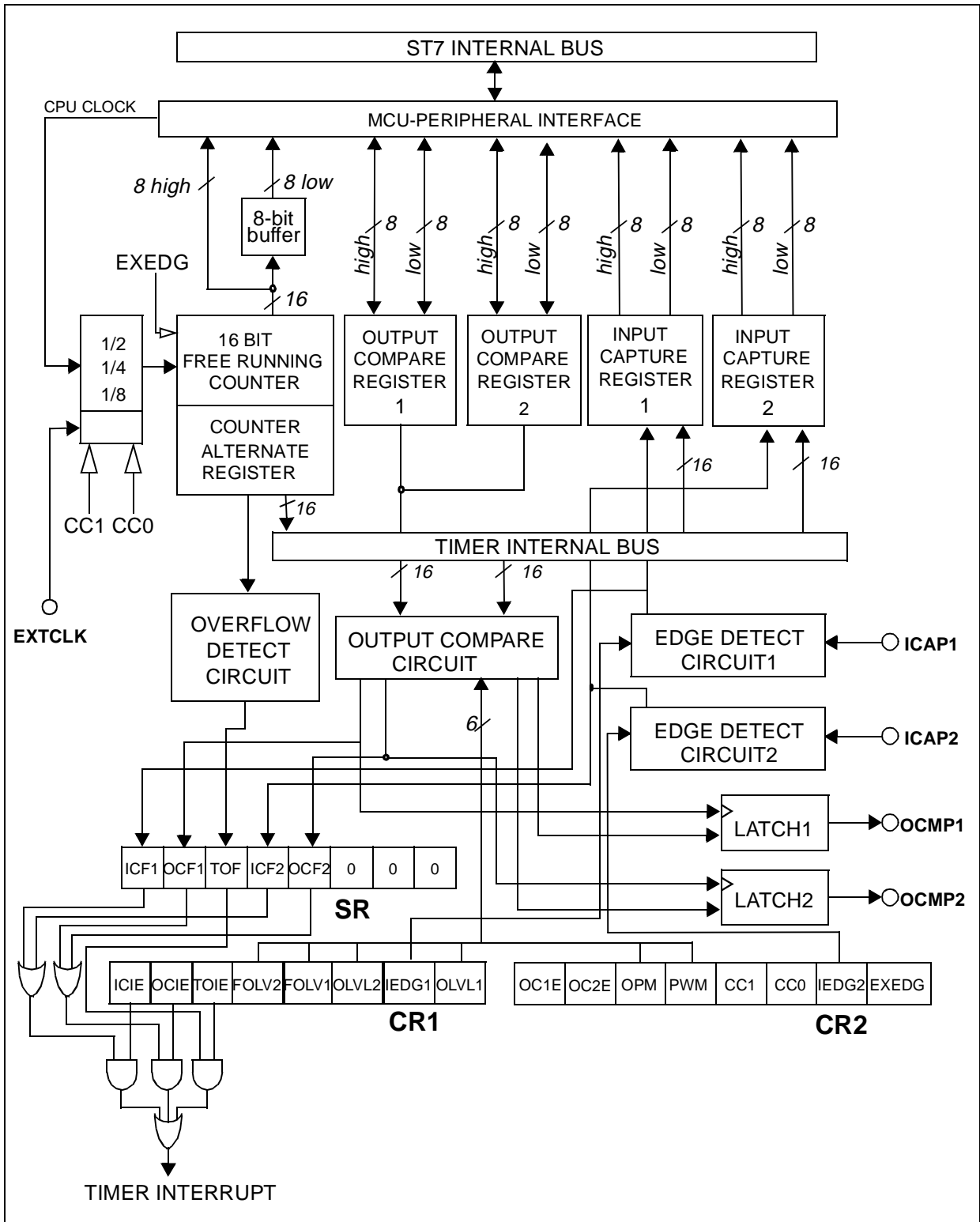
These two read-only 16-bit registers contain the same value but with the difference that reading the ACLR register does not clear the TOF bit (overflow flag), (see note page 43).

Writing in the CLR register or ACLR register resets the free running counter to the FFFCh value.

The timer clock depends on the clock control bits of the CR2 register, as illustrated in Table 15 Clock Control Bits. The value in the counter register repeats every 131.072, 262.144 or 524.288 internal processor clock cycles depending on the CC1 and CC0 bits.

16-BIT TIMER (Cont'd)

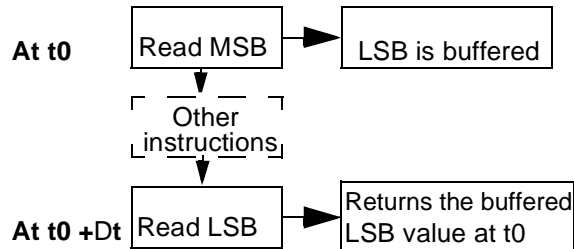
Figure 27. Timer Block Diagram



**16-BIT TIMER** (Cont'd)

**16-bit read sequence:** (from either the Counter Register or the Alternate Counter Register).

*Beginning of the sequence*



*Sequence completed*

The user must read the MSB first, then the LSB value is buffered automatically.

This buffered value remains unchanged until the 16-bit read sequence is completed, even if the user reads the MSB several times.

After a complete reading sequence, if only the CLR register or ACLR register are read, they return the LSB of the count value at the time of the read.

An overflow occurs when the counter rolls over from FFFFh to 0000h then:

- The TOF bit of the SR register is set.
- A timer interrupt is generated if:
  - TOIE bit of the CR1 register is set and
  - I bit of the CC register is cleared.

If one of these conditions is false, the interrupt remains pending to be issued as soon as they are both true.

Clearing the overflow interrupt request is done by:

1. Reading the SR register while the TOF bit is set.

2. An access (read or write) to the CLR register.

**Notes:** The TOF bit is not cleared by accesses to ACLR register. This feature allows simultaneous use of the overflow function and reads of the free running counter at random times (for example, to measure elapsed time) without the risk of clearing the TOF bit erroneously.

The timer is not affected by WAIT mode.

**4.3.3.2 External Clock**

The external clock (where available) is selected if CC0=1 and CC1=1 in CR2 register.

The status of the EXEDG bit determines the type of level transition on the external clock pin EXTCLK that will trigger the free running counter.

The counter is synchronised with the falling edge of the internal CPU clock.

At least four falling edges of the CPU clock must occur between two consecutive active edges of the external clock; thus the external clock frequency must be less than a quarter of the CPU clock frequency.

16-BIT TIMER (Cont'd)

Figure 28. Counter Timing Diagram, internal clock divided by 2

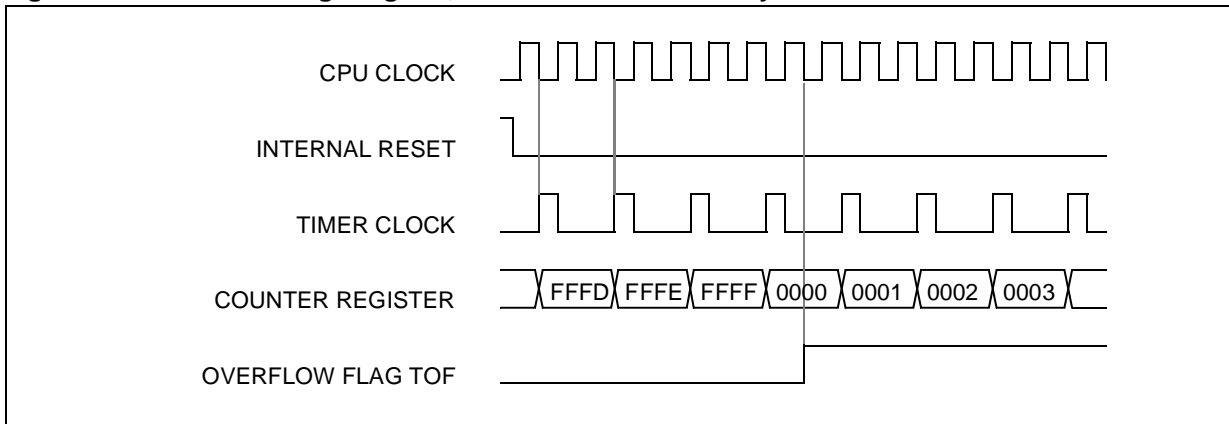


Figure 29. Counter Timing Diagram, internal clock divided by 4

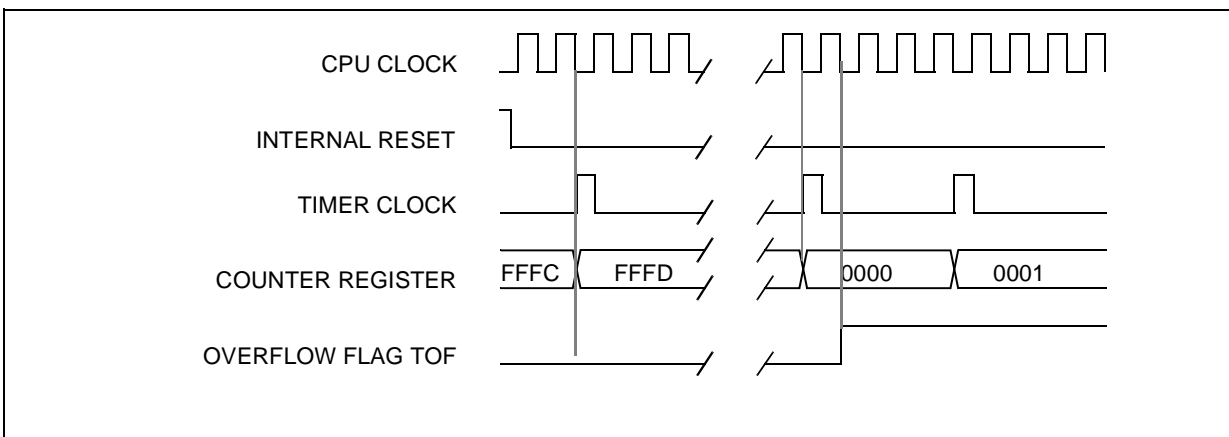
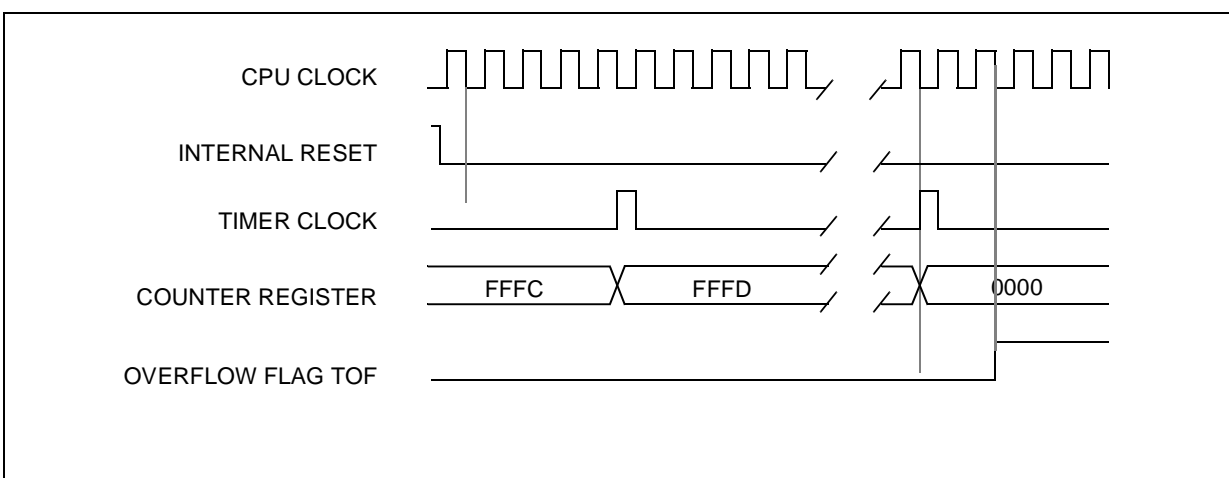


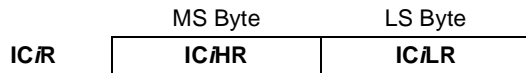
Figure 30. Counter Timing Diagram, internal clock divided by 8



**16-BIT TIMER** (Cont'd)**4.3.3.3 Input Capture**

In this section, the index, *i*, may be 1 or 2.

The two input capture 16-bit registers (IC1R and IC2R) are used to latch the value of the free running counter after a transition detected by the ICAP*i* pin (see figure 5).



IC*i*R register is a read-only register.

The active transition is software programmable through the IEDG*i* bit of the Control Register (CR*i*).

Timing resolution is one count of the free running counter: ( $f_{CPU}/(CC1.CC0)$ ).

**Procedure**

To use the input capture function select the following in the CR2 register:

- Select the timer clock (CC1-CC0) (see Table 15 Clock Control Bits).
- Select the edge of the active transition on the ICAP2 pin with the IEDG2 bit.

And select the following in the CR1 register:

- Set the ICIE bit to generate an interrupt after an input capture.

- Select the edge of the active transition on the ICAP1 pin with the IEDG1 bit.
- When an input capture occurs:

- ICF*i* bit is set.
- The IC*i*R register contains the value of the free running counter on the active transition on the ICAP*i* pin (see Figure 32).
- A timer interrupt is generated if the ICIE bit is set and the I bit is cleared in the CC register. Otherwise, the interrupt remains pending until both conditions become true.

Clearing the Input Capture interrupt request is done by:

1. Reading the SR register while the ICF*i* bit is set.
2. An access (read or write) to the IC*i*LR register.

After reading the IC*i*HR register, transfer of input capture data is inhibited until the IC*i*LR register is also read.

The IC*i*R register always contains the free running counter value which corresponds to the most recent input capture.

16-BIT TIMER (Cont'd)

Figure 31. Input Capture Block Diagram

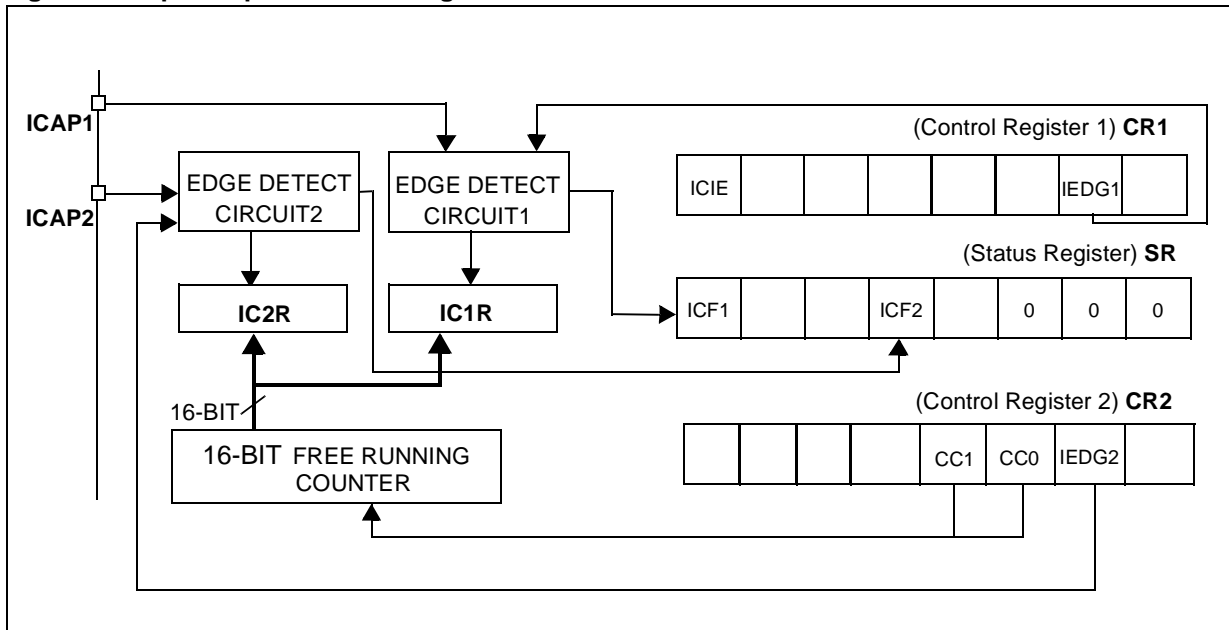
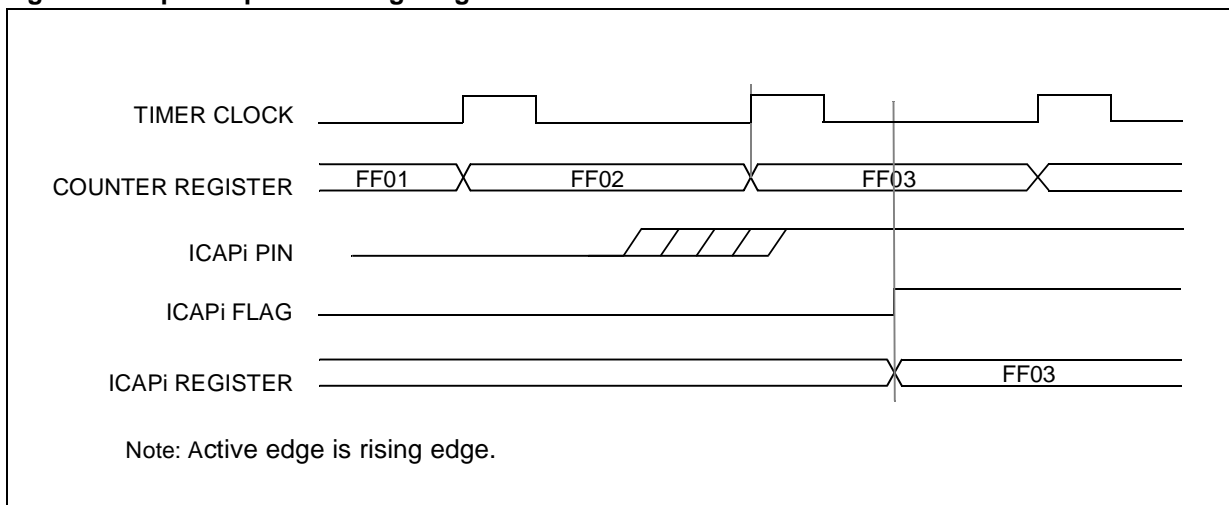


Figure 32. Input Capture Timing Diagram



**16-BIT TIMER (Cont'd)****4.3.3.4 Output Compare**

In this section, the index, *i*, may be 1 or 2.

This function can be used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the Output Compare register and the free running counter, the output compare function:

- Assigns pins with a programmable value if the OCIE bit is set
- Sets a flag in the status register
- Generates an interrupt if enabled

Two 16-bit registers Output Compare Register 1 (OC1R) and Output Compare Register 2 (OC2R) contain the value to be compared to the free running counter each timer clock cycle.

|             | MS Byte      | LS Byte      |
|-------------|--------------|--------------|
| OC <i>R</i> | OC <i>HR</i> | OC <i>LR</i> |

These registers are readable and writable and are not affected by the timer hardware. A reset event changes the OC*R* value to 8000h.

Timing resolution is one count of the free running counter: ( $f_{CPU}/(CC1.CC0)$ ).

**Procedure**

To use the output compare function, select the following in the CR2 register:

- Set the OC*E* bit if an output is needed then the OCMP*i* pin is dedicated to the output compare *i* function.
- Select the timer clock (CC1-CC0) (see Table 15 Clock Control Bits).

And select the following in the CR1 register:

- Select the OLVL*i* bit to applied to the OCMP*i* pins after the match occurs.
- Set the OCIE bit to generate an interrupt if it is needed.

When match is found:

- OCF*i* bit is set.
- The OCMP*i* pin takes OLVL*i* bit value (OCMP*i* pin latch is forced low during reset and stays low until valid compares change it to a high level).

- A timer interrupt is generated if the OCIE bit is set in the CR2 register and the I bit is cleared in the CC register (CC).

Clearing the output compare interrupt request is done by:

3. Reading the SR register while the OCF*i* bit is set.
4. An access (read or write) to the OC*LR* register.

**Note:** After a processor write cycle to the OC*HR* register, the output compare function is inhibited until the OC*LR* register is also written.

If the OC*E* bit is not set, the OCMP*i* pin is a general I/O port and the OLVL*i* bit will not appear when match is found but an interrupt could be generated if the OCIE bit is set.

The value in the 16-bit OC*R* register and the OLV*i* bit should be changed after each successful comparison in order to control an output waveform or establish a new elapsed timeout.

The OC*R* register value required for a specific timing application can be calculated using the following formula:

$$\Delta \text{OC}iR = \frac{\Delta t * f_{CPU}}{(CC1.CC0)}$$

Where:

$\Delta t$  = Desired output compare period (in seconds)

$f_{CPU}$  = Internal clock frequency

CC1-CC0 = Timer clock prescaler

The following procedure is recommended to prevent the OCF*i* bit from being set between the time it is read and the write to the OC*R* register:

- Write to the OC*HR* register (further compares are inhibited).
- Read the SR register (first step of the clearance of the OCF*i* bit, which may be already set).
- Write to the OC*LR* register (enables the output compare function and clears the OCF*i* bit).

16-BIT TIMER (Cont'd)

Figure 33. Output Compare Block Diagram

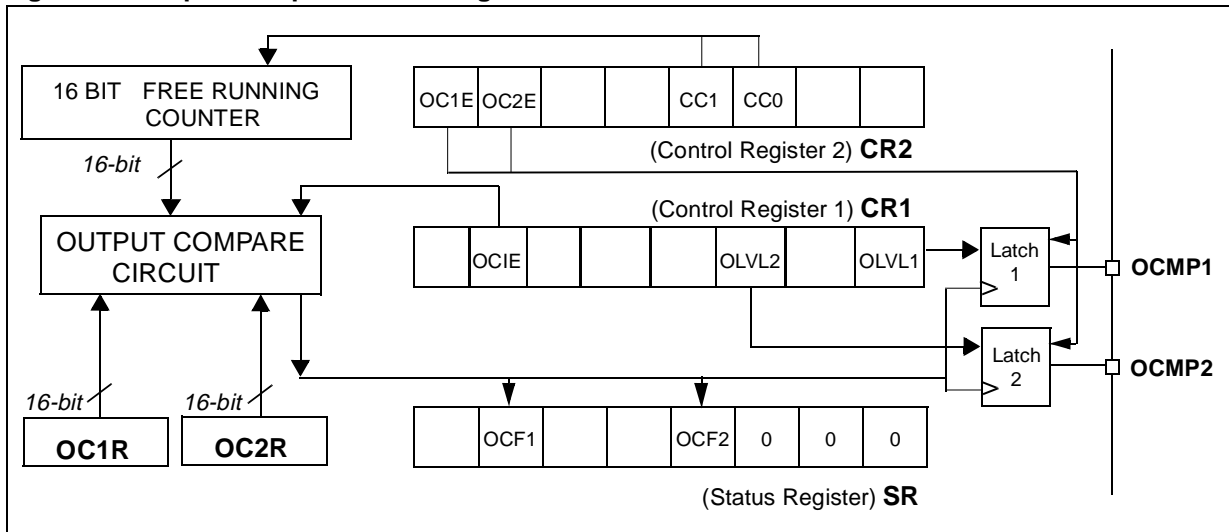
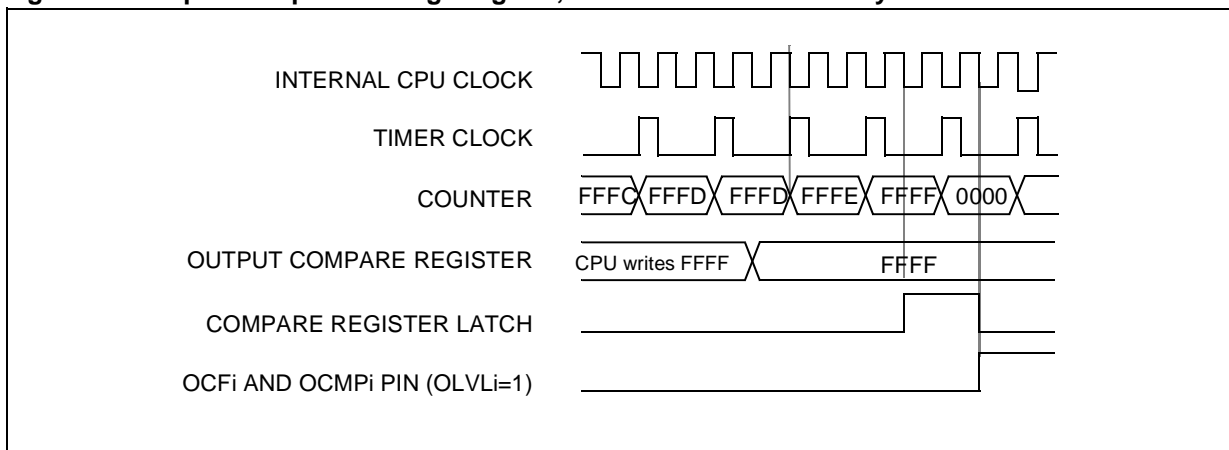


Figure 34. Output Compare Timing Diagram, Internal Clock Divided by 2





**16-BIT TIMER (Cont'd)**

**4.3.3.5 Forced Compare Mode**

In this section *i* may represent 1 or 2.

The following bits of the CR1 register are used:



When the FOLV*i* bit is set, the OLVL*i* bit is copied to the OCMP*i* pin. The FOLV*i* bit is not cleared by software, only by a chip reset. The OLVL*i* bit has to be toggled in order to toggle the OCMP*i* pin when it is enabled (OC/E bit=1).

The OCF*i* bit is not set, and thus no interrupt request is generated.

**4.3.3.6 One Pulse Mode**

One Pulse mode enables the generation of a pulse when an external event occurs. This mode is selected via the OPM bit in the CR2 register.

The one pulse mode uses the Input Capture1 function and the Output Compare1 function.

**Procedure**

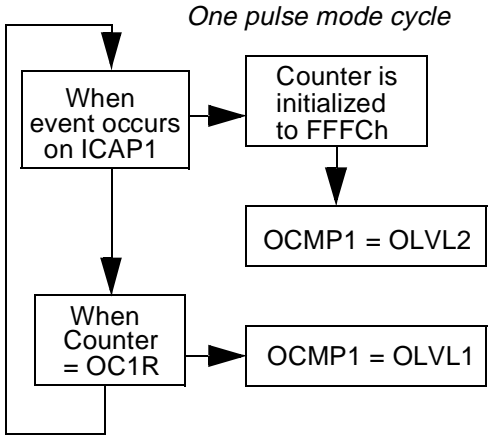
To use one pulse mode, select the following in the the CR1 register:

- Using the OLVL1 bit, select the level to be applied to the OCMP1 pin after the pulse.
- Using the OLVL2 bit, select the level to be applied to the OCMP1 pin during the pulse.
- Select the edge of the active transition on the ICAP1 pin with the IEDG1 bit.

And select the following in the CR2 register:

- Set the OC1E bit, the OCMP1 pin is then dedicated to the Output Compare 1 function.

- Set the OPM bit.
- Select the timer clock CC1-CC0 (see Table 15 Clock Control Bits). Load the OC1R register with the value corresponding to the length of the pulse (see the formula in Section 4.3.3.7).



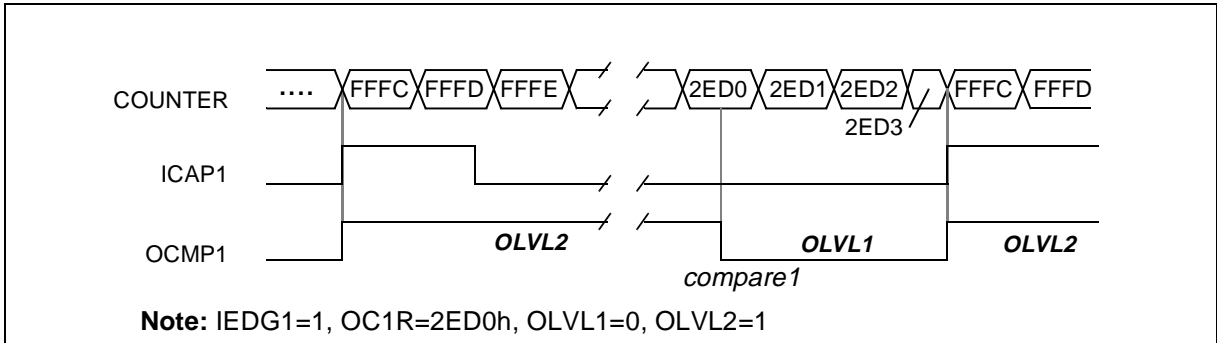
Then, on a valid event on the ICAP1 pin, the counter is initialized to FFFCh and OLVL2 bit is loaded on the OCMP1 pin. When the value of the counter is equal to the value of the contents of the OC1R register, the OLVL1 bit is output on the OCMP1 pin, (See Figure 35).

**Note:** The OCF1 bit cannot be set by hardware in one pulse mode but the OCF2 bit can generate an Output Compare interrupt.

The ICF1 bit is set when an active edge occurs and can generate an interrupt if the ICIE bit is set.

When the Pulse Width Modulation (PWM) and One Pulse Mode (OPM) bits are both set, the PWM mode is the only active one.

**Figure 35. One Pulse Mode Timing**



16-BIT TIMER (Cont'd)

4.3.3.7 Pulse Width Modulation Mode

Pulse Width Modulation mode enables the generation of a signal with a frequency and pulse length determined by the value of the OC1R and OC2R registers.

The pulse width modulation mode uses the complete Output Compare 1 function plus the OC2R register.

Procedure

To use pulse width modulation mode select the following in the CR1 register:

- Using the OLVL1 bit, select the level to be applied to the OCMP1 pin after a successful comparison with OC1R register.
- Using the OLVL2 bit, select the level to be applied to the OCMP1 pin after a successful comparison with OC2R register.

And select the following in the CR2 register:

- Set OC1E bit: the OCMP1 pin is then dedicated to the output compare 1 function.
- Set the PWM bit.
- Select the timer clock (CC1-CC0) (see Table 15 Clock Control Bits).

Load the OC2R register with the value corresponding to the period of the signal.

Load the OC1R register with the value corresponding to the length of the pulse if (OLVL1=0 and OLVL2=1).

If OLVL1=1 and OLVL2=0 the length of the pulse is the difference between the OC2R and OC1R registers.

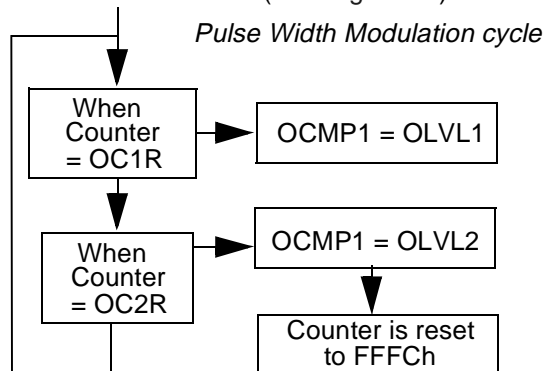
The OC/R register value required for a specific timing application can be calculated using the following formula:

$$OC/R \text{ Value} = \frac{t * f_{CPU}}{(CC1.CC0)} - 5$$

Where:

- t = Desired output compare period (seconds)
- f<sub>CPU</sub> = Internal clock frequency (see Miscellaneous register)
- CC1-CC0 = Timer clock prescaler

The Output Compare 2 event causes the counter to be initialized to FFFCh (See Figure 36).

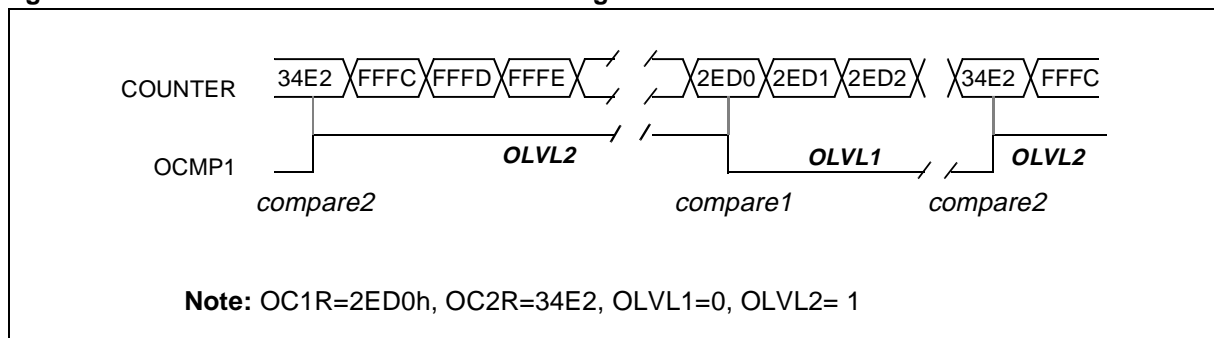


**Note:** After a write instruction to the OC1R register, the output compare function is inhibited until the OC2R register is also written.

The OCF1 and OCF2 bits cannot be set by hardware in PWM mode therefore the Output Compare interrupt is inhibited. The Input Capture interrupts are available.

When the Pulse Width Modulation (PWM) and One Pulse Mode (OPM) bits are both set, the PWM mode is the only active one.

Figure 36. Pulse Width Modulation Mode Timing



#### 4.3.4 Register Description

Each Timer is associated with three control and status registers, and with six pairs of data registers (16-bit values) relating to the two input captures, the two output compares, the counter and the alternate counter.

#### CONTROL REGISTER 1 (CR1)

Read/Write

Reset Value: 0000 0000 (00h)

|      |      |      |       |       |       |       |       |
|------|------|------|-------|-------|-------|-------|-------|
| 7    |      |      |       |       |       |       | 0     |
| ICIE | OCIE | TOIE | FOLV2 | FOLV1 | OLVL2 | IEDG1 | OLVL1 |

Bit 7 = **ICIE** *Input Capture Interrupt Enable*.

- 0: Interrupt is inhibited.
- 1: A timer interrupt is generated whenever the ICF1 or ICF2 bit of the SR register is set.

Bit 6 = **OCIE** *Output Compare Interrupt Enable*.

- 0: Interrupt is inhibited.
- 1: A timer interrupt is generated whenever the OCF1 or OCF2 bit of the SR register is set.

Bit 5 = **TOIE** *Timer Overflow Interrupt Enable*.

- 0: Interrupt is inhibited.
- 1: A timer interrupt is enabled whenever the TOF bit of the SR register is set.

Bit 4 = **FOLV2** *Forced Output Compare 2*.

This bit is not cleared by software, only by a chip reset.

- 0: No effect.
- 1: Forces the OLVL2 bit to be copied to the OCMP2 pin.

Bit 3 = **FOLV1** *Forced Output Compare 1*.

This bit is not cleared by software, only by a chip reset.

- 0: No effect.
- 1: Forces OLVL1 to be copied to the OCMP1 pin.

Bit 2 = **OLVL2** *Output Level 2*.

This bit is copied to the OCMP2 pin whenever a successful comparison occurs with the OC2R register and OCxE is set in the CR2 register. This value is copied to the OCMP1 pin in One Pulse Mode and Pulse Width Modulation mode.

Bit 1 = **IEDG1** *Input Edge 1*.

This bit determines which type of level transition on the ICAP1 pin will trigger the capture.

- 0: A falling edge triggers the capture.
- 1: A rising edge triggers the capture.

Bit 0 = **OLVL1** *Output Level 1*.

The OLVL1 bit is copied to the OCMP1 pin whenever a successful comparison occurs with the OC1R register and the OC1E bit is set in the CR2 register.

**16-BIT TIMER (Cont'd)**  
**CONTROL REGISTER 2 (CR2)**

Read/Write

Reset Value: 0000 0000 (00h)

|      |      |     |     |     |     |       |       |
|------|------|-----|-----|-----|-----|-------|-------|
| 7    |      |     |     |     |     |       | 0     |
| OC1E | OC2E | OPM | PWM | CC1 | CC0 | IEDG2 | EXEDG |

Bit 7 = **OC1E** *Output Compare 1 Enable.*

- 0: Output Compare 1 function is enabled, but the OCMP1 pin is a general I/O.
- 1: Output Compare 1 function is enabled, the OCMP1 pin is dedicated to the Output Compare 1 capability of the timer.

Bit 6 = **OC2E** *Output Compare 2 Enable.*

- 0: Output Compare 2 function is enabled, but the OCMP2 pin is a general I/O.
- 1: Output Compare 2 function is enabled, the OCMP2 pin is dedicated to the Output Compare 2 capability of the timer.

Bit 5 = **OPM** *One Pulse Mode.*

- 0: One Pulse Mode is not active.
- 1: One Pulse Mode is active, the ICAP1 pin can be used to trigger one pulse on the OCMP1 pin; the active transition is given by the IEDG1 bit. The length of the generated pulse depends on the contents of the OC1R register.

Bit 4 = **PWM** *Pulse Width Modulation.*

- 0: PWM mode is not active.
- 1: PWM mode is active, the OCMP1 pin outputs a programmable cyclic signal; the length of the pulse depends on the value of OC1R register; the period depends on the value of OC2R register.

Bit 3, 2 = **CC1-CC0** *Clock Control.*

The value of the timer clock depends on these bits:

**Table 15. Clock Control Bits**

| CC1 | CC0 | Timer Clock                      |
|-----|-----|----------------------------------|
| 0   | 0   | $f_{CPU} / 4$                    |
| 0   | 1   | $f_{CPU} / 2$                    |
| 1   | 0   | $f_{CPU} / 8$                    |
| 1   | 1   | External Clock (where available) |

Bit 1 = **IEDG2** *Input Edge 2.*

This bit determines which type of level transition on the ICAP2 pin will trigger the capture.

- 0: A falling edge triggers the capture.
- 1: A rising edge triggers the capture.

Bit 0 = **EXEDG** *External Clock Edge.*

This bit determines which type of level transition on the external clock pin EXTCLK will trigger the free running counter.

- 0: A falling edge triggers the free running counter.
- 1: A rising edge triggers the free running counter.

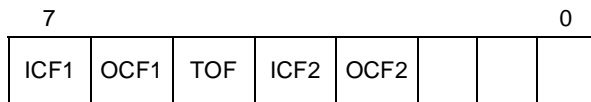
**16-BIT TIMER (Cont'd)**

**STATUS REGISTER (SR)**

Read Only

Reset Value: 0000 0000 (00h)

The three least significant bits are not used.



Bit 7 = **ICF1** Input Capture Flag 1.

- 0: No input capture (reset value).
- 1: An input capture has occurred. To clear this bit, first read the SR register, then read or write the low byte of the IC1R (IC1LR) register.

Bit 6 = **OCF1** Output Compare Flag 1.

- 0: No match (reset value).
- 1: The content of the free running counter has matched the content of the OC1R register. To clear this bit, first read the SR register, then read or write the low byte of the OC1R (OC1LR) register.

Bit 5 = **TOF** Timer Overflow.

- 0: No timer overflow (reset value).
- 1: The free running counter rolled over from FFFFh to 0000h. To clear this bit, first read the SR register, then read or write the low byte of the CR (CLR) register.

**Note:** Reading or writing the ACLR register does not clear TOF.

Bit 4 = **ICF2** Input Capture Flag 2.

- 0: No input capture (reset value).
- 1: An input capture has occurred. To clear this bit, first read the SR register, then read or write the low byte of the IC2R (IC2LR) register.

Bit 3 = **OCF2** Output Compare Flag 2.

- 0: No match (reset value).
- 1: The content of the free running counter has matched the content of the OC2R register. To clear this bit, first read the SR register, then read or write the low byte of the OC2R (OC2LR) register.

Bit 2-0 = Unused.

**INPUT CAPTURE 1 HIGH REGISTER (IC1HR)**

Read Only

Reset Value: Undefined

This is an 8-bit read only register that contains the high part of the counter value (transferred by the input capture 1 event).



**INPUT CAPTURE 1 LOW REGISTER (IC1LR)**

Read Only

Reset Value: Undefined

This is an 8-bit read only register that contains the low part of the counter value (transferred by the input capture 1 event).

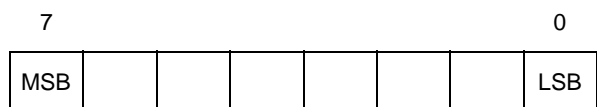


**OUTPUT COMPARE 1 HIGH REGISTER (OC1HR)**

Read/Write

Reset Value: 1000 0000 (80h)

This is an 8-bit register that contains the high part of the value to be compared to the CHR register.



**OUTPUT COMPARE 1 LOW REGISTER (OC1LR)**

Read/Write

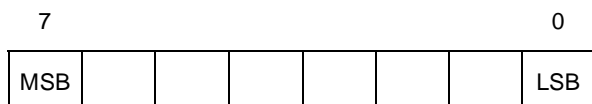
Reset Value: 0000 0000 (00h)

This is an 8-bit register that contains the low part of

**16-BIT TIMER (Cont'd)**  
**OUTPUT COMPARE 2 HIGH REGISTER (OC2HR)**

Read/Write  
 Reset Value: 1000 0000 (80h)

This is an 8-bit register that contains the high part of the value to be compared to the CHR register.



**OUTPUT COMPARE 2 LOW REGISTER (OC2LR)**

Read/Write  
 Reset Value: 0000 0000 (00h)

This is an 8-bit register that contains the low part of the value to be compared to the CLR register.



**COUNTER HIGH REGISTER (CHR)**

Read Only  
 Reset Value: 1111 1111 (FFh)

This is an 8-bit register that contains the high part of the counter value.



**COUNTER LOW REGISTER (CLR)**

Read/Write  
 Reset Value: 1111 1100 (FCh)

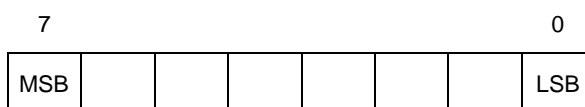
This is an 8-bit register that contains the low part of the counter value. A write to this register resets the counter. An access to this register after accessing the SR register clears the TOF bit.



**ALTERNATE COUNTER HIGH REGISTER (ACHR)**

Read Only  
 Reset Value: 1111 1111 (FFh)

This is an 8-bit register that contains the high part of the counter value.



**ALTERNATE COUNTER LOW REGISTER (ACLR)**

Read/Write  
 Reset Value: 1111 1100 (FCh)

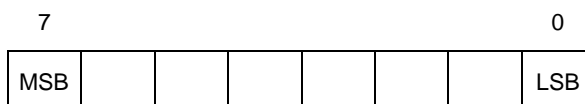
This is an 8-bit register that contains the low part of the counter value. A write to this register resets the counter. An access to this register after an access to SR register does not clear the TOF bit in SR register.



**INPUT CAPTURE 2 HIGH REGISTER (IC2HR)**

Read Only  
 Reset Value: Undefined

This is an 8-bit read only register that contains the high part of the counter value (transferred by the Input Capture 2 event).



**INPUT CAPTURE 2 LOW REGISTER (IC2LR)**

Read Only  
 Reset Value: Undefined

## 16-BIT TIMER (Cont'd)

Table 16. 16-Bit Timer Register Map

| Address<br>(Hex.) | Register<br>Name | 7    | 6    | 5    | 4     | 3     | 2     | 1     | 0     |
|-------------------|------------------|------|------|------|-------|-------|-------|-------|-------|
| 11                | CR2              | OC1E | OC2E | OPM  | PWM   | CC1   | CC0   | IEDG2 | EXEDG |
| 12                | CR1              | ICIE | OCIE | TOIE | FOLV2 | FOLV1 | OLVL2 | IEDG1 | OLVL1 |
| 13                | SR               | ICF1 | OCF1 | TOF  | ICF2  | OCF2  | 0     | 0     | 0     |
| 14                | IC1HR            | MSB  |      |      |       |       |       |       | LSB   |
| 15                | IC1LR            | MSB  |      |      |       |       |       |       | LSB   |
| 16                | OC1HR            | MSB  |      |      |       |       |       |       | LSB   |
| 17                | OC1LR            | MSB  |      |      |       |       |       |       | LSB   |
| 18                | CHR              | MSB  |      |      |       |       |       |       | LSB   |
| 19                | CLR              | MSB  |      |      |       |       |       |       | LSB   |
| 1A                | ACHR             | MSB  |      |      |       |       |       |       | LSB   |
| 1B                | ACLR             | MSB  |      |      |       |       |       |       | LSB   |
| 1C                | IC2HR            | MSB  |      |      |       |       |       |       | LSB   |
| 1D                | IC2LR            | MSB  |      |      |       |       |       |       | LSB   |
| 1E                | OC2HR            | MSB  |      |      |       |       |       |       | LSB   |
| 1F                | OC2LR            | MSB  |      |      |       |       |       |       | LSB   |

4.4 SYNC PROCESSOR (SYNC)

4.4.1 Introduction

The Sync processor handles all the management tasks of the video synchronization signals, and is used with the timer and software to provide information and status on the video standard and timings. This block supports multiple video standards such as: Separate Sync, Composite Sync and (via an external extractor) Sync on Green. The internal clock in the Sync processor is 4 MHz.

4.4.2 Main Features

■ Input Processing

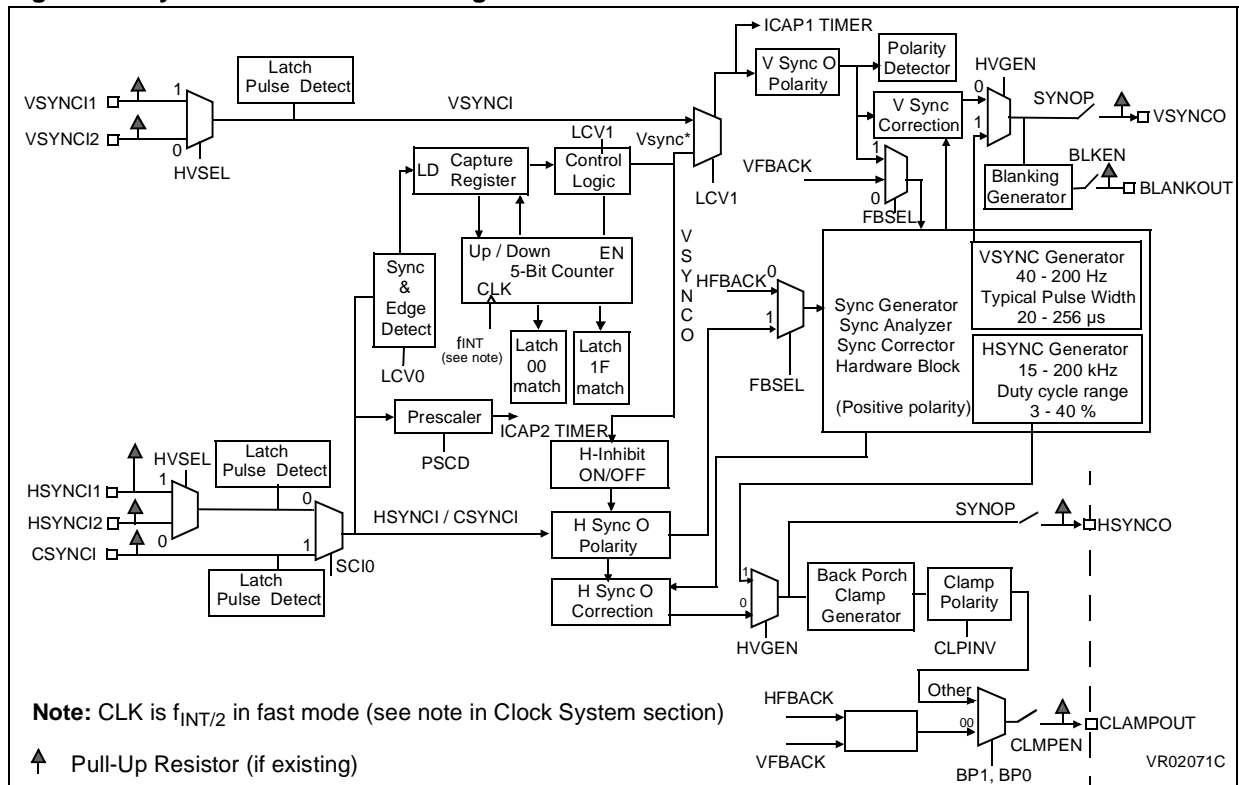
- Presence of incoming signals (edge detection)
- Read the HSYNCl / VSYNCl input signal levels
- Measure the signal periods
- Detect the sync polarities
- Detect the composite sync and extract VSYNCO

■ Output Processing

- Control the sync output polarities
  - Generate free-running frequencies
  - Generate a video blanking signal
  - Generate a clamping signal or a Moire signal
- Analyzer Mode
- Measure the number of scan lines per frame to simplify OSD vertical centering
  - Detect HSYNCl reaching too high a frequency
  - Detect pre/post equalization pulses
  - Measure the low level of HSYNCO or HFBACK
- Corrector Mode
- Inhibit Pre/Post equalization pulses
  - Program VSYNCO pulse width extension
  - Extend VSYNCO pulse widths during:
    - post-equalization pulse detection only
    - pre and post-equalization pulse detection

**Note:** Some external pins are not available on all devices. Refer to the device pinout description.

Figure 37. Sync Processor Block Diagram





**SYNC PROCESSOR (SYNC) (Cont'd)****4.4.3 Input Signals**

The Sync Processor has the following inputs (TTL level):

- VSYNCI1 Vertical Sync input1
- HSYNCI1 Horizontal Sync input1 or Composite sync
- VSYNCI2 Vertical Sync input2
- HSYNCI2 Horizontal Sync input2 or Composite sync

**Note:** The above input pairs can be used for DSUB or BNC connectors. To select these inputs use the HVSEL bit in the POLR register.

- CSYNCI Sync on Green (external extractor)

**Note:** If the CSYNCI pin is needed for another I/O function, the composite sync signal can be connected to HSYNCI using the SCI0 bit in the MCR register.

- HFBACK Horizontal Flyback input
- VFBACK Vertical Flyback input

**4.4.4 Input Signal Waveforms**

- The input signals must contain only synchronization pulses. In case of serration pulses on CSYNCI/HSYNCI, the pulse width should be less than 8 $\mu$ s.
- The VSYNCI signal is internally connected to Timer Input Capture 1 (ICAP1).
- The HSYNCI or CSYNCI signal, prescaled by 256, is internally connected to Timer Input Capture 2 (ICAP2).
- Typical timing range: See Figure 38 and 39
- If the timer clock is 2 MHz (external oscillator frequency 24 MHz):
  - PV accuracy = +/- 1 Timer clock (500ns)
  - PH\*256 accuracy = +/- 1 Timer clock (500ns)

(PV= Vertical pulse, PH = Horizontal pulse)

**4.4.5 Output Signals**

The Sync Processor has the following outputs:

**HSYNCO Horizontal Sync Output**

Enable: SYNOP bit in ENR register

Programmable polarity:

HS0/HS1 bits in MCR register

In case of composite sync signal, the signal can be blanked by software during the vertical period (HINH bit in ENR register).

In case of separate sync, no blanking is generated.

**VSYNCO Vertical Sync Output**

Enable: SYNOP bit in ENR register

Programmable polarity:

VOP bit in the MCR register

In case of composite sync the delay of the extracted Vsync signal is:

minimum: 500ns + HSYNCO pulse width

maximum: 8750ns (max. threshold in extraction mode)

SYNC PROCESSOR (SYNC) (Cont'd)

Figure 38. Typical Horizontal Sync Input Timing

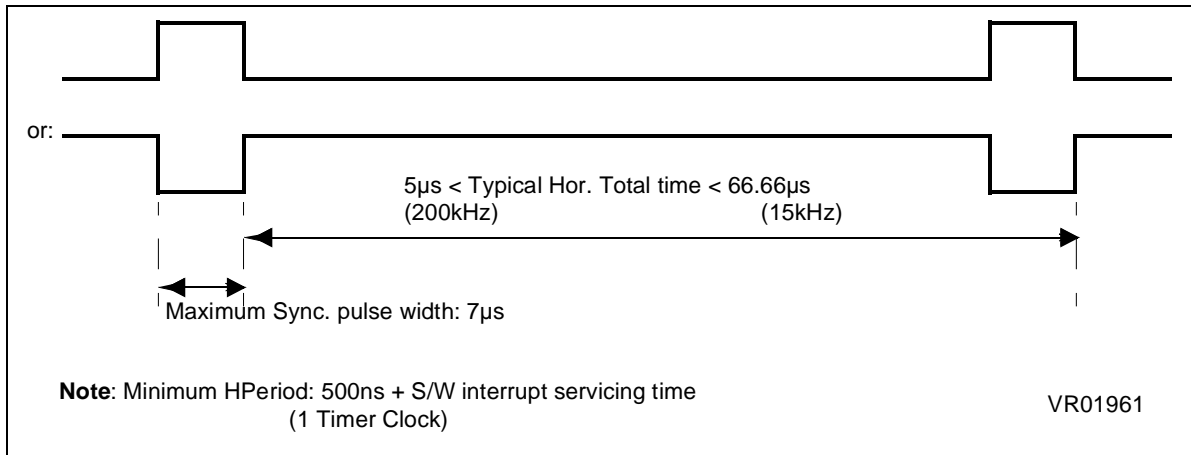
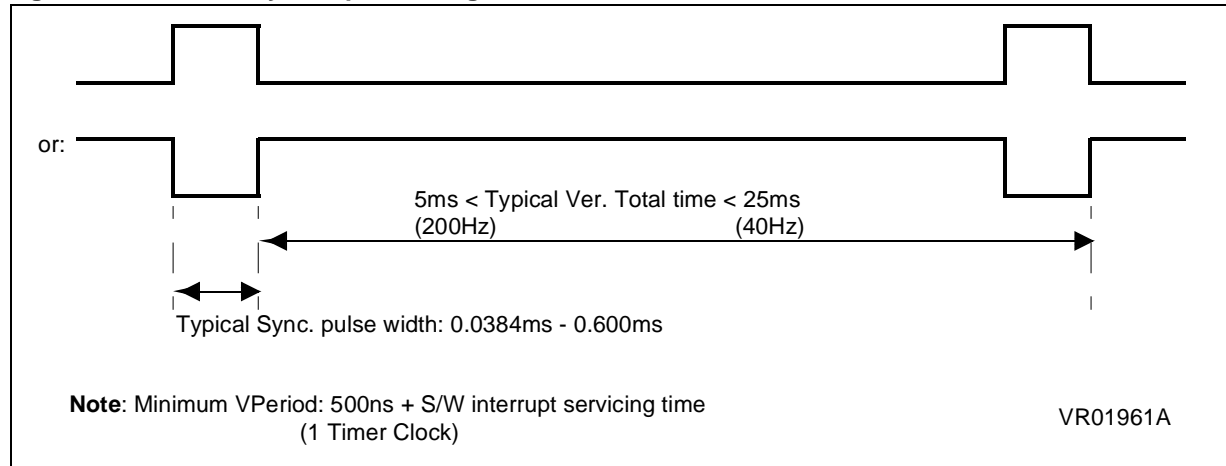


Figure 39. Vertical Sync Input Timing



## SYNC PROCESSOR (SYNC) (Cont'd)

### ClampOut and Moire Signal

#### Clamp Output signal

The clamping pulse generator can control the pulse width and polarity signal and can be configured as pseudo-front porch or back porch.

To use the ClampOut signal:

- Select the Clamping Pulse width: BP0/BP1 bits in MCR register
- Program the Clamp polarity: CLPINV bit in POLR register
- Select the ClampOut signal as back-porch (after falling edge of HSYNCO) or pseudo-front porch (after the rising edge of HSYNCO): HS0/HS1 bits in MCR register.
- Enable the CLAMPOUT signal: CLMPEN bit in ENR register

#### Moire Signal

The Moire output signal is available (instead of the clamping signal) to reduce the screen Moire effect and improve color transitions.

The CLAMPOUT pin is alternatively used to output a Moire signal.

The output signal toggles at each HFBACK rising edge. After each VFBACK falling edge, the value of the Moire output is the opposite of the previous one, independent of the number of HFBACK pulses during the VFBACK low level.

To use the Moire signal:

- Select the Moire signal: Reset the BP0/BP1 bits in MCR register
- Enable the output signal: CLMPEN bit in ENR register

**Figure 40. Clamping Pulse (CLAMPOUT) Delay**

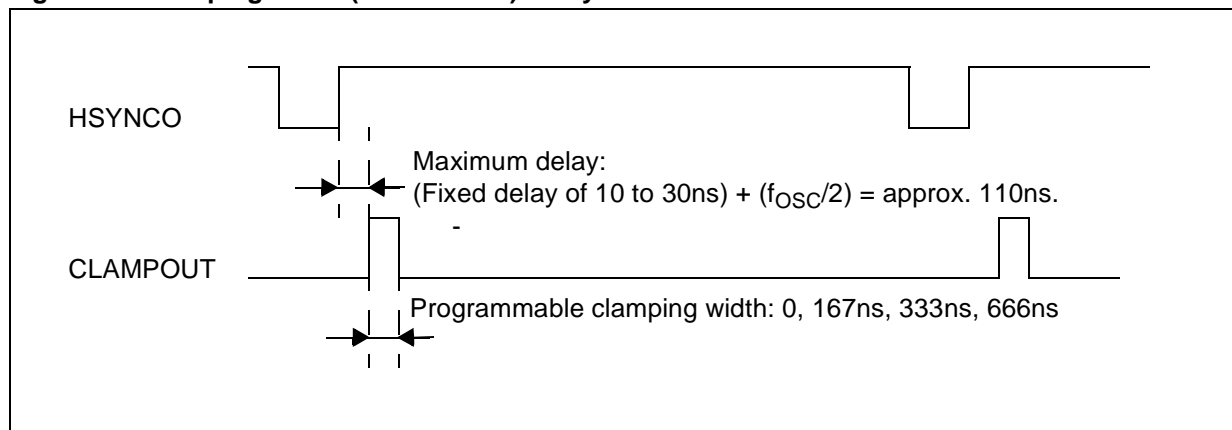
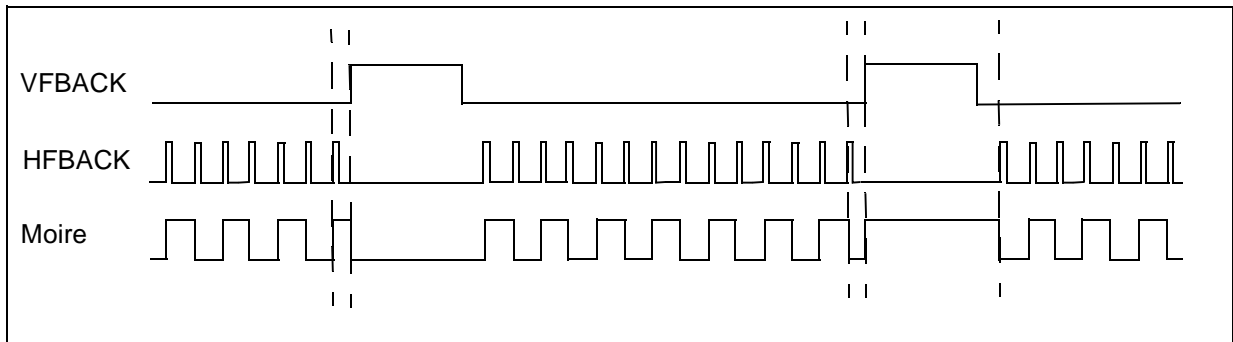


Figure 41. Moire Output (instead of Clamping Output)



4.4.5.1 Blanking output signal

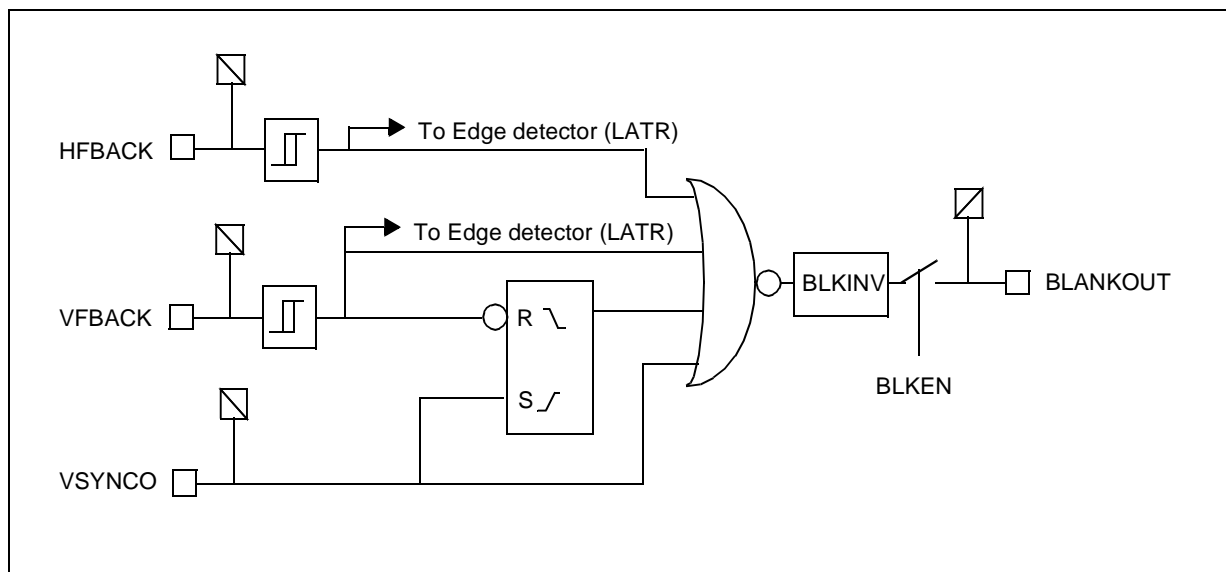
The Video Blanking function uses VSYNCO, HFBACK, VFBACK as input signals and BLANKOUT output as Video Blanking Output. This output pin is a 5V open-drain output and can be AND-wired with any external video blanking signal.

To use the video blanking signal:

- Program the polarity: BLKINV bit in POLR register
- Enable the BLANKOUT output: BLKEN bit in ENR register

**Note:** HFBACK, VFBACK, VSYNCO signals must have positive polarity.

Figure 42. Video Blanking Stage Simplified Schematic



**SYNC PROCESSOR (SYNC) (Cont'd)****4.4.6 Input Processing****4.4.6.1 Detecting Signal Presence**

The Sync Processor provides two ways of checking input signal presence, by directly polling the LATR Latch Register or using the Timer interrupts.

**Polling check**

Use the Latch Register (LATR), to detect the presence of HSYNCI, VSYNCI, CSYNCI, HFBACK and VFBACK signals. These latched bits are set when the falling edge of the corresponding signal is detected. They are cleared by software.

**Interrupts check**

Due to the fact that VSYNCI is connected to Timer Input Capture 1 and HSYNCI or CSYNCI is connected to Timer Input Capture 2, the Timer interrupts can be used to detect the presence of input signals. Refer to the 16-bit Timer chapter for the description of the Timer registers.

To use the interrupt method:

- Select Input Capture1 edge detection: IEDG1 bit in the Timer CR1 register
- Select Input Capture 2 edge detection (must be falling edge): IEDG2 bit = 0 in the Timer CR2 register
- Enable Timer Input Capture interrupts: ICIE bit in the Timer CR1 register.
- Select the Hsync and Vsync input signals: HVSEL bit in the POLR register
- Enable the prescaler for HSYNCI or CSYNCI signal: PSCD bit in the CCR register.
- Select the normal mode: LCV1/LCV0 bits in the CCR register.

Perform any of the following:

- Check for VSYNCI presence by monitoring interrupt requests from Timer ICAP1. When VSYNCI is detected then either detect the VSYNCI polarity or check for HSYNCI presence.
- Check for HSYNCI presence by monitoring interrupt requests from Timer ICAP2. On detecting HSYNCI, either detect its polarity or check if the composite sync on HSYNCI pin is detected or check for CSYNCI presence.

- Check for CSYNCI presence by monitoring interrupt requests from Timer ICAP2.

**4.4.6.2 Measuring Sync Period**

To measure the sync period, the Sync processor block uses the Timer Input Capture interrupts:

- ICAP1 connected to VSYNCI signal
- ICAP2 connected to HSYNCI/CSYNCI signal with a 256 prescaler

Calculating the difference between two subsequent Input Captures (16-bit value) gives the period for 256xPH (horizontal period) and PV (vertical period).

The period accuracy is one timer clock (500ns at 2 MHz), so that the tolerance is 500ns for PH and 256 \* PH (PH accuracy =1.95ns).

**Notes:**

- 1) In case of composite sync, the HSYNCI period measurement can be synchronized on the VSYNCI pulse by setting and resetting the prescaler PSCD bit in the CCR register (for this function, the ICAP2 detection must be selected as falling edge).  
This avoids errors in the period measurement due to the Vsync pulse.
- 2) The Timer Interrupt request should be masked during a write access to any of the Sync processor control registers.

**Important Note:**

Since the recognition of the video mode relies on the accuracy of the measurements, it is highly recommended to implement a counter-style algorithm which performs several consecutive measurements before switching between modes.

The purpose of this algorithm is to filter out any glitches occurring on the video signals.

**SYNC PROCESSOR (SYNC) (Cont'd)****4.4.6.3 Detecting Signal Polarity**

The Sync Processor provides two ways for checking input signal polarity by polling the latches or using the 5-bit up/down counter.

**Polling check**

- HSYNCI polarity detection:
  - UPLAT/DOWNLAT bits in LATR register
  - These bits are directly connected to the 5-bit Up/Down counter.
  - UPLAT=1/ DOWNLAT=0 HSYNCI polarity<0
  - UPLAT=0/ DOWNLAT=1 HSYNCI polarity>0
  
- VSYNCCI Polarity Detection
  - VPOL bit (VSYNCCI polarity) in POLR and
  - VOP bit (VSYNCCI polarity control) in MCR
  - The delay between VSYNCCI polarity changes and the VPOL bit typically toggles within 4 msecs. The polarity detector includes an integrator to filter possible incoming VSYNCCI glitches.

**5-bit Up/Down Counter Check for HSYNCI Polarity**

This method involves the internal 5-bit up/down counter.

The counter value (CV4-CV0 bits) is updated with the 5-bit counter value at every detected edge on the signal monitored.

It is incremented when the signal is high, otherwise it is decremented.

- Start the detection phase:
  - Initialize the 5-bit counter: write '00000' in the CCR register (CV4-CV0 bits).
  - Select normal mode on falling edge:
    - LCV1/LCV0 = 0 in the CCR register.
- Software checks the counter value (CV4-CV0) after an interrupt (with the signal internally connected or ICAP2) or by polling (timeout 150µs).
  - Positive polarity: The counter value < 1Fh.
  - Negative polarity: The counter value =1Fh on the falling edge.

In case of a composite incoming signal, the software just has to check that the VSYNCCI period and polarity are stable.

**4.4.6.4 Extracting VSYNCCI from CSYNCI**

In case of composite sync, the Vertical sync output signal is extracted with the 5-bit up/down counter.

Initially, the width of an Horizontal Sync component pulse is automatically determined by hardware which defines a threshold for the 5-bit counter with a possible user-defined tolerance.

The circuit then monitors for any incoming period greater than this previously captured value. This is then processed as the VSYNCCI signal.

To use the Vsync extractor, the following steps are necessary:

- Detection of a composite sync signal:
  - When the UPLAT and DOWNLAT bits in LATR register are set, a composite sync signal or a HSYNCI polarity change is detected.
  - If these bits are stable during two subsequent ICAP2 interrupt, the composite sync signal is stable.
- Defining a threshold:
  - Select the normal mode (LCV1/LCV0=0 in the CCR register).
  - Initialize the counter capture CV4-CV0 to 0.
  - This automatically measures the HSYNCI pulse width. It defines a threshold in the CV4-CV0 bits used by the 5-bit up/down counter.
  - It also allows to check the HSYNCI polarity (refer to the "5-bit Up/Down Counter Check" paragraph).
  - If a user-defined tolerance is to be added, then an updated value should be written in the CCR register (CV4-CV0 bits).
  - In a composite sync signal, Hsync and Vsync always have the same polarity.
- Starting the VSYNCCI hardware extraction mode:
  - According to the Composite sync polarity, select the extraction mode (LCV1/LCV0 in CCR register) and rewrite the counter if necessary.
  - Negative polarity: minimum threshold (00h)
  - Positive polarity: maximum threshold (1Fh)

**Note:**

The extracted VSYNCCI signal always has negative polarity.

**SYNC PROCESSOR (SYNC) (Cont'd)**

**4.4.6.5 Example of VSYNCO extraction for a negative composite sync with serration pulses**  
Refer to Figure 43.

In extraction mode, the 5-bit counter checks the counter value with respect to the threshold.

When the incoming signal is high, the counter is increased, otherwise it is decreased.

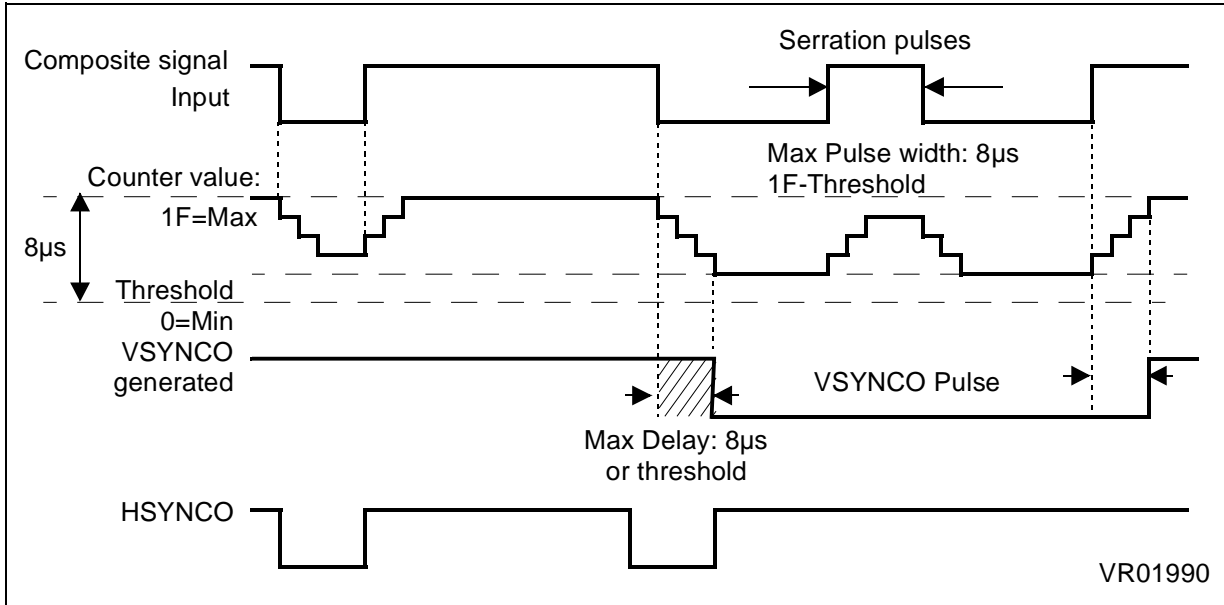
When the counter reaches the threshold on its way down, VSYNCO is asserted. During the vertical blanking, the counter value is decreased down to a programmable minimum, i.e. it does not underflow.

When the vertical period is finished, the counter starts counting up and when the maximum is reached, VSYNCO is negated. The extracted signal may be validated by software since it is input to Timer ICAP1.

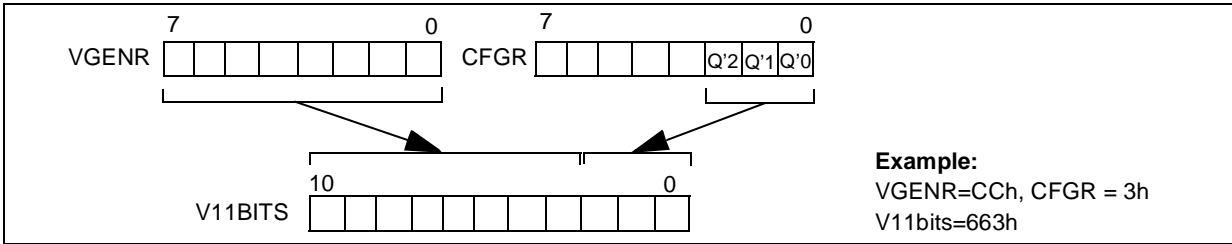
Serration pulses during vertical blanking can be filtered if the serration pulse widths are less than 8µs.

In the same way, positive composite sync signals can be used by properly selecting the edge sensitivity in HSYNCl width measurement mode (LCV0 bit).

**Figure 43. VSYNCO Extraction from a Composite Signal (negative polarity)**



**Figure 44. Obtaining the 11-bit Vertical Period (V11BITS)**



**SYNC PROCESSOR (SYNC) (Cont'd)**

**4.4.7 Output Processing**

**4.4.7.1 Generating Free-Running Frequencies**

The free-running frequencies function is used to:

- Drive the monitor when no or bad sync signals are received.
- Stabilize the OSD screen when the monitor is unlocked.
- Perform fast alignment for maintenance purposes.

**Note:** When free-running mode is active, the analyzer and corrector modes must be disabled.

- VCORDIS = 1, VEXT = 0 in CFGR and POLR registers for vertical output measurement
- 2FHINH = 0 in CFGR register for horizontal low level measurement
- VACQ, HACQ = 0, in CFGR register for analyzer mode

The Sync processor can generate any of the following output sync signals HSYNCO, VSYNCO, CLAMPOUT, BLANKOUT.

To select the generation mode:

- Program the horizontal period using the HGENR register.
- Program the vertical period using the VGENR (8 bits) and CFGR (3 bits) registers (2047 scan lines per frame). Refer to Figure 44.

- Configure the following bits:

- SYNOP = 0
- HVGEN = 1
- HACQ = 0
- VACQ = 0

**Horizontal Period**

PH = Horizontal period = ((HGENR+1)/4) μs

Pulse width: 2 μs => HGENR min=8

Polarity: Positive

HGENR range: [8..255]

**Vertical Period**

PV = Vertical period = (PH \* V11bits) μs

V11bits is a concatenation of VGENR and the Q'2 Q'1 Q'0 bits of the CFGR register.

Refer to Figure 44.

Pulse width: 4 \* PH => min value= 8μs

Polarity: Positive

VGENR/CFGR range: [5..7FF]

**Table 17. Typical values for generated HSYNC signals**

| HGENR (hex value) | H Period | HFREQ     | Pulse Width | Duty Cycle |
|-------------------|----------|-----------|-------------|------------|
| 13                | 5 μs     | 200 kHz   | 2 μs        | 40%        |
| 1F                | 8 μs     | 125 kHz   | 2 μs        | 25%        |
| 3F                | 16 μs    | 62.5 kHz  | 2 μs        | 12.5%      |
| 7F                | 32 μs    | 31.25 kHz | 2 μs        | 6.2%       |
| FF                | 64 μs    | 15.6 kHz  | 2 μs        | 3.1%       |

**Table 18. Typical values for generated VSYNC signals**

| HGENR (hex value) | H Period | H Freq    | V11bits (hex value) | V Period | V Freq  | Pulse width |
|-------------------|----------|-----------|---------------------|----------|---------|-------------|
| 13                | 5 μs     | 200 kHz   | 7FF (2047)          | 10.2 ms  | 97.7 Hz | 20 μs       |
| 13                | 5 μs     | 200 kHz   | 400 (1024)          | 5.1 ms   | 195 Hz  | 20 μs       |
| 1F                | 8 μs     | 125 kHz   | 7FF (2047)          | 16.3 ms  | 61 Hz   | 32 μs       |
| 1F                | 8 μs     | 125 kHz   | 400 (1024)          | 8.2 ms   | 122 Hz  | 32 μs       |
| 3F                | 16 μs    | 62.5 kHz  | 7FF (2047)          | 32.6 ms  | 30.6 Hz | 64 μs       |
| 3F                | 16 μs    | 62.5 kHz  | 400 (1024)          | 16.4 ms  | 60.9 Hz | 64 μs       |
| 7F                | 32 μs    | 31.25 kHz | 7FF (2047)          | 65.5 ms  | 15 Hz   | 128 μs      |
| 7F                | 32 μs    | 31.25 kHz | 400 (1024)          | 32.8 ms  | 30 Hz   | 128 μs      |



**SYNC PROCESSOR (SYNC) (Cont'd)****4.4.8 Analyzer Mode**

The analyzer block is used for all extra measurements on the sync signals to manage the monitor functions:

- Measure the number of scan lines per frame (VSYNCO or VFBACK) to simplify the OSD vertical centering.
- Measure the low level of HSYNCO or HFBACK. This function can be used for VSYNCO pulse extension or for a fast estimation of the incoming Hsync signal period.
- Detection of the pre/post equalization pulses.

**Notes:**

1. Analyzer mode should be performed before corrector mode.
2. When analyzer mode is active, the free-running frequencies generator and corrector mode must be disabled.
  - HVGEN = 0 in ENR register
  - 2FHINH 0 in CFGR register for Horizontal low level measurement
  - VEXT = 0, VCORDIS = 1 in CFGR, POLR registers for Vertical output measurement
3. If H/VBACK are selected (FBSEL=0) corrector mode must be disabled
4. For all measurements, HSYNCO and VSYNCO must be **POSITIVE**.

**4.4.8.1 Horizontal Low Level Measurement**

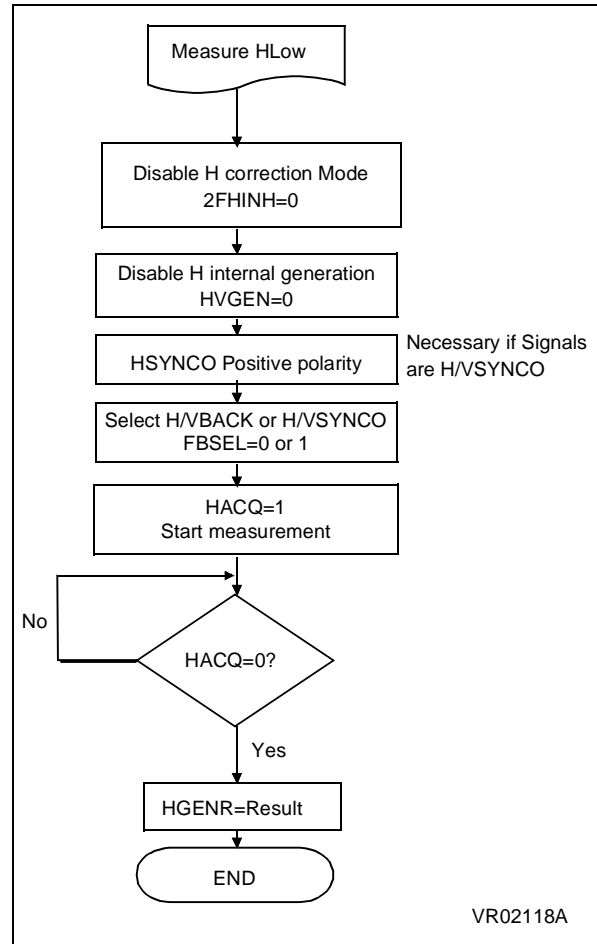
The measurement starts in setting HACQ by software. When this bit is cleared by hardware, the HGENR register returns the result.

The algorithm is shown in Figure 45.

$$HLow = ((255-HGENR+1)/4) \mu s$$

**Note:** HLow maximum value = 64 $\mu$ s (even if real value is greater)

For maximum accuracy, it is possible to measure the low level of HFBACK with the same technique (FBSEL bit in the MCR register).

**Figure 45. Horizontal Low Level Measurement**

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**SYNC PROCESSOR (SYNC) (Cont'd)**

**4.4.8.2 Vertical Output Measurement**

The function of vertical pulse measurement is to:

- Capture the number of HSYNCO pulses during a Low level of VSYNCO.
  - Capture the number of HFBACK pulses during a Low level of VFBACK (maximum accuracy).
- Start the measurement by setting VACQ in the CFGR. When the measurement is completed this bit is cleared by hardware. The VGENR and CFGR registers return the result.

The algorithm is shown in Figure 46.

$HLine = 2048 - (V11bits)$   
 Hline maximum value = 2048 (even if real value is greater)

V11bits = VGENR(8 MSB) and Q'2,Q'1,Q'0 (3 LSB). Refer to Figure 44.

**Note:** In case of pre/post equalization pulses, set the 2FHINH bit in the CFGR register.

**4.4.8.3 Detection of pre equalization pulses**

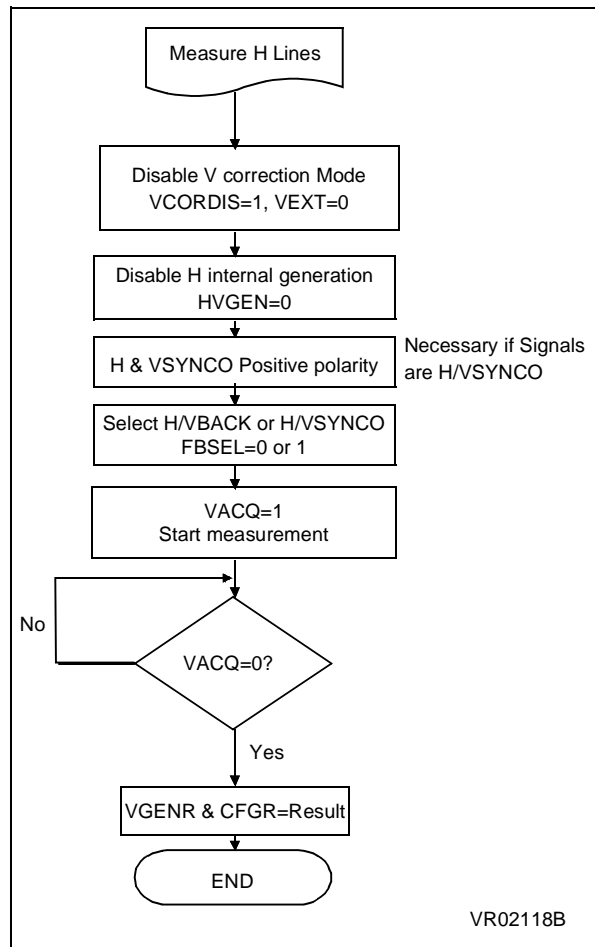
This function uses two bits:

- 2FHDET in POLR register continuously updated by hardware
- 2FHLAT in LATR register set by hardware when a higher frequency is detected and reset by software

A measurement of the low level of HSYNCO is necessary before reading this information.

**Note:** Reset the 2FHLAT bit in the LATR register on the third Hsync pulse after the Vsync pulse.

**Figure 46. Vertical Output Measurement**



**SYNC PROCESSOR (SYNC)** (Cont'd)**4.4.9 Corrector Mode**

In this mode, you can perform the following functions:

- Inhibit pre/post equalization pulses  
This removes all pre/post equalization pulses on the HSYNCO signal.

The inhibition starts on the falling edge of HSYNCO and lasts for  $((\text{HGENR}+1)/4)-2$   $\mu\text{s}$ . The decrease of 2 $\mu\text{s}$  (one minimum pulse width) avoids the removal of the next pulse of HSYNCO.

Procedure:

1. HSYNCO and VSYNCO polarities must be positive.
2. Measure the low level of HSYNCO.
3. Set the 2FHINH bit in the CFGR register.

- Extend VSYNCO pulse width by several scan lines

This function can be also used to extend the video blanking signal.

Procedure:

1. HSYNCO and VSYNCO polarities must be positive.
2. Set the 2FHINH bit in the CFGR register only if some pre/post equalizations pulses are detected. (2FHLAT, 2FHDET flags).
3. The extension will be the number of HSYNCO periods set in the VGENR register.
4. Reset the VCORDIS bit in the POLR register.

- Extend VSYNCO width during all post equalization pulses.

This function extends the VSYNCO pulse width when post equalization pulses are detected (2FHDET bit in the POLR register and 2FHLAT bit in the LATR register).

Procedure:

1. HSYNCO and VSYNCO polarities must be positive.
2. Set the 2FHINH bit in the CFGR register to remove pre/post equalization pulses.
3. Measure the low level of HSYNCO.
4. Update  $\text{HGENR} = (\text{FFh} - (\text{HGENR} + 1)) + 4$  to add tolerance
5. Write  $\text{VGENR} > 0$ .
6. Reset the VCORDIS bit in the POLR register
7. Set the VEXT bit in the CFGR register.

- Extend VSYNCO pulse width during pre and post equalization pulses (for test only).  
This function allows extending the VSYNCO pulse width as long as equalization pulses are detected. ( $\text{VSYNCO} = \text{VSYNCO} + 2\text{FHDET}$ ).

Procedure:

1. HSYNCO and VSYNCO polarities must be positive.
2. Set the 2FHINH bit in the CFGR register to remove pre/post equalization pulses.
3. Measure the low level of HSYNCO.
4. Update  $\text{HGENR} = (\text{FFh} - (\text{HGENR} + 1)) + 4$ .
5. Write  $\text{VGENR} > 0$ .
6. Reset the VCORDIS bit in the POLR register.
7. Set the VEXT bit in the CFGR register.
8. Set the 2FHEN bit in the ENR register.

**Notes:**

1. When corrector mode is active, the free-running frequencies generator and analyzer mode must be disabled.  
( $\text{HVGEN}=0$  in ENR register,  $\text{HACQ}=0$ ,  $\text{VACQ}=0$  in the CFGR register).
2. If  $\text{VGENR}=0$ , all VSYNCO correction functions are disabled except the 2FHEN bit which must be cleared if  $\text{VGENR} = 0$  or  $\text{VCORDIS} = 1$ .

**SYNC PROCESSOR (SYNC)** (Cont'd)

**4.4.10 Register Description  
CONFIGURATION REGISTER (CFGR)**

Read/Write

Reset Value: 0000 0000 (00h)

|      |      |   |        |      |     |     |     |
|------|------|---|--------|------|-----|-----|-----|
| 7    |      |   |        |      |     |     | 0   |
| HACQ | VACQ | - | 2FHINH | VEXT | Q'2 | Q'1 | Q'0 |

Bit 7 = **HACQ** Horizontal Sync Analyzer Mode  
Set by software, reset by hardware when the measurement is done. The sync generator must be disabled (HVGEN=0).

- 0 : Measurement is done, the result can be read in HGENR.
- 1: Start measuring HSYNCO/HFBACK low level.

Bit 6 = **VACQ** Vertical Sync Analyzer Mode  
Set by software, reset by hardware when the measurement is done. The sync generator must be disabled (HVGEN=0).

- 0: Measurement is done, and the result can be read in VGENR.

- 1: Start measuring the number of scan lines during VSYNCO/VFBACK low level.

Bit 5 = Reserved. Must be cleared.

Bit 4 = **2FHINH** Inhibition of Pre/Post equalization pulses.

This function removes pre/post equalization pulses on HSYNCO signal. The sync generator and the Horizontal sync analyzer must both be disabled (HVGEN=HACQ=0).

- 0: Disable
- 1: Enable

Bit 3 = **VEXT** VSYNCO pulse width extension in case of post-equalization pulses.

The sync generator and the Horizontal and Vertical sync analyzer must be disabled (HVGEN = 0, HACQ = 0, VACQ = 0, VCORDIS=0). Vertical extension must be enabled (VGENR > 0).

- 0: Disable
- 1: Enable

Bits 2:0 = **Q'2..Q'0**

These are the read/write LSB of the VGENR 11-bit counter. Refer to Figure 44.

**SYNC PROCESSOR (SYNC) (Cont'd)**  
**MUX CONTROL REGISTER (MCR)**

Read/Write

Reset Value: 0010 0000 (20h)

|     |     |       |      |     |     |     |   |
|-----|-----|-------|------|-----|-----|-----|---|
| 7   |     |       |      |     |     |     | 0 |
| BP1 | BP0 | FBSEL | SCI0 | HS1 | HS0 | VOP | - |

Bit 7:6 = **BP1, BP0** Back Porch Pulse control

| BP1 | BP0 | Back Porch pulse width               |
|-----|-----|--------------------------------------|
| 0   | 0   | No Back Porch, Moire output selected |
| 0   | 1   | 167ns Back Porch ± 10 ns             |
| 1   | 0   | 333ns Back Porch ± 10 ns             |
| 1   | 1   | 666ns Back Porch ± 10 ns             |

Bit 5 = **FBSEL** VSYNCO/HSYNCO or VFBACK/HFBACK analysis

- 0: HFBACK & VFBACK
- 1: HSYNCO & VSYNCO

Bit 4 = **SCI0** HSYNCI/CSYNCI selection

- 0: HSYNCI
- 1: CSYNCI

Bit 3:2 = **HS1, HS0** Horizontal Signal selection  
 These bits allow inversion of the HSYNCI/CSYNCI

| HS1 | HS0 | HSYNCI Selection Mode                                                                                       |
|-----|-----|-------------------------------------------------------------------------------------------------------------|
| 0   | 0   | CLAMPOUT after HSYNCO rising edge<br>HSYNC0 <- (HSYNCI, CSYNCI)                                             |
| 0   | 1   | CLAMPOUT after HSYNCO rising edge<br>HSYNC0 <- ( $\overline{\text{HSYNCI}}$ , $\overline{\text{CSYNCI}}$ )  |
| 1   | 0   | CLAMPOUT after HSYNCO falling edge<br>HSYNC0 <- ( $\overline{\text{HSYNCI}}$ , $\overline{\text{CSYNCI}}$ ) |
| 1   | 1   | CLAMPOUT after HSYNCO falling edge<br>HSYNC0 <- (HSYNCI, CSYNCI)                                            |

**Note:** In case of composite sync, if HSYNCO blanking is enabled (HINH=0 in the ENR register), HS1 must = 1 (CLAMPOUT after HSYNCO rising edge not allowed).

Bit 1 = **VOP** Vertical Polarity control

The VOP bit inverts the VSYNCO Sync signal.

- 0: No polarity inversion (VSYNC0 <- VSYNCI)
- 1: Inversion enabled (VSYNC0 <-  $\overline{\text{VSYNCI}}$ )

**Note:** If at each vertical input capture the VPOL bit is copied by software on the VOP bit, the VSYNCO signal will have a constant positive polarity.

**Note:** The internally extracted VSYNCO has ALWAYS negative polarity.

Bit 0 = Reserved. Must always be cleared.

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**SYNC PROCESSOR (SYNC) (Cont'd)  
COUNTER CONTROL REGISTER (CCR)**

Read/Write

Reset Value: 0000 0000 (00h)

|      |      |      |     |     |     |     |     |   |
|------|------|------|-----|-----|-----|-----|-----|---|
| 7    |      |      |     |     |     |     |     | 0 |
| PSCD | LCV1 | LCV0 | CV4 | CV3 | CV2 | CV1 | CV0 |   |

Bit 7 = **PSCD** Prescaler Enable bit.

- 0: Enable the Prescaler by 256
- 1: Disable the Prescaler and reset it to 7Fh. This also disables the ICAP2 event.

Bit 6:5 = **LCV1, LCV0** VSYNC0 Extraction Control

| LCV1 | LCV0 | VSYNC0 Control Bits                                                                     |
|------|------|-----------------------------------------------------------------------------------------|
| 0    | 0    | Normal mode<br>Counter capture on input falling edge                                    |
| 0    | 1    | Normal mode<br>Counter capture on input rising edge                                     |
| 1    | 0    | Extraction mode<br>CSYNCI/HSYNCI Negative polarity<br>CV4-0 = counter minimum threshold |
| 1    | 1    | Extraction mode<br>CSYNCI/HSYNCI Positive polarity<br>CV4-0 = counter maximum threshold |

Bit 4:0 = **CV4-CV0** Counter Captured Value.  
These bits contain the counter captured value in different modes.

In VSYNC0 extraction mode, they contain the HSYNCI pulse-width measurement.

**POLARITY REGISTER (POLR)**

Bits 5-4 Read Only, other bits Read/Write

Reset Value: 0000 1000 (08h)

|     |   |      |        |       |         |        |        |   |
|-----|---|------|--------|-------|---------|--------|--------|---|
| 7   |   |      |        |       |         |        |        | 0 |
| SOG | 0 | VPOL | 2FHDET | HVSEL | VCORDIS | CLPINV | BLKINV |   |

Bit 7 = **SOG** Sync On Green Detector  
SOG is set by hardware if CSYNCI pulse is not included in the window between HSYNCI rising edge and HSYNCI falling edge + dt .  
Cleared by software.

**Table 19. Sync On Green Window**

| WINDOW DELAY | min.   | max.   |
|--------------|--------|--------|
| dt           | 165 ns | 250 ns |

Bit 6 = Reserved, forced by hardware to 0.

Bit 5 = **VPOL** Vertical Sync polarity (read only)

- 0: Positive polarity
- 1: Negative polarity

**Note:** If the Vertical Sync polarity is changing, the VPOL bit will be updated after a typical delay of 4 msec.

Bit 4 = **2FHDET** Detection of Pre/Post Equalization pulses (read only).

This bit is continuously updated by hardware. It is valid when the sync generator and horizontal analyzer are disabled (HVGEN = 0, HACQ = 0).

- 0: None detected
- 1: Pre/Post Equalization pulses detected

Bit 3 = **HVSEL** Alternate Sync Input Select.

This bit selects between the two sets of Horizontal and Vertical Sync inputs

- 0: HSYNCI2 / VSYNCI2
- 1: HSYNCI1 / VSYNCI1

Bit 2 = **VCORDIS** Extension Disable Signal (Extension with VGENR Register)

- 0: enable
- 1: disable

Bit 1 = **CLPINV** Programmable ClampOut pulse polarity.

- 0: Positive
- 1: Negative

Bit 0 = **BLKINV** Programmable blanking polarity

- 0: Negative
- 1: Positive



**SYNC PROCESSOR (SYNC) (Cont'd)  
LATCH REGISTER (LATR)**

Read/Write

Reset Value: 0000 0000 (00h)

|      |      |      |      |      |       |        |        |   |
|------|------|------|------|------|-------|--------|--------|---|
| 7    |      |      |      |      |       |        |        | 0 |
| CSYN | HSYN | VSYN | HFLY | VFLY | UPLAT | DWNLAT | 2FHLAT |   |

Bit 7 = **CSYN** *Detection of pulses on CSYNCl*  
Set on falling edge of CSYNCl  
Cleared by software (by writing zero).

Bit 6 = **HSYN** *Detection of pulses on HSYNCl*  
Set on falling edge of HSYNCl1 or HSYNCl2  
Cleared by software (by writing zero).

Bit 5 = **VSYN** *Detection of pulses on VSYNCl*  
Set on falling edge of VSYNCl1 or VSYNCl2  
Cleared by software (by writing zero).

Bit 4 = **HFLY** *Detection of pulses on HFBACK*  
Set on falling edge of HFBACK input  
Cleared by software (by writing zero).

Bit 3 = **VFLY** *Detection of pulses on VFBACK*  
Set on falling edge of VFBACK input  
Cleared by software (by writing zero).

Bit 2 = **UPLAT** *Detection of the maximum value of 5-bit up/down counter.*  
Set when the 5 bit up/down counter reaches its maximum value (1Fh or Threshold)  
Cleared by software (by writing zero).

Bit 1 = **DWNLAT** *Detection of minimum value of 5-bit up/down counter.*

Set when the 5 bit up/down counter reaches its minimum value (00 or Threshold)  
Cleared by software (by writing zero).

**Note:** DWNLAT and UPLAT may be used for HSYNCl polarity detection and Composite Sync detection as follows:

| UPLAT | DWNLAT | HSYNCl Characteristics |
|-------|--------|------------------------|
| 0     | 0      | No Info                |
| 0     | 1      | Positive Polarity      |
| 1     | 0      | Negative Polarity      |
| 1     | 1      | Composite Sync         |

Bit 0 = **2FHLAT** *equalization pulses latch.*

This bit may be used to detect pre/postequalization pulses or a too high horizontal frequency.

Set by hardware when Pre/Post equalization pulses are detected.

Must be reset by software.

It is valid when the sync generator and Horizontal analyzer are disabled (HVGEN = 0, HACQ = 0)

**SYNC PROCESSOR (SYNC) (Cont'd)**  
**HORIZONTAL SYNC GENERATOR REGISTER (HGENR)**

Read/Write

Reset Value: 0000 0000 (00h)



**Case HVGEN = 1:** Generation mode  
 In this mode, this register contains the Hsync free-running frequency.  
 The generated signal is:

- Pulse width: 2  $\mu$ s.
- Period PH = ((HGENR+1)/4)  $\mu$ s.
- Polarity: Positive

**Note:** The value in HGENR must be in the range [8..255].

**Case HVGEN = 0:** Analyzer/corrector Mode

**Sub-case HACQ = 1:** Analyzer Mode  
 By setting HACQ bit by software the Analyzer mode starts. When HACQ is cleared by hardware, HGENR returns the duration of HSYNCO/HFBACK low level. The analysis should be done before corrector mode.

**Sub-case HACQ = 0:** Corrector Mode  
 In this mode, the final HSYNCO signal on the pin can be corrected in order to detect and inhibit pre/post equalization pulses.

**VERTICAL SYNC GENERATOR REGISTER (VGENR)**

Read/Write

Reset Value: 0000 0000 (00h)



**Case HVGEN = 1:** Generation mode  
 In this mode, this register contains the Vsync free-running frequency (11-bit value).  
 The generated signal is:

- Pulse width: 4 \* PH  $\mu$ s (horizontal period).
- Period PV = PH \* (V11bits)  $\mu$ s.
- Polarity: Positive

**Note:** The value in VGENR must be in the range [5..255]  
 The Vsync generation mode works as an 11-bit horizontal line counter (2047 scan lines per frame max.). The 3 LSB are in the CFGR register. Refer to Figure 44.

**Case HVGEN = 0:** Analyzer/Corrector Mode

**Sub-case VACQ = 1:** Analyzer Mode  
 Set the VACQ bit to start analyzer mode. When VACQ is cleared by hardware, VGENR/CFGR returns the number of scan lines during the VSYNCO/VFBACK low level period.

**Sub-case VACQ = 0:** Corrector Mode  
 VSYNCO pulse width is extended by VGENR scan lines. If VGENR = 0, all VSYNCO corrections are disabled.



**SYNC PROCESSOR (SYNC) (Cont'd)  
ENABLE REGISTER (ENR)**

Read/Write

Reset Value: 1100 0011 (C3h)

|       |        |       |       |       |      |       |       |
|-------|--------|-------|-------|-------|------|-------|-------|
| 7     |        |       |       |       |      |       | 0     |
| SYNOP | CLMPEN | BLKEN | HVGEN | 2FHEN | HINH | HSIN1 | VSIN1 |

Bit 3 = **2FHEN** *VSYNCO Extension*

VSYNCO is forced high when detecting pre- and post-equalization pulses. It is valid when the sync generator and analyzer are disabled (HVGEN = 0, HACQ = 0, VACQ = 0). Refer to the procedure in Section 4.4.9 Corrector Mode.

0: Disabled  
1: Enabled

Bit 7 = **SYNOP** *HSYNCO, VSYNCO outputs enable*

0: Enabled  
1: Disabled

Bit 2 = **HINH** *HSYNCO Blanking*

HSYNCO is blanked during the extracted VSYNCO pulse.

0: Enabled  
1: Disabled

Bit 6 = **CLMPEN** *Clamping or Moire output enable*

0: Clamping or Moire output (function of BP0, BP1) enabled  
1: Clamping or Moire output disabled

Bit 1 = **HSIN1** (read only)

Returns the HSYN11 pin level

Bit 5 = **BLKEN** *Blanking Output*

0: Disabled  
1: Enabled

Bit 0 = **VSIN1** (read only)

Returns the VSYN11 pin level

Bit 4 = **HVGEN** *Sync Generation function*

0: Analyzer/Corrector Mode  
1: Generation of HSYNCO and VSYNCO free-running frequencies

**Table 20. Summary of the Main Sync Processor Modes**

| Sync Processor Mode                                                           | SYNOP | HVSEL | HVGEN | HACQ | VACQ |
|-------------------------------------------------------------------------------|-------|-------|-------|------|------|
| DSUB Selected as Inputs (HSYN11/VSYN11)                                       | ---   | 1     | ---   | ---  | ---  |
| BNC Selected as Inputs (HSYN12/VSYN12)                                        | ---   | 0     | ---   | ---  | ---  |
| Don't drive the monitor with any Sync signals                                 | 1     | ---   | ---   | ---  | ---  |
| Generate Sync Signals to drive the Monitor hardware                           | 0     | ---   | 1     | 0    | 0    |
| Use the Sync Processor to drive the monitor hardware by incoming Sync signals | 0     | ---   | 0     | ---  | ---  |
| Analyse the number of Scan Lines during one vertical frame                    | ---   | --    | 0     | ---  | 1    |
| Analyse the HSYNC delay between two pulses                                    | ---   | ---   | 0     | 1    | ---  |

SYNC PROCESSOR (SYNC) (Cont'd)

Table 21. SYNC Register Map and Reset Values

| Address (Hex.) | Register Name               | 7          | 6           | 5          | 4           | 3          | 2            | 1           | 0           |
|----------------|-----------------------------|------------|-------------|------------|-------------|------------|--------------|-------------|-------------|
| 40             | <b>CFGR</b><br>Reset Value  | HACQ<br>0  | VACQ<br>0   | -<br>0     | 2FHINH<br>0 | VEXT<br>0  | Q'2<br>0     | Q'1<br>0    | Q'0<br>0    |
| 41             | <b>MCR</b><br>Reset Value   | BP1<br>0   | BP0<br>0    | FBSEL<br>1 | SCI0<br>0   | HS1<br>0   | HS0<br>0     | VOP<br>0    | -<br>0      |
| 42             | <b>CCR</b><br>Reset Value   | PSCD<br>0  | LCV1<br>0   | LCV0<br>0  | CV4<br>0    | CV3<br>0   | CV2<br>0     | CV1<br>0    | CV0<br>0    |
| 43             | <b>POLR</b><br>Reset Value  | SOG<br>0   | 0<br>0      | VPOL<br>0  | 2FHDET<br>0 | HVSEL<br>1 | VCORDIS<br>0 | CLPINV<br>0 | BLKINV<br>0 |
| 44             | <b>LATR</b><br>Reset Value  | CSYN<br>0  | HSYN<br>0   | VSYN<br>0  | HFLY<br>0   | VFLY<br>0  | UPLAT<br>0   | DWNLAT<br>0 | 2FHLAT<br>0 |
| 45             | <b>HGENR</b><br>Reset Value | MSB<br>0   | 0<br>0      | 0<br>0     | 0<br>0      | 0<br>0     | 0<br>0       | 0<br>0      | LSB<br>0    |
| 46             | <b>VGENR</b><br>Reset Value | MSB<br>0   | 0<br>0      | 0<br>0     | 0<br>0      | 0<br>0     | 0<br>0       | 0<br>0      | LSB<br>0    |
| 47             | <b>ENR</b><br>Reset Value   | SYNOP<br>1 | CLMPEN<br>1 | BLKEN<br>0 | HVGEN<br>0  | 2FHEN<br>0 | HINH<br>0    | HSIN1<br>1  | VSIN1<br>1  |

## 4.5 TIMING MEASUREMENT UNIT (TMU)

### 4.5.1 Introduction

The timing measurement unit (TMU) allows the analysis of the current video timing characteristics in order to control display position and size.

It consists of measuring the timing between the horizontal or vertical sync output signals and the active video signal input (AV).

### 4.5.2 Main Features

- Horizontal or vertical timing measurement
- Oscillator clock  $f_{OSC}$  (24 or 12 MHz) used for horizontal measurement
- Horizontal sync signal (HSYNCO or HFBACK) and Vertical sync signal (VSYNCO or VFBACK) used for all measurements
- Measurements performed on positive signals only
- 11-bit counter
- Overflow detection

### 4.5.3 Functional Description

The Timing Measurement Unit is centered around an 11-bit counter. Depending on the H\_V bit of the control register, the TMU measures the horizontal or vertical video characteristics.

For horizontal analysis (refer to Figure 48):

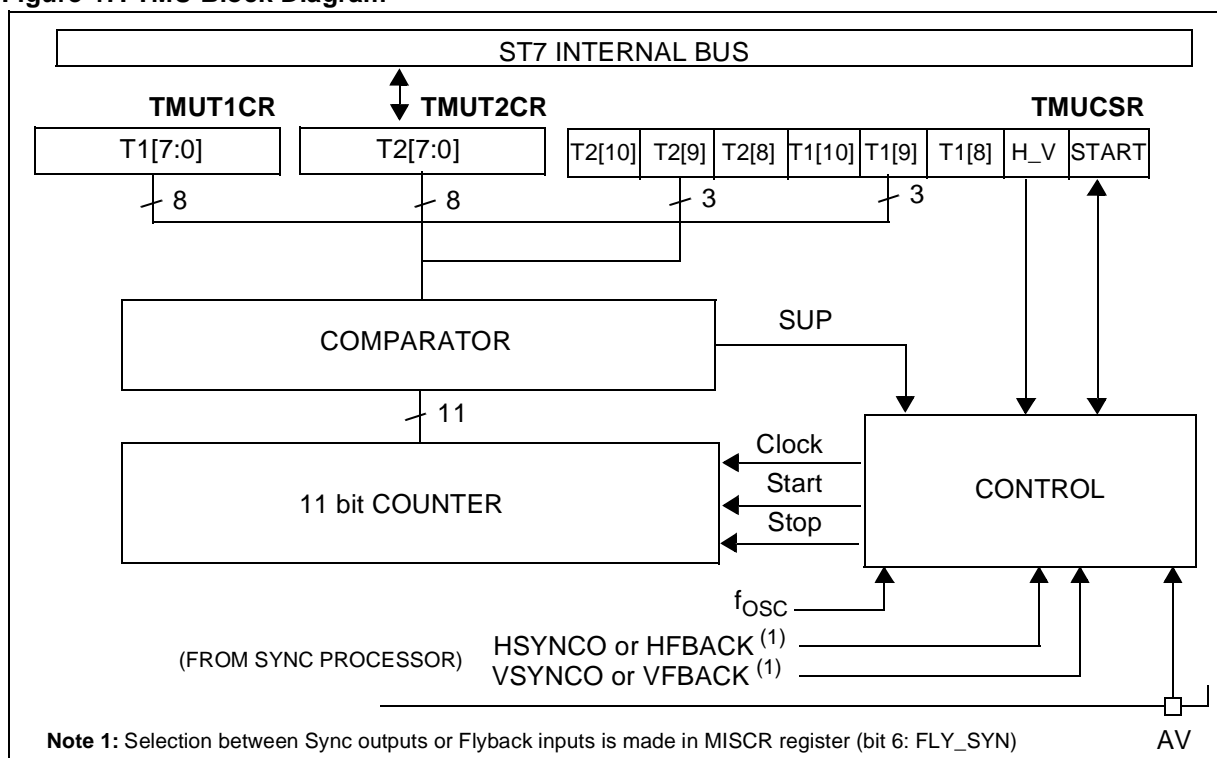
- Obtain the minimum number of oscillator clock cycles (H1) between the falling edge of the horizontal sync signal (HSYNCO or HFBACK) and the first rising edge of the active video input (AV), for all lines, between 2 consecutive vertical sync pulses.
- Obtain the minimum number of oscillator clock cycles (H2) between the last falling edge of the active video input (AV) and the rising edge of the horizontal sync signal (HSYNCO or HFBACK) for all lines, between 2 consecutive vertical sync pulses.

**Note:** Horizontal measurement is inhibited during the high level of VSYNCO or VFLYBACK.

For vertical analysis (refer to Figure 49):

- Obtain the minimum number of horizontal sync pulses (V1) between the falling edge of the vertical sync signal (VSYNCO or VFBACK) and the first rising edge of the active video input, during 2 consecutive frames.

Figure 47. TMU Block Diagram



**TIMING MEASUREMENT UNIT (Cont'd)**

- Obtain the minimum number of horizontal sync output pulses (V2) between the last falling edge of the active video input (AV) and the rising edge of the vertical sync signal (VSYNCO or VFBACK) during two consecutive frames.

The H\_V bit selects horizontal or vertical measurement. This selection should be made prior to starting the measurement by setting the START bit. This bit is set by software but only cleared by hardware at the end of the measurement.

When the measurement is finished (rising edge of AV, horizontal or vertical sync signals), the results (T1,T2) are transferred into the corresponding registers (H1,H2) or (V1,V2).

**Note:** The values of the H1/H2 or V1/V2 registers are available only at the end of a measurement (after the START bit has been cleared).

**4.5.3.1 Horizontal Measurement**

When the H\_V bit = 1, and when the START bit is set by software, the measurement starts after the next vertical sync pulse. The TMU searches the minimum values of H1 and H2 until the rising edge of the next following vertical sync pulse. The START bit is then cleared by hardware.

The values of the H1 and H2 registers are available only at the end of a measurement, in other words when the START bit is at 0.

**4.5.3.2 Vertical Measurement**

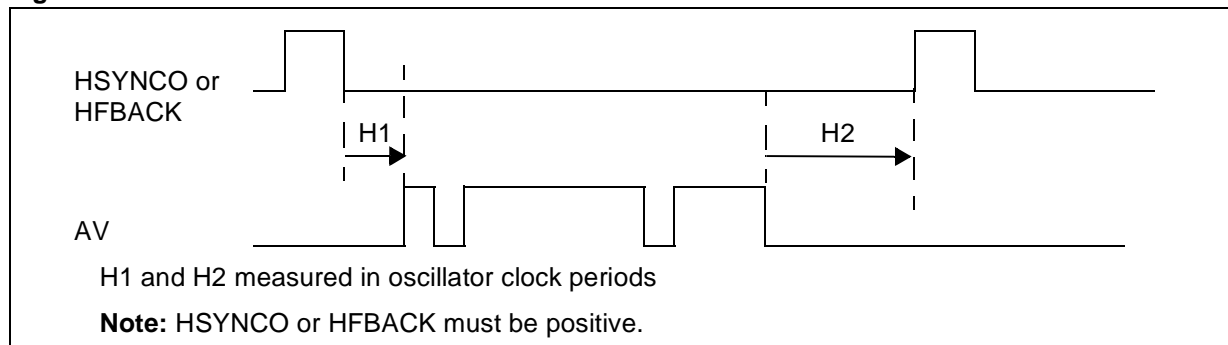
When the H\_V bit = 0 and, when the START bit is set by software, the TMU measures the minimum V1 and V2 values during 2 consecutive vertical frames. The START bit is then cleared by hardware.

**4.5.3.3 Special cases**

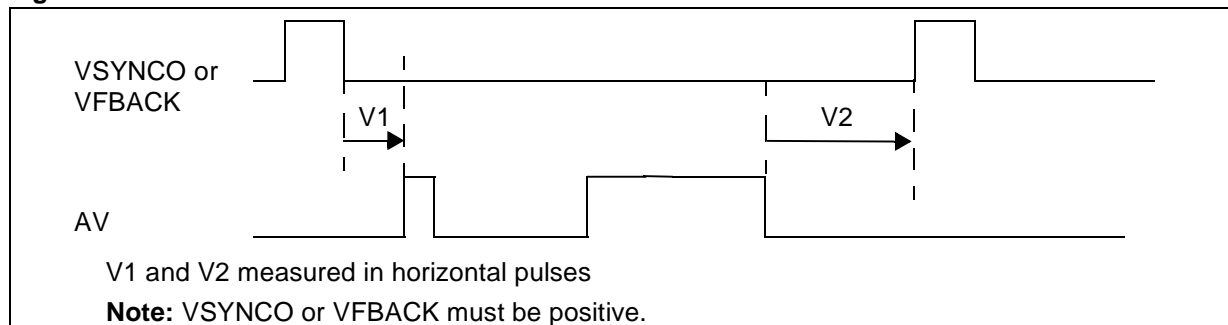
- If an overflow of the counter occurs during any of the measurements, the measured T1 or T2 values will be 7FFh.
- If the AV signal is always low (no active video), the measured T1 or T2 values will also be 7FFh.
- If  $T1 \leq 0$  (AV already high when the falling edge of the sync signal occurs), the measured T1 value will be fixed to 1.
- If  $T2 \leq 0$  (AV still high when the rising edge of the sync signal occurs), a specific T2 value will be returned.

**Note:** Refer to Application Note AN1183 for further details.

**Figure 48. Horizontal Measurement**



**Figure 49. Vertical Measurement**

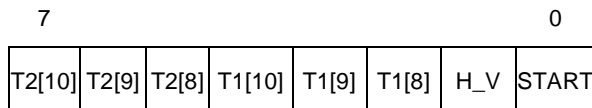


**TIMING MEASUREMENT UNIT (Cont'd)****4.5.4 Register Description****CONTROL STATUS REGISTER (TMUCSR)**

Bit 7:2 - Read only

Bit 1:0 - Read/Write

Reset Value: 1111 1100 (FCh)

Bit 7:5 = **T2[10:8]** MSB of T2 Counter.

Most Significant Bits of the T2 counter value (see T2 Counter register description).

Bit 4:2 = **T1[10:8]** MSB T1 Counter.

Most Significant Bits of the T1 counter value (see T1 Counter register description).

Bit 1 = **H\_V** Horizontal or Vertical Measurement.

This bit is set and cleared by software to select the type of measurement. It cannot be modified while the START bit = 1 (measurement in progress).

0: Vertical measurement.

1: Horizontal measurement.

Bit 0 = **START** Start measurement.

This bit is set by software and cleared by hardware when the measurements are completed. It can not be cleared by software.

0: Measurement done.

1: Start measurement.

**T1 COUNTER REGISTER (TMUT1CR)**

Read Only

Reset Value: 1111 1111 (FFh)

This is an 8-bit register that contains the low part of the counter value.



When a T1 measurement is finished (rising edge on AV input), the 11-bit counter value is transferred to this register and to the T1[10:8] bits in the CSR register.

T1 is H1 value if the H\_V bit = 1.

T1 is V1 value if the H\_V bit = 0.

**T2 COUNTER REGISTER (TMUT2CR)**

Read Only

Reset Value: 1111 1111(FFh)

This is an 8-bit register that contains the low part of the counter value.



When a T2 measurement is finished (rising edge on the selected sync signal), the 11-bit counter value is transferred to this register and to the T2[10:8] bits in the CSR register.

T2 is H2 value if the H\_V bit = 1.

T2 is V2 value if the H\_V bit = 0.

## TIMING MEASUREMENT UNIT (Cont'd)

Table 22. TMU Register Map and Reset Values

| Address<br>(Hex.) | Register<br>Name           | 7           | 6          | 5          | 4           | 3          | 2          | 1        | 0          |
|-------------------|----------------------------|-------------|------------|------------|-------------|------------|------------|----------|------------|
| 0E                | <b>CSR</b><br>Reset Value  | T2[10]<br>1 | T2[9]<br>1 | T2[8]<br>1 | T1[10]<br>1 | T1[9]<br>1 | T1[8]<br>1 | H_V<br>0 | START<br>0 |
| 0F                | <b>T1CR</b><br>Reset Value | T1[7]<br>1  | 1          | 1          | 1           | 1          | 1          | 1        | T1[0]<br>1 |
| 10                | <b>T2CR</b><br>Reset Value | T2[7]<br>1  | 1          | 1          | 1           | 1          | 1          | 1        | T2[0]<br>1 |

## 4.6 USB INTERFACE (USB)

### 4.6.1 Introduction

The USB Interface implements a low-speed function interface between the USB and the ST7 microcontroller. It is a highly integrated circuit which includes the transceiver, 3.3 voltage regulator, SIE and DMA. No external components are needed apart from the external pull-up on USBDM for low speed recognition by the USB host.

### 4.6.2 Main Features

- USB Specification Version 1.0 Compliant
- Supports Low-Speed USB Protocol
- Two or Three Endpoints (including default one) depending on the device (see device feature list and register map)
- CRC generation/checking, NRZI encoding/decoding and bit-stuffing
- USB Suspend/Resume operations
- DMA Data transfers
- On-Chip 3.3V Regulator
- On-Chip USB Transceiver

### 4.6.3 Functional Description

The block diagram in Figure 50, gives an overview of the USB interface hardware.

For general information on the USB, refer to the "Universal Serial Bus Specifications" document available at <http://www.usb.org>.

### Serial Interface Engine

The SIE (Serial Interface Engine) interfaces with the USB, via the transceiver.

The SIE processes tokens, handles data transmission/reception, and handshaking as required by the USB standard. It also performs frame formatting, including CRC generation and checking.

### Endpoints

The Endpoint registers indicate if the microcontroller is ready to transmit/receive, and how many bytes need to be transmitted.

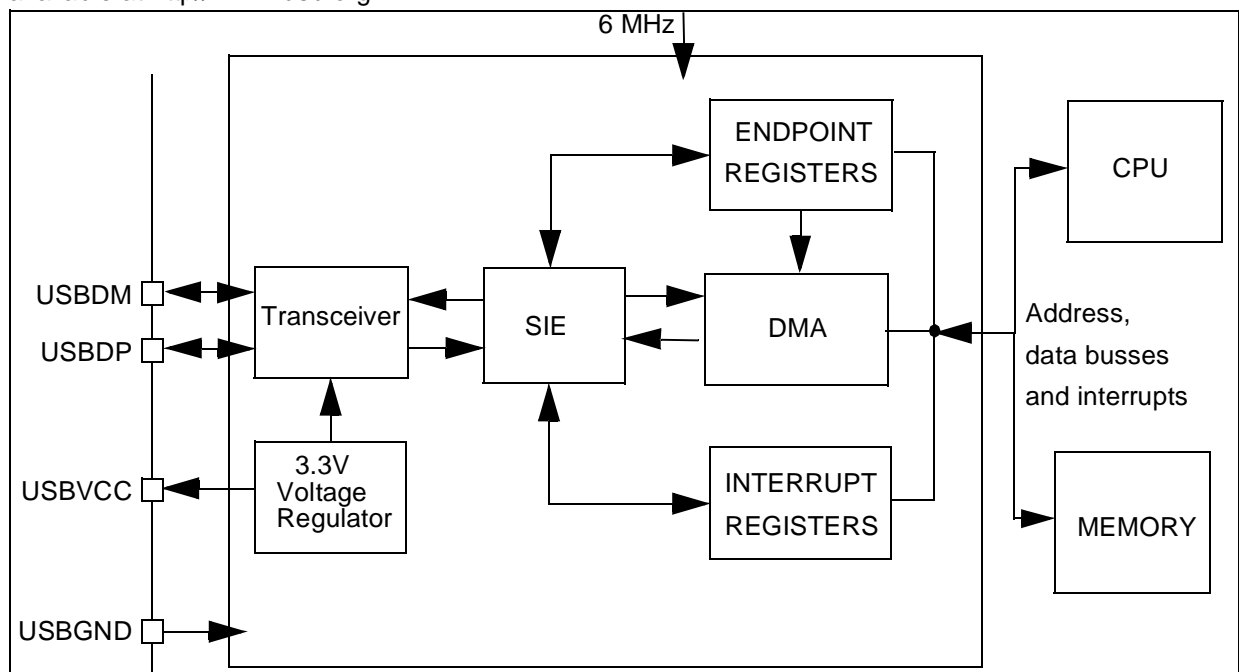
### DMA

When a token for a valid Endpoint is recognized by the USB interface, the related data transfer takes place, using DMA. At the end of the transaction, an interrupt is generated.

### Interrupts

By reading the Interrupt Status register, application software can know which USB event has occurred.

Figure 50. USB block diagram



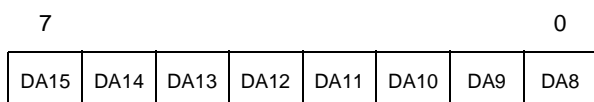
USB INTERFACE (Cont'd)

4.6.4 Register Description

DMA ADDRESS REGISTER (DMAR)

Read / Write

Reset Value: Undefined

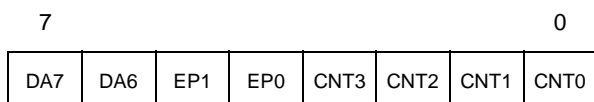


Bits 7:0=DA[15:8] DMA address bits 15-8.  
See the description of bits DA7-6 in the next register (IDR).

INTERRUPT/DMA REGISTER (IDR)

Read / Write

Reset Value: xxxx 0000 (x0h)



Bits 7:6 = DA[7:6] DMA address bits 7-6.  
The software must write the start address of the DMA memory area whose most significant bits are given by DA15-DA6. The remaining 6 address bits are set by hardware. See Figure 51.

Bits 5:4 = EP[1:0] Endpoint number (read-only).  
These bits identify the endpoint which required attention.

- 00: Endpoint 0
- 01: Endpoint 1
- 10: Endpoint 2

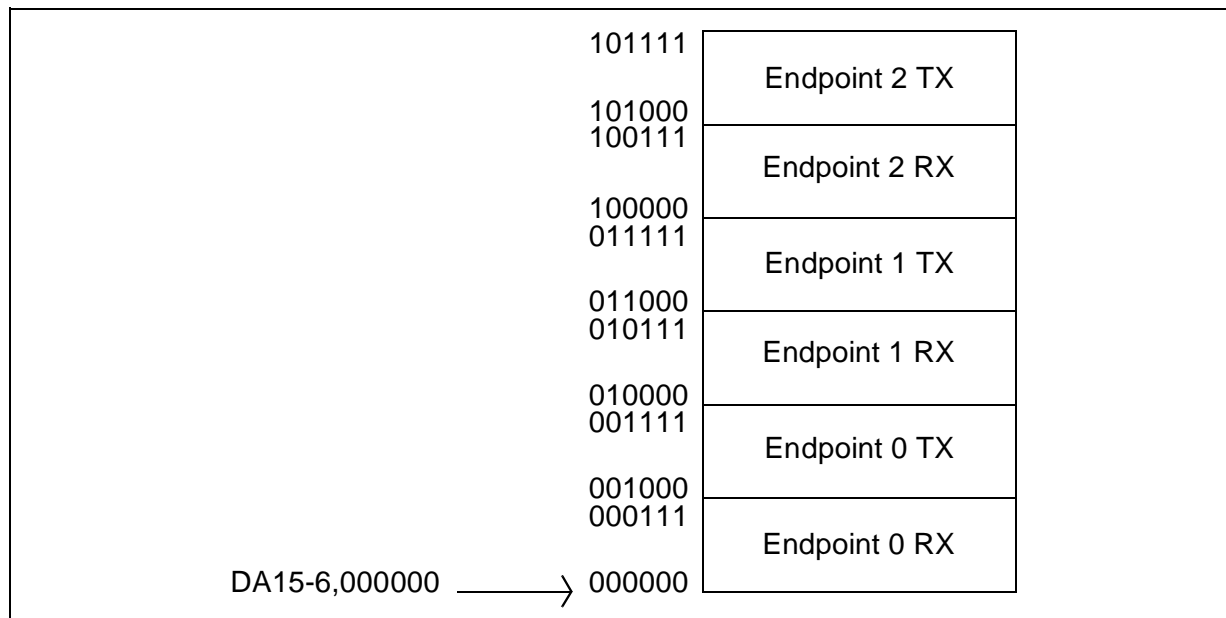
When a CTR interrupt occurs (see register ISTR) the software should read the EP bits to identify the endpoint which has sent or received a packet.

Bits 3:0 = CNT[3:0] Byte count (read only).

This field shows how many data bytes have been received during the last data reception.

**Note:** Not valid for data transmission.

Figure 51. DMA buffers





**USB INTERFACE (Cont'd)**  
**PID REGISTER (PIDR)**

Read only

Reset Value: xx00 0000 (x0h)

|     |     |   |   |   |   |   |   |
|-----|-----|---|---|---|---|---|---|
| 7   |     |   |   |   |   |   | 0 |
| TP3 | TP2 | 0 | 0 | 0 | 0 | 0 | 0 |

Bits 7:6 = **TP3-TP2** *Token PID bits 3 & 2*.  
 USB token PIDs are encoded in four bits. **TP3-TP2** correspond to the variable token PID bits 3 & 2.

**Note:** PID bits 1 & 0 have a fixed value of 01.  
 When a CTR interrupt occurs (see register ISTR) the software should read the TP3 and TP2 bits to retrieve the PID name of the token received.

The USB standard defines TP bits as:

| TP3 | TP2 | PID Name |
|-----|-----|----------|
| 0   | 0   | OUT      |
| 1   | 0   | IN       |
| 1   | 1   | SETUP    |

Bit 5:0 Reserved. Forced by hardware to 0.

**INTERRUPT STATUS REGISTER (ISTR)**

Read / Write

Reset Value: 0000 0000 (00h)

|   |      |     |     |      |       |       |     |
|---|------|-----|-----|------|-------|-------|-----|
| 7 |      |     |     |      |       |       | 0   |
| 0 | DOVR | CTR | ERR | IOVR | ESUSP | RESET | SOF |

When an interrupt occurs these bits are set by hardware. Software must read them to determine the interrupt type and clear them after servicing.

**Note:** These bits cannot be set by software.

Bit 7 = Reserved. Forced by hardware to 0.

Bit 6 = **DOVR** *DMA over/underrun*.  
 This bit is set by hardware if the ST7 processor can't answer a DMA request in time.

- 0: No over/underrun detected
- 1: Over/underrun detected

Bit 5 = **CTR** *Correct Transfer*. This bit is set by hardware when a correct transfer operation is performed. The type of transfer can be determined by looking at bits TP3-TP2 in register PIDR. The Endpoint on which the transfer was made is identified by bits EP1-EP0 in register IDR.

- 0: No Correct Transfer detected
- 1: Correct Transfer detected

**Note:** A transfer where the device sent a NAK or STALL handshake is considered not correct (the host only sends ACK handshakes). A transfer is considered correct if there are no errors in the PID and CRC fields, if the DATA0/DATA1 PID is sent as expected, if there were no data overruns, bit stuffing or framing errors.

Bit 4 = **ERR** *Error*.  
 This bit is set by hardware whenever one of the errors listed below has occurred:

- 0: No error detected
- 1: Timeout, CRC, bit stuffing or nonstandard framing error detected

Bit 3 = **IOVR** *Interrupt overrun*.  
 This bit is set when hardware tries to set ERR, ESUSP or SOF before they have been cleared by software.

- 0: No overrun detected
- 1: Overrun detected

Bit 2 = **ESUSP** *End suspend mode*.  
 This bit is set by hardware when, during suspend mode, activity is detected that wakes the USB interface up from suspend mode.

This interrupt is serviced by a specific vector.

- 0: No End Suspend detected
- 1: End Suspend detected

Bit 1 = **RESET** *USB reset*.  
 This bit is set by hardware when the USB reset sequence is detected on the bus.

- 0: No USB reset signal detected
- 1: USB reset signal detected

**Note:** The DADDR, EP0RA, EP0RB, EP1RA, EP1RB, EP2RA and EP2RB registers are reset by a USB reset.

**USB INTERFACE (Cont'd)**

Bit 0 = **SOF** *Start of frame*.

This bit is set by hardware when a low-speed SOF indication (keep-alive strobe) is seen on the USB bus.

- 0: No SOF signal detected
- 1: SOF signal detected

**Note:** To avoid spurious clearing of some bits, it is recommended to clear them using a load instruction where all bits which must not be altered are set, and all bits to be cleared are reset. Avoid read-modify-write instructions like AND , XOR..

**INTERRUPT MASK REGISTER (IMR)**

Read / Write

Reset Value: 0000 0000 (00h)

|   |           |          |          |           |            |            |          |  |   |
|---|-----------|----------|----------|-----------|------------|------------|----------|--|---|
|   |           |          |          |           |            |            |          |  |   |
| 7 |           |          |          |           |            |            |          |  | 0 |
| 0 | DOV<br>RM | CTR<br>M | ERR<br>M | IOVR<br>M | ESU<br>SPM | RES<br>ETM | SOF<br>M |  |   |

Bit 7 = Reserved. Forced by hardware to 0.

Bits 6:0 = These bits are mask bits for all interrupt condition bits included in the ISTR. Whenever one of the IMR bits is set, if the corresponding ISTR bit is set, and the I bit in the CC register is cleared, an interrupt request is generated. For an explanation of each bit, please refer to the corresponding bit description in ISTR.

**CONTROL REGISTER (CTLR)**

Read / Write

Reset Value: 0000 0110 (06h)

|   |   |   |   |        |      |      |      |  |   |
|---|---|---|---|--------|------|------|------|--|---|
|   |   |   |   |        |      |      |      |  |   |
| 7 |   |   |   |        |      |      |      |  | 0 |
| 0 | 0 | 0 | 0 | RESUME | PDWN | SUSP | FRES |  |   |

Bits 7:4 = Reserved. Forced by hardware to 0.

Bit 3 = **RESUME** *Resume*.

This bit is set by software to wake-up the Host when the ST7 is in suspend mode.

- 0: Resume signal not forced
- 1: Resume signal forced on the USB bus.

Software should clear this bit after the appropriate delay.

Bit 2 = **PDWN** *Power down*.

This bit is set by software to turn off the 3.3V on-chip voltage regulator that supplies the external pull-up resistor and the transceiver.

- 0: Voltage regulator on
- 1: Voltage regulator off

**Note:** After turning on the voltage regulator, software should allow at least 3 μs for stabilisation of the power supply before using the USB interface.

Bit 1 = **SUSP** *Suspend mode*.

This bit is set by software to enter Suspend mode.

- 0: Suspend mode inactive
- 1: Suspend mode active

When the hardware detects USB activity, it resets this bit (it can also be reset by software).

Bit 0 = **FRES** *Force reset*.

This bit is set by software to force a reset of the USB interface, just as if a RESET sequence came from the USB.

- 0: Reset not forced
- 1: USB interface reset forced.

The USB is held in RESET state until software clears this bit, at which point a “USB-RESET” interrupt will be generated if enabled.

**DEVICE ADDRESS REGISTER (DADDR)**

Read / Write

Reset Value: 0000 0000 (00h)

|   |      |      |      |      |      |      |      |  |   |
|---|------|------|------|------|------|------|------|--|---|
|   |      |      |      |      |      |      |      |  |   |
| 7 |      |      |      |      |      |      |      |  | 0 |
| 0 | ADD6 | ADD5 | ADD4 | ADD3 | ADD2 | ADD1 | ADD0 |  |   |

Bit 7 = Reserved. Forced by hardware to 0.

Bits 6:0 = **ADD[6:0]** *Device address, 7 bits*.

Software must write into this register the address sent by the host during enumeration.

**Note:** This register is also reset when a USB reset is received from the USB bus or forced through bit FRES in the CTLR register.

**USB INTERFACE (Cont'd)**  
**ENDPOINT n REGISTER A (EPnRA)**

Read / Write

Reset Value: 0000 xxxx (0xh)

|            |                 |                          |                          |                  |                  |                  |                  |
|------------|-----------------|--------------------------|--------------------------|------------------|------------------|------------------|------------------|
| 7          |                 |                          |                          |                  |                  |                  | 0                |
| ST_<br>OUT | D<br>TOG<br>_TX | S<br>T<br>A<br>T<br>_TX1 | S<br>T<br>A<br>T<br>_TX0 | T<br>B<br>C<br>3 | T<br>B<br>C<br>2 | T<br>B<br>C<br>1 | T<br>B<br>C<br>0 |

These registers (**EP0RA**, **EP1RA** and **EP2RA**) are used for controlling data transmission. They are also reset by the USB bus reset.

**Note:** Endpoint 2 and the EP2RA register are not available on some devices (see device feature list and register map).

Bit 7 = **ST\_OUT** *Status out.*

This bit is set by software to indicate that a status out packet is expected: in this case, all nonzero OUT data transfers on the endpoint are STALLED instead of being ACKed. When ST\_OUT is reset, OUT transactions can have any number of bytes, as needed.

Bit 6 = **DTOG\_TX** *Data Toggle, for transmission transfers.*

It contains the required value of the toggle bit (0=DATA0, 1=DATA1) for the next transmitted data packet. This bit is set by hardware at the reception of a SETUP PID. DTOG\_TX toggles only when the transmitter has received the ACK signal from the USB host. DTOG\_TX and also DTOG\_RX (see EPnRB) are normally updated by hardware, at the receipt of a relevant PID. They can be also written by software.

Bits 5:4 = **STAT\_TX[1:0]** *Status bits, for transmission transfers.*

These bits contain the information about the endpoint status, which are listed below:

| STAT_TX1 | STAT_TX0 | Meaning                                                                                          |
|----------|----------|--------------------------------------------------------------------------------------------------|
| 0        | 0        | <b>DISABLED:</b> transmission transfers cannot be executed.                                      |
| 0        | 1        | <b>STALL:</b> the endpoint is stalled and all transmission requests result in a STALL handshake. |
| 1        | 0        | <b>NAK:</b> the endpoint is naked and all transmission requests result in a NAK handshake.       |
| 1        | 1        | <b>VALID:</b> this endpoint is enabled for transmission.                                         |

These bits are written by software. Hardware sets the STAT\_TX bits to NAK when a correct transfer has occurred (CTR=1) related to a IN or SETUP transaction addressed to this endpoint; this allows the software to prepare the next set of data to be transmitted.

Bits 3:0 = **TBC[3:0]** *Transmit byte count for Endpoint n.*

Before transmission, after filling the transmit buffer, software must write in the TBC field the transmit packet size expressed in bytes (in the range 0-8).

## ST72774/ST727754/ST72734

### USB INTERFACE (Cont'd) ENDPOINT n REGISTER B (EPnRB)

Read / Write

Reset Value: 0000 xxxx (0xh)

|              |                 |
|--------------|-----------------|
| 7            | 0               |
| CTRL         | D<br>TOG<br>_RX |
| STAT<br>_RX1 | STAT<br>_RX0    |
| EA3          | EA2             |
| EA1          | EA0             |

These registers (**EP1RB** and **EP2RB**) are used for controlling data reception on Endpoints 1 and 2. They are also reset by the USB bus reset.

**Note:** Endpoint 2 and the EP2RB register are not available on some devices (see device feature list and register map).

Bit 7 = **CTRL** Control.

This bit should be 0.

**Note:** If this bit is 1, the Endpoint is a control endpoint. (Endpoint 0 is always a control Endpoint, but it is possible to have more than one control Endpoint).

Bit 6 = **DTOG\_RX** Data toggle, for reception transfers.

It contains the expected value of the toggle bit (0=DATA0, 1=DATA1) for the next data packet. This bit is cleared by hardware in the first stage (Setup Stage) of a control transfer (SETUP transactions start always with DATA0 PID). The receiver toggles DTOG\_RX only if it receives a correct data packet and the packet's data PID matches the receiver sequence bit.

Bit 5:4 = **STAT\_RX [1:0]** Status bits, for reception transfers.

These bits contain the information about the endpoint status, which are listed in the following table:

| STAT_RX1 | STAT_RX0 | Meaning                                                                                       |
|----------|----------|-----------------------------------------------------------------------------------------------|
| 0        | 0        | <b>DISABLED:</b> reception transfers cannot be executed.                                      |
| 0        | 1        | <b>STALL:</b> the endpoint is stalled and all reception requests result in a STALL handshake. |
| 1        | 0        | <b>NAK:</b> the endpoint is naked and all reception requests result in a NAK handshake.       |
| 1        | 1        | <b>VALID:</b> this endpoint is enabled for reception.                                         |

These bits are written by software. Hardware sets the STAT\_RX bits to NAK when a correct transfer has occurred (CTR=1) related to an OUT or SETUP transaction addressed to this endpoint, so the software has the time to elaborate the received data before acknowledging a new transaction.

Bits 3:0 = **EA[3:0]** Endpoint address.

Software must write in this field the 4-bit address used to identify the transactions directed to this endpoint. Usually EP1RB contains "0001" and EP2RB contains "0010".

### ENDPOINT 0 REGISTER B (EP0RB)

Read / Write

Reset Value: 1000 0000 (80h)

|             |                |
|-------------|----------------|
| 7           | 0              |
| 1           | D<br>TOG<br>RX |
| STAT<br>RX1 | STAT<br>RX0    |
| 0           | 0              |
| 0           | 0              |
| 0           | 0              |

This register is used for controlling data reception on Endpoint 0. It is also reset by the USB bus reset.

Bit 7 = Forced by hardware to 1.

Bit 6:4 = Refer to the EPnRB register for a description of these bits.

Bit 3:0 = Forced by hardware to 0.

**USB INTERFACE (Cont'd)****4.6.5 Programming Considerations**

In the following, the interaction between the USB interface and the application program is described. Apart from system reset, action is always initiated by the USB interface, driven by one of the USB events associated with the Interrupt Status Register (ISTR) bits.

**4.6.5.1 Initializing the Registers**

At system reset, the software must initialize all registers to enable the USB interface to properly generate interrupts and DMA requests.

1. Initialize the DMAR, IDR, and IMR registers (choice of enabled interrupts, address of DMA buffers). Refer the paragraph titled initializing the DMA Buffers.
2. Initialize the EP0RA and EP0RB registers to enable accesses to address 0 and endpoint 0 to support USB enumeration. Refer to the paragraph titled Endpoint Initialization.
3. When addresses are received through this channel, update the content of the DADDR.
4. If needed, write the endpoint numbers in the EA fields in the EP1RB and EP2RB register.

**4.6.5.2 Initializing DMA buffers**

The DMA buffers are a contiguous zone of memory whose maximum size is 48 bytes. They can be placed anywhere in the memory space, typically in RAM, to enable the reception of messages. The 10 most significant bits of the start of this memory area are specified by bits DA15-DA6 in registers DMAR and IDR, the remaining bits are 0. The memory map is shown in Figure 51.

Each buffer is filled starting from the bottom (last 3 address bits=000) up.

**4.6.5.3 Endpoint Initialization**

To be ready to receive:

Set STAT\_RX to VALID (11b) in EP0RB to enable reception.

To be ready to transmit:

1. Write the data in the DMA transmit buffer.
2. In register EPnRA, specify the number of bytes to be transmitted in the TBC field

3. Enable the endpoint by setting the STAT\_TX bits to VALID (11b) in EPnRA.

**Note:** Once transmission and/or reception are enabled, registers EPnRA and/or EPnRB (respectively) must not be modified by software, as the hardware can change their value on the fly.

When the operation is completed, they can be accessed again to enable a new operation.

**4.6.5.4 Interrupt Handling****Start of Frame (SOF)**

The interrupt service routine must monitor the SOF events and measure the interval between each SOF event. If 3ms pass without a SOF event, the software should set the USB interface to suspend mode.

**USB Reset (RESET)**

When this event occurs, the DADDR register is reset, and communication is disabled in all endpoint registers (the USB interface will not respond to any packet). Software is responsible for reenabling endpoint 0 within 10 ms of the end of reset. To do this you set the STAT\_RX bits in the EP0RB register to VALID.

**End Suspend (ESUSP)**

The CPU is alerted by activity on the USB, which causes an ESUSP interrupt.

**Correct Transfer (CTR)**

1. When this event occurs, the hardware automatically sets the STAT\_TX or STAT\_RX to NAK.

**Note:** Every valid endpoint is NAKed until software clears the CTR bit in the ISTR register, independently of the endpoint number addressed by the transfer which generated the CTR interrupt.

**Note:** If the event triggering the CTR interrupt is a SETUP transaction, both STAT\_TX and STAT\_RX are set to NAK.

2. Read the PIDR to obtain the token and the IDR to get the endpoint number related to the last transfer.

**Note:** When a CTR interrupt occurs, the TP3-TP2 bits in the PIDR register and EP1-EP0 bits in the IDR register stay unchanged until the CTR bit in the ISTR register is cleared.

3. Clear the CTR bit in the ISTR register.

USB INTERFACE (Cont'd)

Table 23. USB Register Map and Reset Values

| Address (Hex.) | Register Name        | 7           | 6            | 5             | 4             | 3           | 2           | 1           | 0         |
|----------------|----------------------|-------------|--------------|---------------|---------------|-------------|-------------|-------------|-----------|
| 25             | PIDR<br>Reset Value  | TP3<br>x    | TP2<br>x     | 0<br>0        | 0<br>0        | RX_SEZ<br>0 | RXD<br>0    | 0<br>0      | 0<br>0    |
| 26             | DMAR<br>Reset Value  | DA15<br>x   | DA14<br>x    | DA13<br>x     | DA12<br>x     | DA11<br>x   | DA10<br>x   | DA9<br>x    | DA8<br>x  |
| 27             | IDR<br>Reset Value   | DA7<br>x    | DA6<br>x     | EP1<br>x      | EP0<br>x      | CNT3<br>0   | CNT2<br>0   | CNT1<br>0   | CNT0<br>0 |
| 28             | ISTR<br>Reset Value  | SUSP<br>0   | DOVR<br>0    | CTR<br>0      | ERR<br>0      | IOVR<br>0   | ESUSP<br>0  | RESET<br>0  | SOF<br>0  |
| 29             | IMR<br>Reset Value   | SUSPM<br>0  | DOVRM<br>0   | CTRM<br>0     | ERRM<br>0     | IOVRM<br>0  | ESUSPM<br>0 | RESETM<br>0 | SOFM<br>0 |
| 2A             | CTLR<br>Reset Value  | 0<br>0      | 0<br>0       | 0<br>0        | 0<br>0        | RESUME<br>0 | PDWN<br>1   | FSUSP<br>1  | FRES<br>0 |
| 2B             | DADDR<br>Reset Value | 0<br>0      | ADD6<br>0    | ADD5<br>0     | ADD4<br>0     | ADD3<br>0   | ADD2<br>0   | ADD1<br>0   | ADD0<br>0 |
| 2C             | EP0RA<br>Reset Value | ST_OUT<br>0 | DTOG_TX<br>0 | STAT_TX1<br>0 | STAT_TX0<br>0 | TBC3<br>x   | TBC2<br>x   | TBC1<br>x   | TBC0<br>x |
| 2D             | EP0RB<br>Reset Value | 1<br>1      | DTOG_RX<br>0 | STAT_RX1<br>0 | STAT_RX0<br>0 | 0<br>0      | 0<br>0      | 0<br>0      | 0<br>0    |
| 2E             | EP1RA<br>Reset Value | ST_OUT<br>0 | DTOG_TX<br>0 | STAT_TX1<br>0 | STAT_TX0<br>0 | TBC3<br>x   | TBC2<br>x   | TBC1<br>x   | TBC0<br>x |
| 2F             | EP1RB<br>Reset Value | CTRL<br>0   | DTOG_RX<br>0 | STAT_RX1<br>0 | STAT_RX0<br>0 | EA3<br>x    | EA2<br>x    | EA1<br>x    | EA0<br>x  |
| 30             | EP2RA<br>Reset Value | ST_OUT<br>0 | DTOG_TX<br>0 | STAT_TX1<br>0 | STAT_TX0<br>0 | TBC3<br>x   | TBC2<br>x   | TBC1<br>x   | TBC0<br>x |
| 31             | EP2RB<br>Reset Value | CTRL<br>0   | DTOG_RX<br>0 | STAT_RX1<br>0 | STAT_RX0<br>0 | EA3<br>x    | EA2<br>x    | EA1<br>x    | EA0<br>x  |

## 4.7 I<sup>2</sup>C SINGLE MASTER BUS INTERFACE (I2C)

### 4.7.1 Introduction

The I<sup>2</sup>C Bus Interface serves as an interface between the microcontroller and the serial I<sup>2</sup>C bus. It provides single master functions, and controls all I<sup>2</sup>C bus-specific sequencing, protocol and timing. It supports fast I<sup>2</sup>C mode (400kHz).

### 4.7.2 Main Features

- Parallel bus/I<sup>2</sup>C protocol converter
- Interrupt generation
- Standard I<sup>2</sup>C mode/Fast I<sup>2</sup>C mode
- 7-bit Addressing

#### ■ I<sup>2</sup>C single Master Mode

- End of byte transmission flag
- Transmitter/Receiver flag
- Clock generation

### 4.7.3 General Description

In addition to receiving and transmitting data, this interface converts it from serial to parallel format and vice versa, using either an interrupt or polled handshake. The interrupts are enabled or disabled by software. The interface is connected to the I<sup>2</sup>C bus by a data pin (SDAI) and by a clock pin (SCLI). It can be connected both with a standard I<sup>2</sup>C bus and a Fast I<sup>2</sup>C bus. This selection is made by software.

### Mode Selection

The interface can operate in the two following modes:

- Master transmitter/receiver
- By default, it is idle.

The interface automatically switches from idle to master after it generates a START condition and from master to idle after it generates a STOP condition.

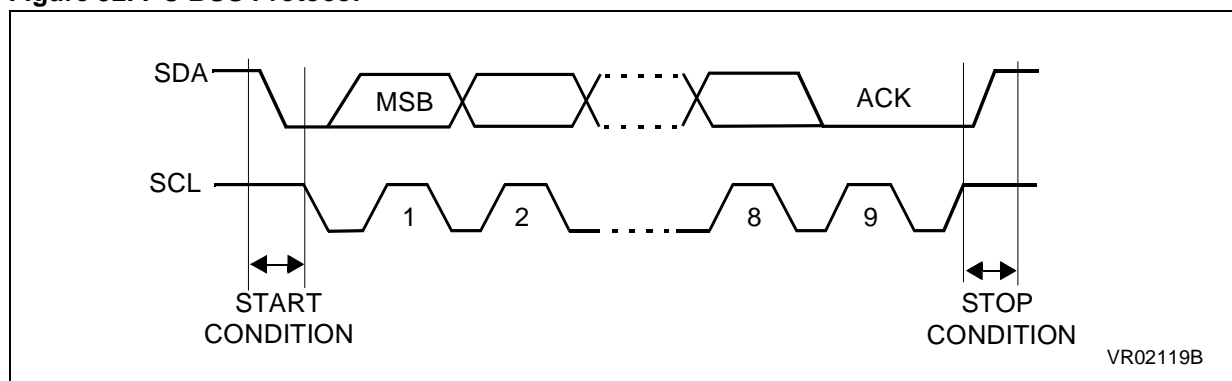
### Communication Flow

The interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a start condition and ends with a stop condition. Both start and stop conditions are generated by software.

Data and addresses are transferred as 8-bit bytes, MSB first. The first byte following the start condition is the address byte.

A 9th clock pulse follows the 8 clock cycles of a byte transfer, during which the receiver must send an acknowledge bit to the transmitter. Refer to Figure 52.

Figure 52. I<sup>2</sup>C BUS Protocol



**I<sup>2</sup>C SINGLE MASTER BUS INTERFACE (Cont'd)**

Acknowledge may be enabled and disabled by software.

The speed of the I<sup>2</sup>C interface may be selected between Standard (0-100KHz) and Fast I<sup>2</sup>C (100-400KHz).

**SDA/SCL Line Control**

**Transmitter mode:** the interface holds the clock line low before transmission to wait for the microcontroller to write the byte in the Data Register.

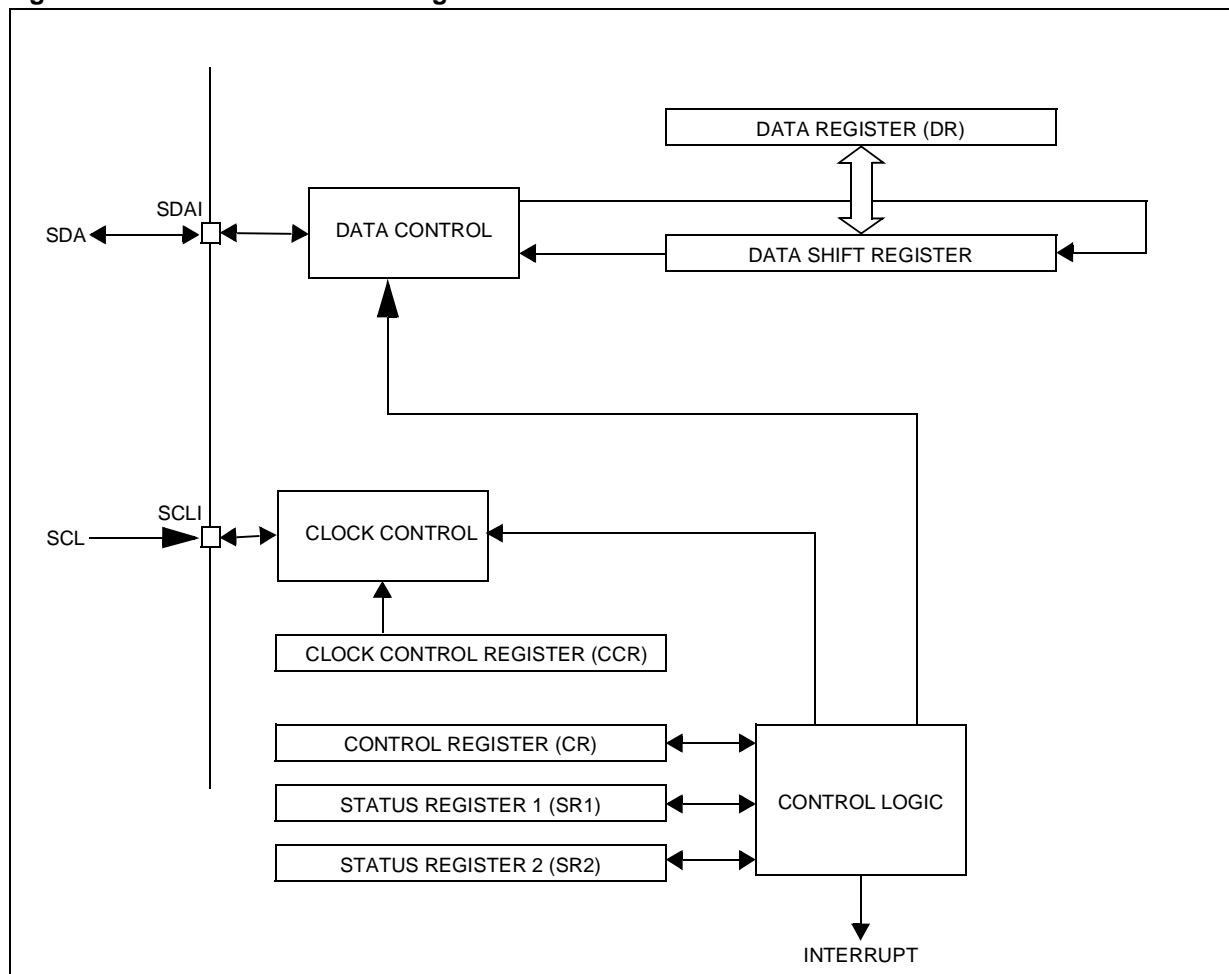
**Receiver mode:** the interface holds the clock line low after reception to wait for the microcontroller to read the byte in the Data Register.

The SCL frequency ( $F_{scl}$ ) is controlled by a programmable clock divider which depends on the I<sup>2</sup>C bus mode.

When the I2C cell is enabled, the SDA and SCL ports must be configured as floating open-drain output or floating input. In this case, the value of the external pull-up resistance used depends on the application.

When the I2C cell is disabled, the SDA and SCL ports revert to being standard I/O port pins.

**Figure 53. I<sup>2</sup>C Interface Block Diagram**





**I<sup>2</sup>C SINGLE MASTER BUS INTERFACE** (Cont'd)**4.7.4 Functional Description (Master Mode)**

Refer to the CR, SR1 and SR2 registers in Section 4.7.5. for the bit definitions.

By default the I<sup>2</sup>C interface operates in idle mode (M/IDL bit is cleared) except when it initiates a transmit or receive sequence.

To switch from default idle mode to Master mode a Start condition generation is needed.

**Start condition and Transmit Slave address**

Setting the START bit causes the interface to switch to Master mode (M/IDL bit set) and generates a Start condition.

Once the Start condition is sent:

- The EVF and SB bits are set by hardware with an interrupt if the ITE bit is set.
- Then the master waits for a read of the SR1 register followed by a write in the DR register with the Slave address byte, **holding the SCL line low** (see Figure 54 Transfer sequencing EV1).

Then the slave address byte is sent to the SDA line via the internal shift register.

After completion of this transfer (and acknowledge from the slave if the ACK bit is set):

- The EVF bit is set by hardware with interrupt generation if the ITE bit is set.
- Then the master waits for a read of the SR1 register followed by a write in the CR register (for example set PE bit), **holding the SCL line low** (see Figure 54 Transfer sequencing EV2).

Next the master must enter Receiver or Transmitter mode.

**Master Receiver**

Following the address transmission and after SR1 and CR registers have been accessed, the master receives bytes from the SDA line into the DR register via the internal shift register. After each byte the interface generates in sequence:

- Acknowledge pulse if the ACK bit is set
  - EVF and BTF bits are set by hardware with an interrupt if the ITE bit is set.
- Then the interface waits for a read of the SR1 register followed by a read of the DR register, **holding the SCL line low** (see Figure 54 Transfer sequencing EV3).

To close the communication: before reading the last byte from the DR register, set the STOP bit to generate the Stop condition. The interface goes automatically back to idle mode (M/IDL bit cleared).

**Note:** In order to generate the non-acknowledge pulse after the last received data byte, the ACK bit must be cleared just before reading the second last data byte.

**Master Transmitter**

Following the address transmission and after SR1 register has been read, the master sends bytes from the DR register to the SDA line via the internal shift register.

The master waits for a read of the SR1 register followed by a write in the DR register, **holding the SCL line low** (see Figure 54 Transfer sequencing EV4).

When the acknowledge bit is received, the interface sets:

- EVF and BTF bits with an interrupt if the ITE bit is set.
- To close the communication: after writing the last byte to the DR register, set the STOP bit to generate the Stop condition. The interface goes automatically back to idle mode (M/IDL bit cleared).

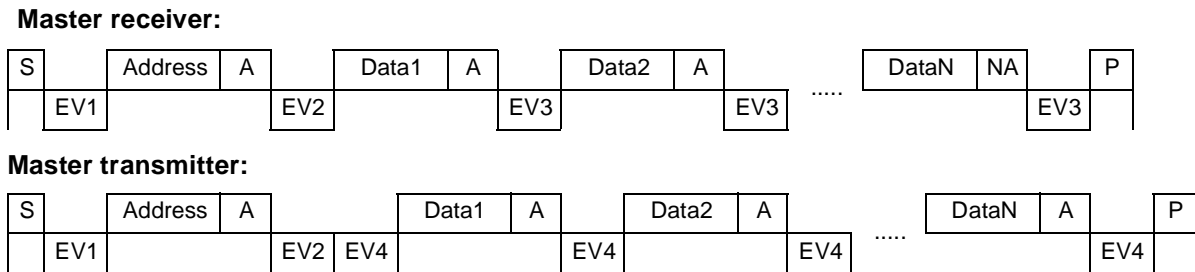
**Error Case**

- **AF:** Detection of a non-acknowledge bit. In this case, the EVF and AF bits are set by hardware with an interrupt if the ITE bit is set. To resume, set the START or STOP bit.

**Note:** The SCL line is not held low.

PC SINGLE MASTER BUS INTERFACE (Cont'd)

Figure 54. Transfer Sequencing



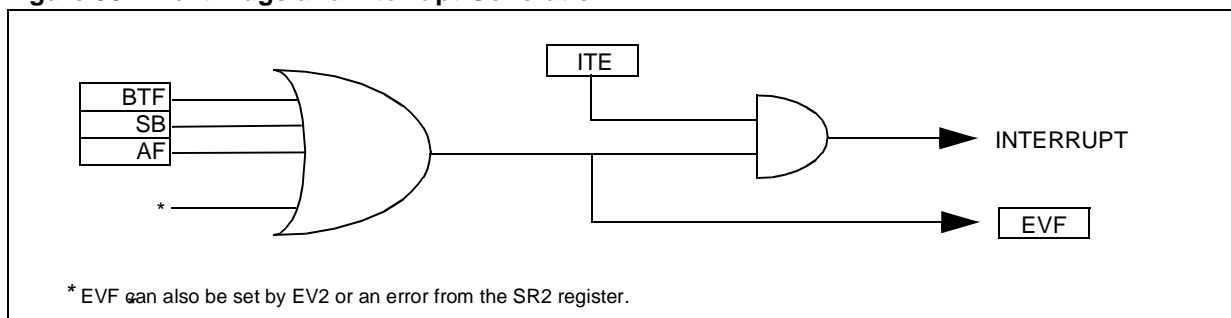
**Legend:**

S=Start, P=Stop, A=Acknowledge, NA=Non-acknowledge

EVx=Event (with interrupt if ITE=1)

- EV1:** EVF=1, SB=1, cleared by reading SR1 register followed by writing DR register.
- EV2:** EVF=1, cleared by reading SR1 register followed by writing CR register (for example PE=1).
- EV3:** EVF=1, BTF=1, cleared by reading SR1 register followed by reading DR register.
- EV4:** EVF=1, BTF=1, cleared by reading SR1 register followed by writing DR register.

Figure 55. Event Flags and Interrupt Generation



**I<sup>2</sup>C SINGLE MASTER BUS INTERFACE** (Cont'd)**4.7.5 Register Description****I<sup>2</sup>C CONTROL REGISTER (CR)**

Read / Write

Reset Value: 0000 0000 (00h)

|   |   |    |   |       |     |      |     |
|---|---|----|---|-------|-----|------|-----|
| 7 |   |    |   |       |     |      | 0   |
| 0 | 0 | PE | 0 | START | ACK | STOP | ITE |

Bit 7:6 = Reserved. Forced to 0 by hardware.

Bit 5 = **PE** *Peripheral enable*.

This bit is set and cleared by software.

- 0: Peripheral disabled
- 1: Master capability

**Note:** When PE=0, all the bits of the CR register and the SR register except the Stop bit are reset. All outputs are released while PE=0

**Note:** When PE=1, the corresponding I/O pins are selected by hardware as alternate functions.

**Note:** To enable the I<sup>2</sup>C interface, write the CR register **TWICE** with PE=1 as the first write only activates the interface (only PE is set).

Bit 4 = Reserved. Forced to 0 by hardware.

Bit 3 = **START** *Generation of a Start condition*.

This bit is set and cleared by software. It is also cleared by hardware when the interface is disabled (PE=0) or when the Start condition is sent (with interrupt generation if ITE=1).

In master mode:

- 0: No start generation
- 1: Repeated start generation

In idle mode:

- 0: No start generation
- 1: Start generation when the bus is free

Bit 2 = **ACK** *Acknowledge enable*.

This bit is set and cleared by software. It is also cleared by hardware when the interface is disabled (PE=0).

- 0: No acknowledge returned
- 1: Acknowledge returned after a data byte is received

Bit 1 = **STOP** *Generation of a Stop condition*.

This bit is set and cleared by software. It is also cleared by hardware when the interface is disabled (PE=0) or when the Stop condition is sent.

In Master mode only:

- 0: No stop generation
- 1: Stop generation after the current byte transfer or after the current Start condition is sent.

Bit 0 = **ITE** *Interrupt enable*.

This bit is set and cleared by software and cleared by hardware when the interface is disabled (PE=0).

- 0: Interrupts disabled
- 1: Interrupts enabled

Refer to Figure 55 for the relationship between the events and the interrupt. SCL is held low when the SB or BTF flags or an EV2 event (See Figure 54) is detected.

## ST72774/ST727754/ST72734

### I<sup>2</sup>C SINGLE MASTER BUS INTERFACE (Cont'd) I<sup>2</sup>C STATUS REGISTER 1 (SR1)

Read Only

Reset Value: 0000 0000 (00h)

|     |   |     |   |     |   |       |    |
|-----|---|-----|---|-----|---|-------|----|
| 7   |   |     |   |     |   |       | 0  |
| EVF | 0 | TRA | 0 | BTF | 0 | M/IDL | SB |

Bit 7 = **EVF** *Event flag*.

This bit is set by hardware as soon as an event occurs. It is cleared by software reading SR2 register in case of error event or as described in Figure 54. It is also cleared by hardware when the interface is disabled (PE=0).

- 0: No event
- 1: One of the following events has occurred:
  - BTF=1 (Byte received or transmitted)
  - SB=1 (Start condition generated)
  - AF=1 (No acknowledge received after byte transmission if ACK=1)
  - Address byte successfully transmitted.

Bit 6 = Reserved. Forced to 0 by hardware.

Bit 5 = **TRA** *Transmitter/Receiver*.

When BTF is set, TRA=1 if a data byte has been transmitted. It is cleared automatically when BTF is cleared. It is also cleared by hardware when the interface is disabled (PE=0).

- 0: Data byte received (if BTF=1)
- 1: Data byte transmitted

Bit 4 = Reserved. Forced to 0 by hardware.

Bit 3 = **BTF** *Byte transfer finished*.

This bit is set by hardware as soon as a byte is correctly received or transmitted with interrupt generation if ITE=1. It is cleared by software reading SR1 register followed by a read or write of DR register. It is also cleared by hardware when the interface is disabled (PE=0).

– Following a byte transmission, this bit is set after reception of the acknowledge clock pulse. In case an address byte is sent, this bit is set only after the EV2 event (See Figure 54). BTF is cleared by reading SR1 register followed by writing the next byte in DR register.

– Following a byte reception, this bit is set after transmission of the acknowledge clock pulse if ACK=1. BTF is cleared by reading SR1 register followed by reading the byte from DR register. The SCL line is held low while BTF=1.

- 0: Byte transfer not done
- 1: Byte transfer succeeded

Bit 2 = Reserved. Forced to 0 by hardware.

Bit 1 = **M/IDL** *Master/Idle*.

This bit is set by hardware as soon as the interface is in Master mode (writing START=1). It is cleared by hardware after generating a Stop condition on the bus. It is also cleared when the interface is disabled (PE=0).

- 0: Idle mode
- 1: Master mode

Bit 0 = **SB** *Start bit generated*.

This bit is set by hardware as soon as the Start condition is generated (following a write START=1). An interrupt is generated if ITE=1. It is cleared by software reading SR1 register followed by writing the address byte in DR register. It is also cleared by hardware when the interface is disabled (PE=0).

- 0: No Start condition
- 1: Start condition generated

**I<sup>2</sup>C SINGLE MASTER BUS INTERFACE (Cont'd)**  
**I<sup>2</sup>C STATUS REGISTER 2 (SR2)**

Read Only

Reset Value: 0000 0000 (00h)

|   |   |   |    |   |   |   |   |
|---|---|---|----|---|---|---|---|
| 7 |   |   |    |   |   |   | 0 |
| 0 | 0 | 0 | AF | 0 | 0 | 0 | 0 |

Bit 7:5 = Reserved. Forced to 0 by hardware.

Bit 4 = **AF Acknowledge failure.**

This bit is set by hardware when no acknowledge is returned. An interrupt is generated if ITE=1. It is cleared by software reading SR2 register or by hardware when the interface is disabled (PE=0).

The SCL line is not held low while AF=1.

0: No acknowledge failure

1: Acknowledge failure

Bit 3:0 = Reserved. Forced to 0 by hardware.

**I<sup>2</sup>C CLOCK CONTROL REGISTER (CCR)**

Read / Write

Reset Value: 0000 0000 (00h)

|       |     |     |     |     |     |     |     |
|-------|-----|-----|-----|-----|-----|-----|-----|
| 7     |     |     |     |     |     |     | 0   |
| FM/SM | CC6 | CC5 | CC4 | CC3 | CC2 | CC1 | CC0 |

Bit 7 = **FM/SM Fast/Standard I<sup>2</sup>C mode.**

This bit is set and cleared by software. It is not cleared when the interface is disabled (PE=0).

0: Standard I<sup>2</sup>C mode  
 1: Fast I<sup>2</sup>C mode

Bit 6:0 = **CC6-CC0 7-bit clock divider.**

These bits select the speed of the bus (F<sub>SCL</sub>) depending on the I<sup>2</sup>C mode. They are not cleared when the interface is disabled (PE=0).

– Standard mode (FM/SM=0): F<sub>SCL</sub> ≤ 100kHz  
 $F_{SCL} = F_{CPU} / (2 \times ([CC6..CC0] + 2))$

– Fast mode (FM/SM=1): F<sub>SCL</sub> > 100kHz  
 $F_{SCL} = F_{CPU} / (3 \times ([CC6..CC0] + 2))$

**Note:** The programmed F<sub>SCL</sub> assumes no load on SCL and SDA lines.

**I<sup>2</sup>C DATA REGISTER (DR)**

Read / Write

Reset Value: 0000 0000 (00h)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 7  |    |    |    |    |    |    | 0  |
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

Bit 7:0 = **D7-D0 8-bit Data Register.**

These bits contains the byte to be received or transmitted on the bus.

– Transmitter mode: Byte transmission start automatically when the software writes in the DR register.

– Receiver mode: the first data byte is received automatically in the DR register using the least significant bit of the address.

Then, the next data bytes are received one by one after reading the DR register.

## I2C SINGLE MASTER BUS INTERFACE (Cont'd)

Table 24. I<sup>2</sup>C Register Map

| Address<br>(Hex.) | Register<br>Name   | 7          | 6        | 5        | 4        | 3          | 2        | 1          | 0        |
|-------------------|--------------------|------------|----------|----------|----------|------------|----------|------------|----------|
| 5F                | CR<br>Reset Value  | 0          | 0        | PE<br>0  | 0        | START<br>0 | ACK<br>0 | STOP<br>0  | ITE<br>0 |
| 5E                | SR1<br>Reset Value | EVF<br>0   | 0        | TRA<br>0 | 0        | BTF<br>0   | 0        | M/IDL<br>0 | SB<br>0  |
| 5D                | SR2<br>Reset Value | 0          | 0        | 0        | AF<br>0  | 0          | 0        | 0          | 0        |
| 5C                | CCR<br>Reset Value | FM/SM<br>0 | CC6<br>0 | CC5<br>0 | CC4<br>0 | CC3<br>0   | CC2<br>0 | CC1<br>0   | CC0<br>0 |
| 59                | DR<br>Reset Value  | DR7<br>0   | DR6<br>0 | DR5<br>0 | DR4<br>0 | DR3<br>0   | DR2<br>0 | DR1<br>0   | DR0<br>0 |

## 4.8 DDC INTERFACE (DDC)

### 4.8.1 Introduction

The DDC (Display Data Channel) Bus Interface is mainly used by the monitor to identify itself to the video controller, by the monitor manufacturer to perform factory alignment, and by the user to adjust the monitor's parameters.

The DDC interface consists of two parts:

- A fully hardware-implemented interface, supporting DDC1 and DDC2B (VESA specification 3.0 compliant). It accesses the ST7 on-chip memory directly through a built-in DMA engine.
- A second interface, supporting the slave I<sup>2</sup>C functions for handling DDC/CI mode (DDC2Bi), factory alignment or Enhanced DDC (EDDC) by software.

### 4.8.2 DDC Interface Features

#### 4.8.2.1 Hardware DDC1/2B Interface Features

- Full hardware support for DDC1/2B communications (VESA specification versions 2 and 3)
- Hardware detection of DDC2B addresses A0h/A1h and optionally A2h/A3h (P&D) or A6h/A7h (FPDI-2)
- Separate mapping of EDID version 1 (128 bytes) and EDID version 2 (256 bytes) when both must coexist
- Support for error recovery mechanism
- Detection of misplaced Start and Stop conditions

- I<sup>2</sup>C byte, random and sequential read modes
- DMA transfer from any memory location and to RAM
- Automatic memory address incrementation
- End of data downloading flag and interrupt capability

#### 4.8.2.2 DDC/CI - Factory Interface Features

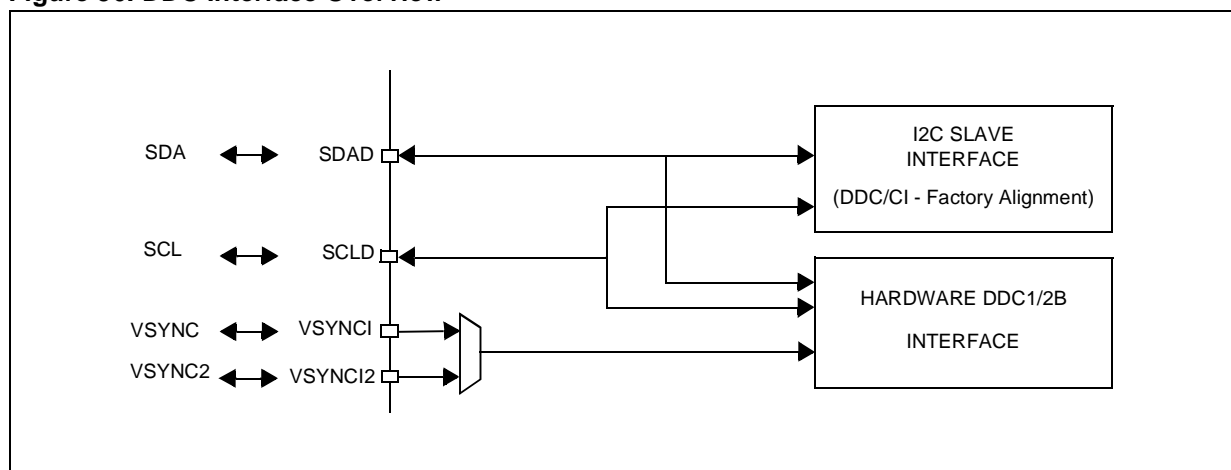
##### General I<sup>2</sup>C Features:

- Parallel bus/I<sup>2</sup>C protocol converter
- Interrupt generation
- Standard I<sup>2</sup>C mode/Fast I<sup>2</sup>C mode
- 7-bit Addressing

##### I<sup>2</sup>C Slave Features:

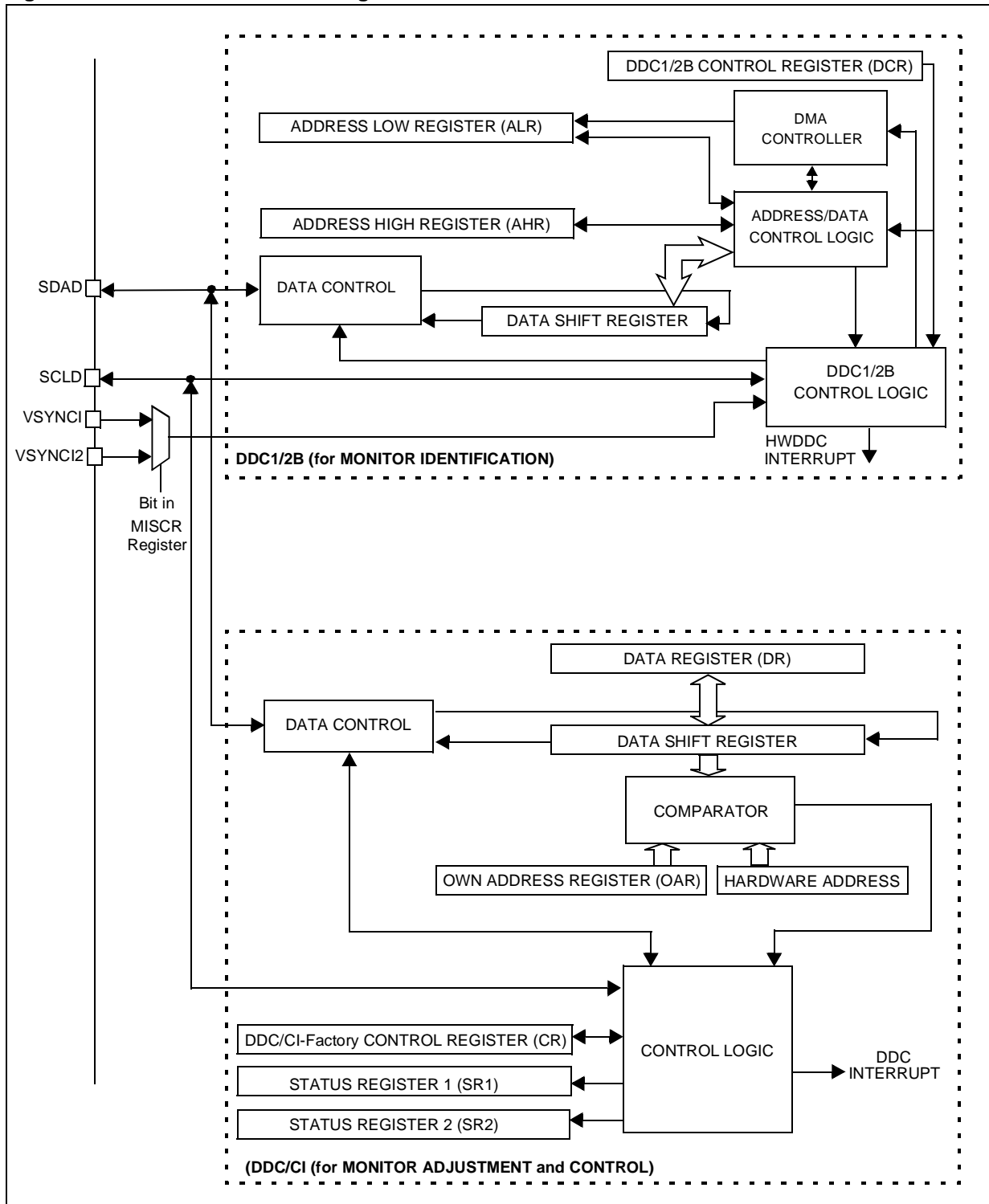
- I<sup>2</sup>C bus busy flag
- Start bit detection flag
- Detection of misplaced Start or Stop condition
- Transfer problem detection
- Address Matched detection
- Programmable Address detection and/or Hardware detection of Enhanced DDC (EDDC) addresses (60h/61h)
- End of byte transmission flag
- Transmitter/Receiver flag
- Stop condition Detection

Figure 56. DDC Interface Overview



DDC INTERFACE (Cont'd)

Figure 57. DDC Interface Block Diagram





**DDC INTERFACE (Cont'd)****4.8.3 Signal Description  
Serial Data (SDA)**

The SDA bidirectional pin is used to transfer data in and out of the device. It is an open-drain output that may be or-wired with other open-drain or open-collector pins. An external pull-up resistor must be connected to the SDA line. Its value depends on the load of the line and the transfer rate.

**Serial Clock (SCL)**

The SCL input pin is used to synchronize all data in and out of the device when in I<sup>2</sup>C bidirectional mode. An external pull-up resistor must be connected to the SCL line. Its value depends on the load of the line and the transfer rate.

**Note:**When the DDC1/2B and DDC/CI-Factory Interfaces are disabled (HWPE bit=0 in the DCR register and PE bit=0 in the CR register), SDA and SCL pins revert to standard I/O pins.

**Transmit-only Clock (Vsync/Vsync2)**

The Vsync input pins are used to synchronize all data in and out of the device when in Transmit-only mode.

These pins are ONLY used by the DDC1/2B interface (when in DDC1 mode).

**DDC INTERFACE (Cont'd)**

**4.8.4 I<sup>2</sup>C BUS Protocol**

A standard I<sup>2</sup>C communication is normally based on four parts: START condition, device slave address transmission, data transfer and STOP condition. They are described briefly in the following section and illustrated in Figure 58 (for more details, refer to the I<sup>2</sup>C bus specification).

**4.8.4.1 START condition**

When the bus is free (both SCL and SDA lines are at a high level), a master can initiate a communication by sending a START signal. This signal is defined as a high-to-low transition of SDA while SCL is stable high. The bus is considered to be busy after a START condition.

This START condition must precede any command for data transfer.

**4.8.4.2 Slave Address Transmission**

The first byte following a START condition is the slave address transmitted by the master. This address is 7-bit long followed by an 8th bit (Least significant bit: LSB) which is the data direction bit (R/W bit).

- A "0" indicates a transmission (WRITE) from the master to the slave.
- A "1" indicates a request for data (READ) from the slave to the master.

If a slave device is present on the bus at the given address, an Acknowledge will be generated on the 9th clock pulse.

**4.8.4.3 Data Transfer**

Once the slave address is acknowledged, the data transfer can proceed in the direction given by the R/W bit sent in the address.

Data is transferred with the most significant bit (MSB) first. Data bits can be changed only when SCL is low and must be held stable when SCL is high.

One complete data byte transfer requires 9 clock pulses: 8 bits + 1 acknowledge bit.

**4.8.4.4 Acknowledge Bit (ACK / NACK)**

Every byte put on the SDA line is 8-bit long followed by an acknowledge bit.

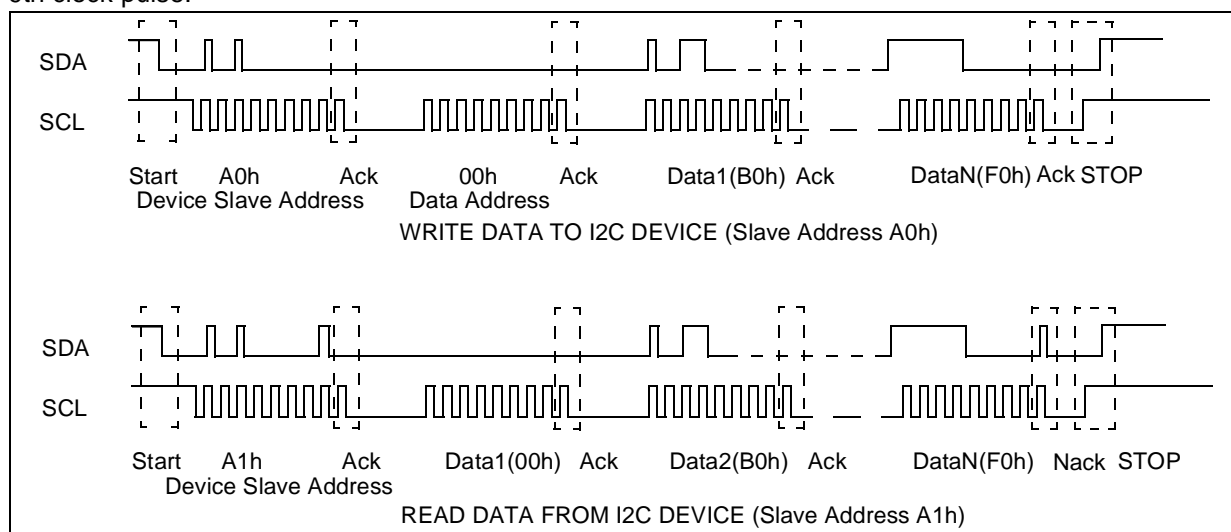
This bit is used to indicate a successful data transfer. The bus transmitter, either master or slave, releases the SDA line during the 9th clock period (after sending all 8 bits of data), then:

- To generate an Acknowledge (ACK) of the current byte, the receiver pulls the SDA line low.
- To generate a No-Acknowledge (NACK) of the current byte, the receiver releases the SDA line (hence at a high level).

**4.8.4.5 STOP Condition**

A STOP condition is defined by a low-to-high transition of SDA while SCL is stable high. It ends the communication between the Interface and the bus master.

**Figure 58. I<sup>2</sup>C Signal Diagram**



**DDC INTERFACE (Cont'd)****4.8.5 DDC Standard**

The DDC standard is divided in several data transfer protocols: DDC1, DDC2B, DDC/CI.

For DDC1/2B, refer to the “VESA DDC Standard v3.0” specification. For DDC/CI refer to the “VESA DDC Commands Interface v1.0”

- DDC1 is a uni-directional transmission of EDID v1 (128 bytes) from display to host clocked by VSYNCl.
- DDC2B is a uni-directional channel from display to host. The host computer uses base-level I<sup>2</sup>C commands to read the EDID data from the display which is always in slave mode. Specific types of display contain EDID at fixed I<sup>2</sup>C device addresses within the device (refer to Table 25).
- DDC/CI is a bi-directional channel between the host computer and the display. The DDC/CI offers a display control interface based on I<sup>2</sup>C bus. It includes the DDC2Bi and DDC2AB standards.

**Note:** The DDC2AB standard is no longer handled by the interface.

**4.8.5.1 DDC1/2B Interface****4.8.5.1.1 Functionnal description**

Refer to the DCR, AHR registers in Section 4.8.6. for the bit definitions.

The DDC1/2B Interface acts as an I/O interface between a DDC bus and the microcontroller memory. In addition to receiving and transmitting serial data, this interface directly transfers parallel data to and from memory using a DMA engine, only halting CPU activity for two clock cycles during each byte transfer.

The interface supports by hardware:

- Two DDC communication protocols called DDC1 and DDC2B.

- Write operations into RAM.

- Read operations from RAM.

In DDC1, the interface reads sequential EDID v1 data bytes from the microcontroller memory, and transmits them on SDA synchronized with Vsync.

In DDC2B mode, it operates in I<sup>2</sup>C slave mode.

The DDC1/2B Interface supports several DDC versions configured using the CF[2:0] bits in the DCR register which can only be changed while the interface is disabled (HWPE bit=0 in the DCR register). They define which EDID structure version is used and which Device Addresses are recognized.

Depending on the DDC version, one or two device address pairs will be recognized and the corresponding EDID structure will be validated (refer to Table 25):

- **DDC v2 (CF2=0,CF1=0,CF0=0):** DDC1 is enabled and device addresses A0h/A1h are recognized. EDID v1 is used.
- **DDC v2 (CF2=1,CF1=0,CF0=0):** DDC1 is disabled and device addresses A0h/A1h are recognized. EDID v1 is used.
- **Plug and Display (CF2=0,CF1=0,CF0=1):** DDC1 is disabled and device addresses A2h/A3h are recognized. EDID v2 is used.
- **Plug and Display + DDC v2 (CF2=0,CF1=1,CF0=0):** DDC1 is enabled and device addresses A0h/A1h and A2h/A3h are recognized. Both EDID structures v1 and v2 are used.
- **Plug and Display + DDC v2 (CF2=1,CF1=1,CF0=0):** DDC1 is disabled and device addresses A0h/A1h and A2h/A3h are recognized. Both EDID structures v1 and v2 are used.
- **FPDI (CF2=0,CF1=1,CF0=1):** DDC1 is disabled and device addresses A6h/A7h are recognized. EDID v2 is used.

**Table 25. Valid Device Addresses and EDID structure**

| Device Address                    | CF2 bit | CF1 bit | CF0 bit | Transfer Type                      |
|-----------------------------------|---------|---------|---------|------------------------------------|
| EDID v1:<br>A0h / A1h = 1010 000x | x       | x       | 0       | 128-byte EDID structure write/read |
| EDID v2:<br>A2h / A3h = 1010 001x | 0       | 0       | 1       | 256-byte EDID structure write/read |
|                                   | 0       | 1       | 0       |                                    |
|                                   | 1       | 1       | 0       |                                    |
| EDID v2:<br>A6h / A7h = 1010 011x | 1       | 1       | 1       | 256-byte EDID structure write/read |
| reserved                          | 1       | x       | 1       | reserved                           |

**DDC INTERFACE (Cont'd)**

The Write and Read operations allow the EDID data to be downloaded during factory alignment (for example).

Writes to the memory by the DMA engine can be inhibited by means of the WP bit in the DCR register.

A write of the last data structure byte sets a flag and may be programmed to generate an interrupt request.

The Data address (sub-address) is either the second byte of write transfers or is pointed to by the internal address counter automatically incremented after each byte transfer.

Physical address mapping of the data structure within the memory space is performed with a dedicated register accessible by software.

**4.8.5.1.2 Mode description**

**DDC1 Mode:** This mode is only enabled when the DDC v2 or P&D-DDC v2 standards are validated. It transmits only the EDID v1 data (128 bytes).

To switch the DDC1/2B Interface to DDC1 mode, software must first clear the CF0 bit in the DCR

register while the HWPE bit=0 and then set the HWPE bit to enable the DDC1/2B Interface.

A proper initialization sequence (see Figure 59) must supply nine clock pulses on the VSYNCI pin in order to internally synchronize the device. During this initialization sequence, the SDA pin is in high impedance. On the rising edge of the 10th pulse applied on VSYNCI, the device outputs on SDA the most significant (MSB) bit of the byte located at data address 00h.

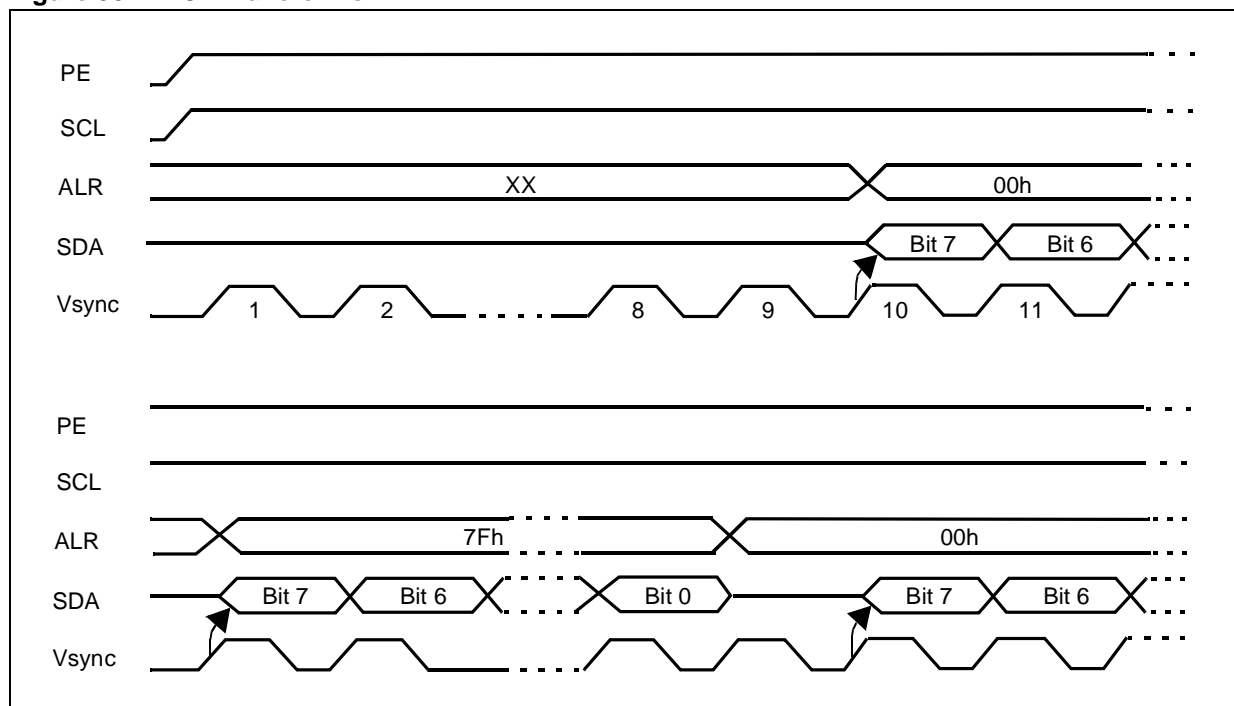
A byte is clocked out by means of 9 clock pulses on Vsync, 8 clock pulses for the data byte itself and an extra pulse for a Don't Care bit.

As long as SCL is not held low, each byte of the memory array is transmitted serially on SDA.

The internal address counter is incremented automatically until the last byte is transmitted. Then, it rolls over to relative location 00h.

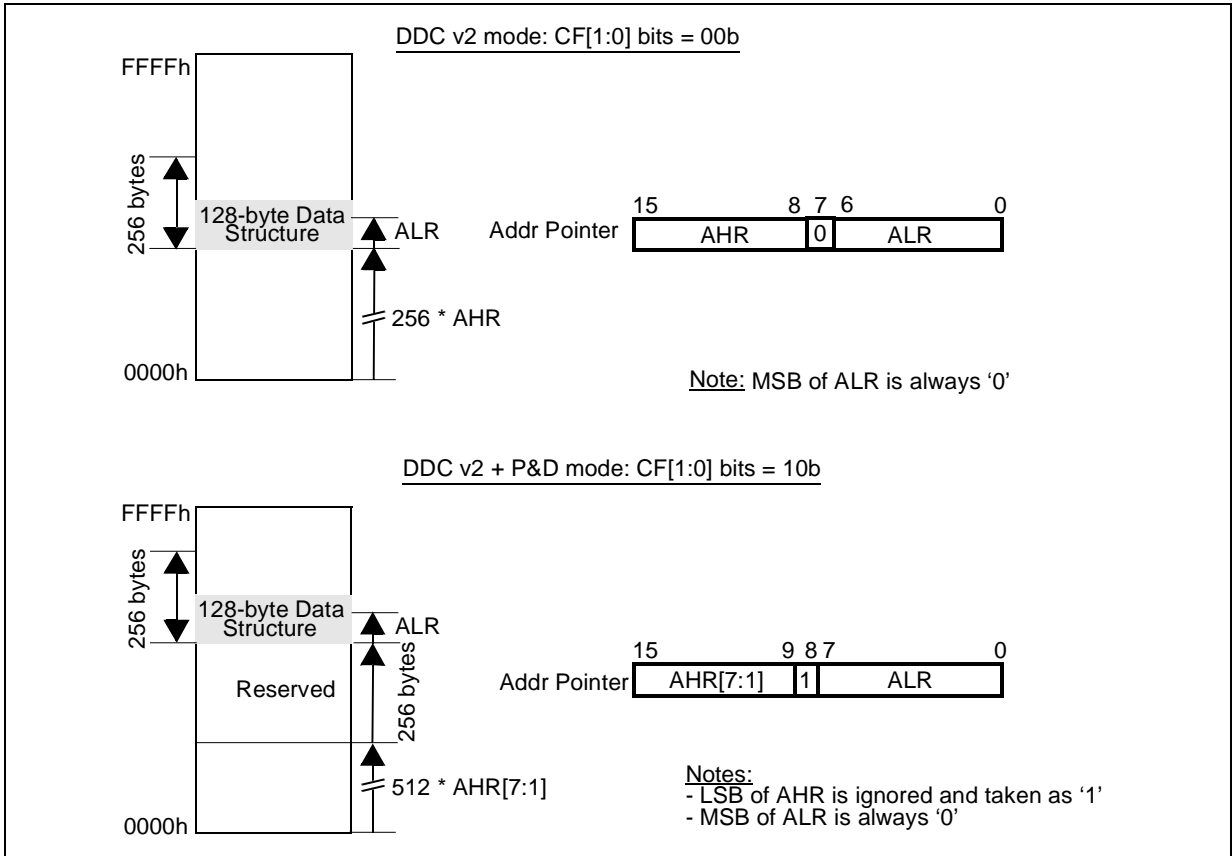
The physical mapping of the data structure depends on the configuration and on the content of the AHR register which can be set by software (see Figure 60).

**Figure 59. DDC1 Waveforms**



DDC INTERFACE (Cont'd)

Figure 60. Mapping of DDC1 data structure



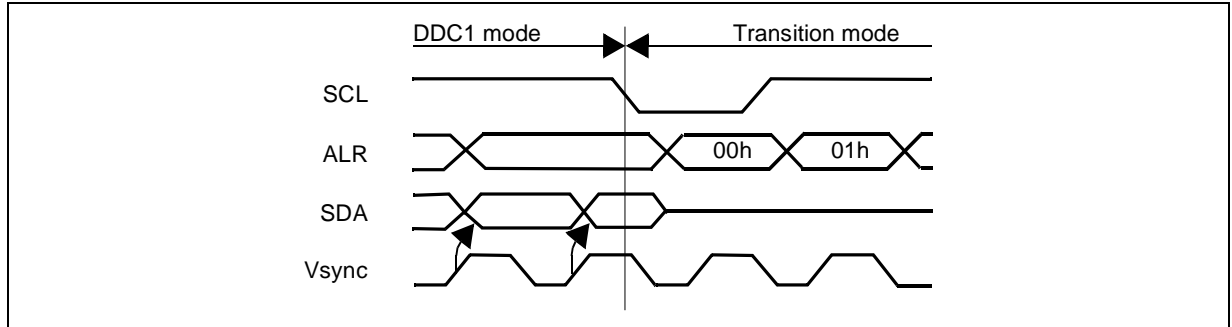
**DDC2B Transition Mode:** This mode avoids the display switching to DDC2B mode if spurious noise is detected on SCL while the host is in DDC1 mode.

When the DDC1/2B interface is in DDC1 mode and detects a falling edge on SCL, it enters the transition state (see Figure 61).

If a valid I<sup>2</sup>C sequence (START followed by a valid Device Address for CF0 = 0 (see Table 25)) is not

received within either 128 Vsync pulses or a period of approximately 2 seconds, then the interface will revert to DDC1 mode at the EDID start address. If the interface decodes a valid DDC2B Device Address, it will lock into DDC2B mode and subsequently disregard VSYNCI. When in transition mode, the Vsync pulse counter or the 2-sec. timeout counter is reset by any activity on the SCL line.

Figure 61. Transition Mode Waveforms



**DDC INTERFACE (Cont'd)**

**DDC2B Mode:** The DDC1/2B Interface enters DDC2B mode either from the transition state or from the initial state if software sets the HWPE bit while P&D only or FPDI-2 mode is selected. Once in DDC2B mode, the Interface always acts as a slave following the protocol described in Figure 62.

The DDC1/2B Interface continuously monitors the SDA and SCL lines for a START condition and will

not respond (no acknowledge) until one is found. A STOP condition at the end of a Read command (after a NACK) forces the stand-by state. A STOP condition at the end of a Write command triggers the internal DMA write cycle.

The Interface samples the SDA line on the rising edge of SCL and outputs data on the falling edge of SCL. In any case SDA can only change when SCL is low.

**Figure 62. DDC2B protocol (example)**

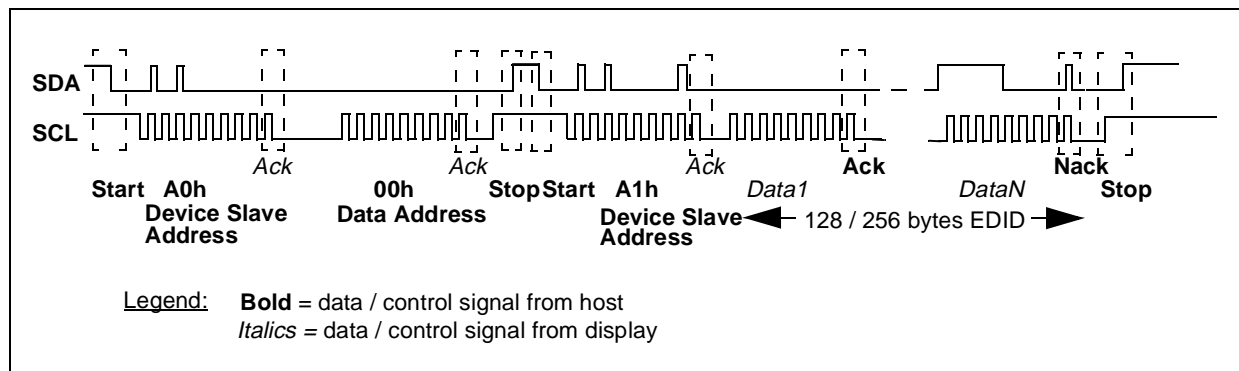
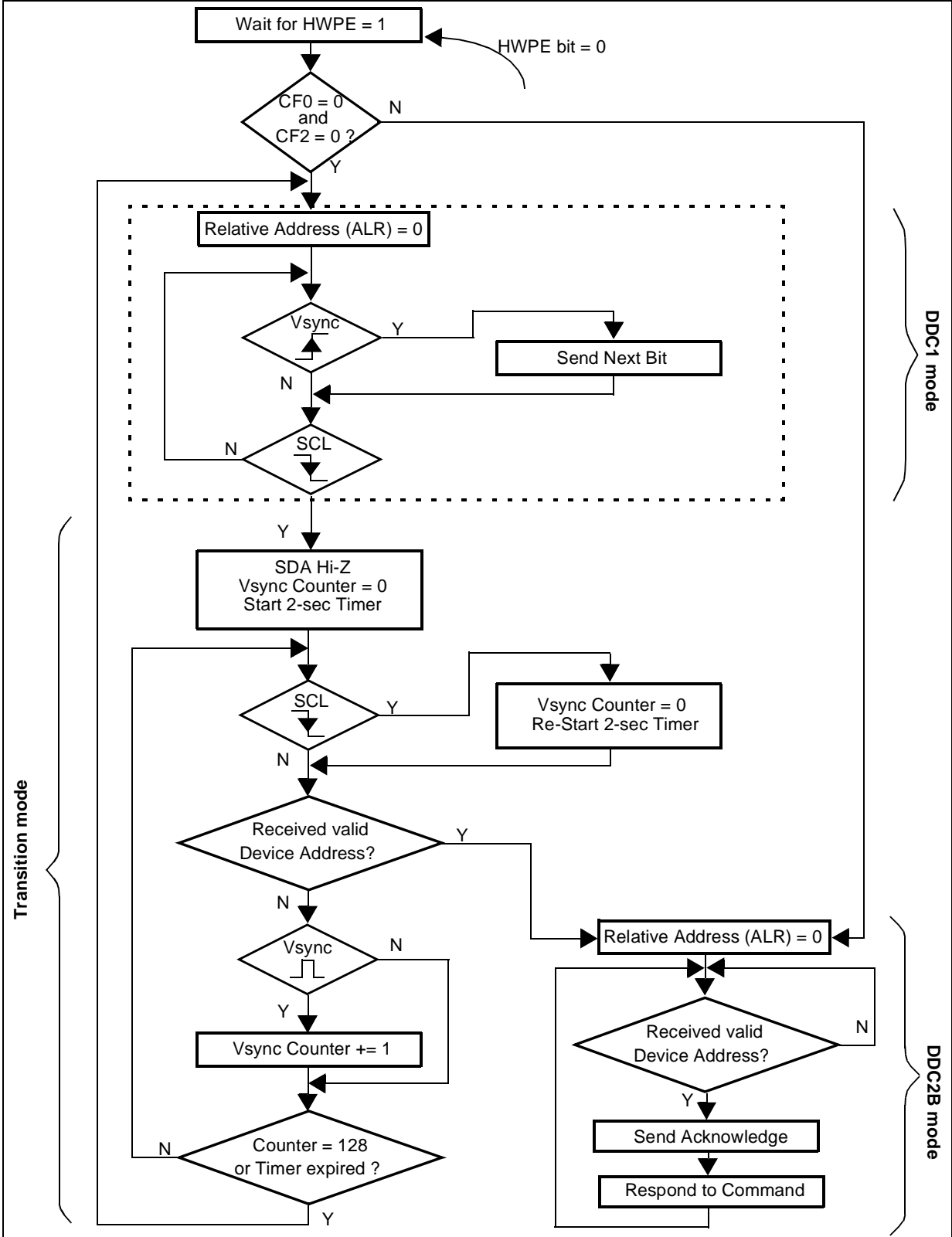


Figure 63. DDC1/2B Operation Flowchart



**DDC INTERFACE (Cont'd)**

**EDID Data structure mapping:** An internal address pointer defines the memory location being addressed. It is made of two 8-bit registers AHR and ALR.

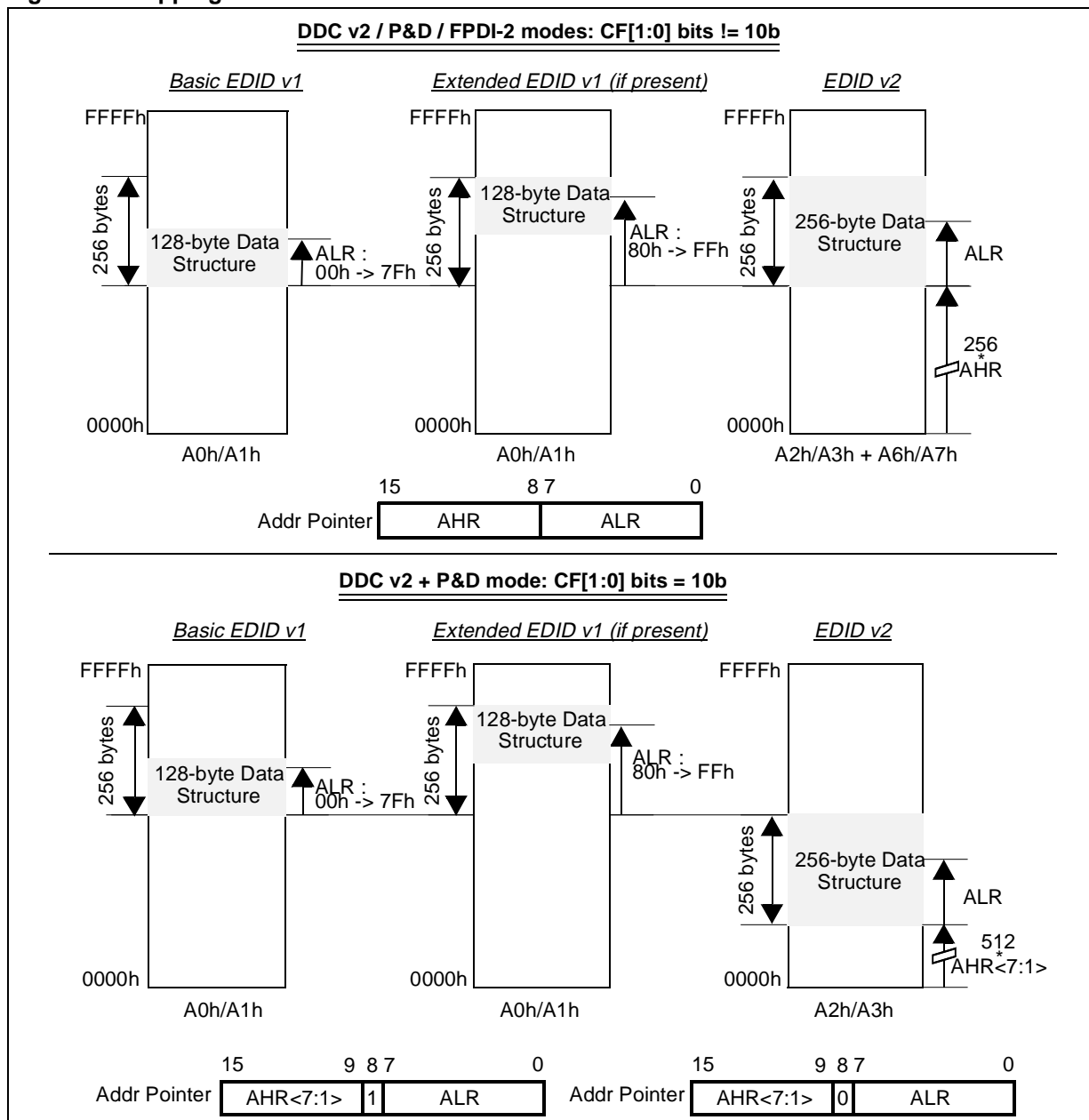
AHR is initialized by software. It defines the 256-byte block within the 64K address space containing the data structure.

ALR is loaded with the data address sent by the master after a write Device Address. It defines the

byte within the data structure currently addressed. ALR is reset upon entry into the DDC2B mode.

One exception to this arrangement is when the CF[1:0] bits = 10b. In this case the two EDID versions must coexist at non-overlapping addresses. The LSB of AHR is therefore ignored and automatically set to 1 to address the 128-byte EDID and set to 0 to address its 256-byte counterpart (see Figure 64).

**Figure 64. Mapping of DDC2B data structure**





**DDC INTERFACE (Cont'd)****■ Write Operation**

Once the DDC1/2B Interface has acknowledged a write transfer request, i.e. a Device Address with RW=0, it waits for a data address. When the latter is received, it is acknowledged and loaded into the ALR.

Then, the master may send any number of data bytes that are all acknowledged by the DDC1/2B Interface. The data bytes are written in RAM if the WP bit=0 in the DCR register, otherwise the RAM location is not modified.

**In any case, all write operations are performed in RAM and therefore do not delay DDC transfers, although concurrent software execution is halted for 2 cycles.**

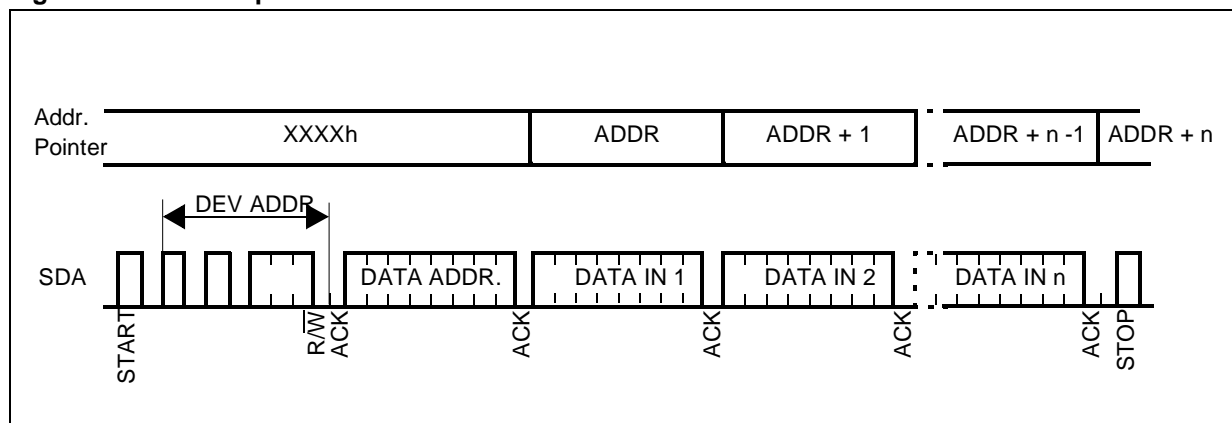
After each byte is transferred, the internal address counter is automatically incremented.

If the counter is pointing to the top of the structure, it rolls over to the bottom since the incrementation is performed only on the 7 or 8 LSB's of the pointer depending on the selected data structure size. In other words, ALR rolls over from FFh to 00h for Device Addresses A2h/A3h and A6h/A7h. Otherwise, it rolls over from 7Fh to 00h or from FFh to 80h depending on the MSB of the last data address received.

Then after that last byte has been effectively written in RAM, the EDF flag is set and an interrupt is generated if EDE is set.

The transfer is terminated by the master generating a STOP condition.

**Figure 65. Write sequence**

**■ Read Operations**

All read operations consist of retrieving the data pointed to by an internal address counter which is initialized by a dummy write and incremented by any read. The DDC1/2B Interface always waits for an acknowledge during the 9th bit-time. If the master does not pull the SDA line low during this bit-time, the DDC1/2B Interface ends the transfer and switches to a stand-by state.

– **Current address read:** After generating a START condition the master sends a read device address (RW = 1). The DDC1/2B Interface acknowledges this and outputs the data byte pointed to by the internal address pointer which is subsequently incremented. The master must NOT acknowledge this byte and must terminate the transfer with a STOP condition.

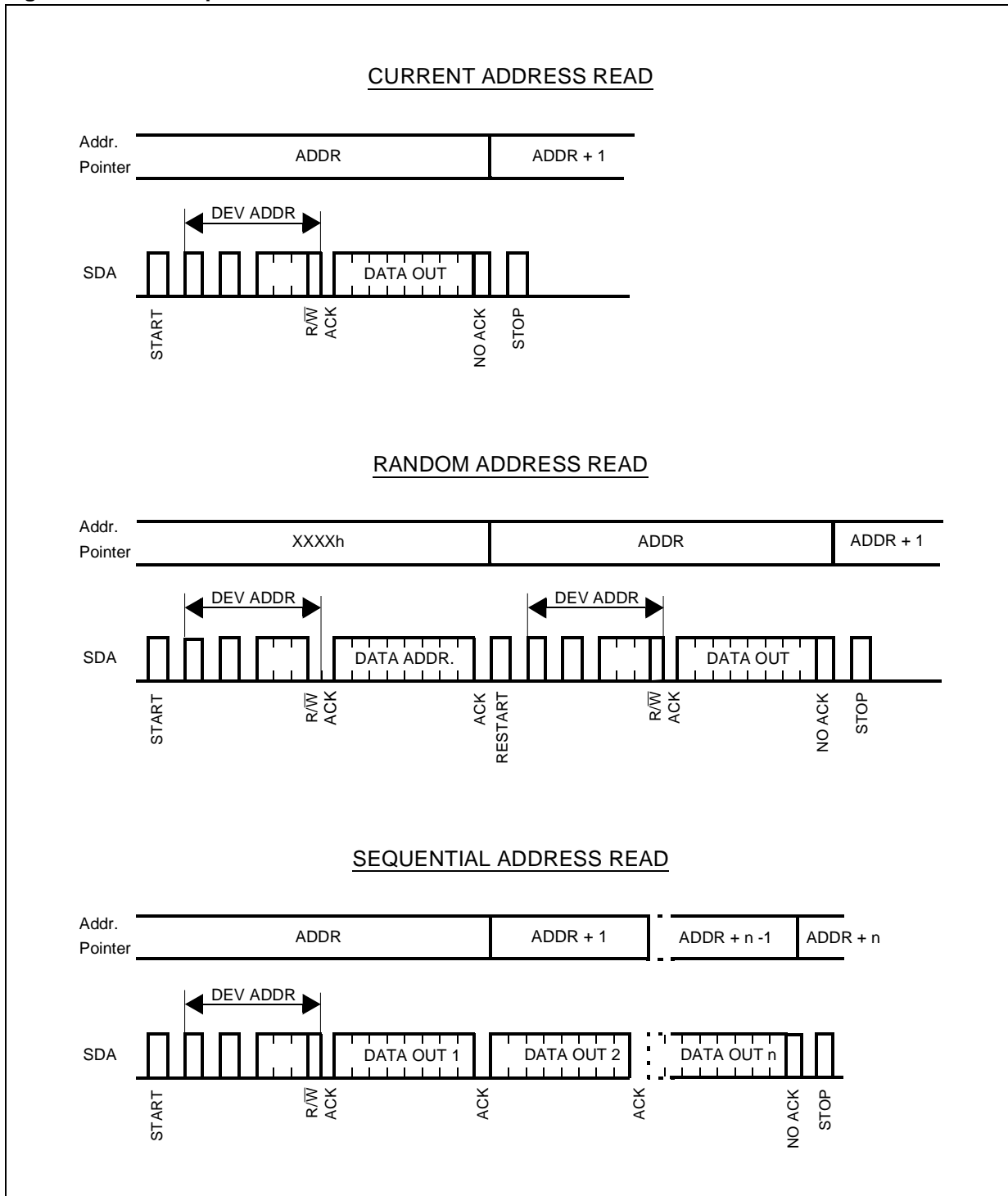
– **Random address read:** The master performs a dummy write to load the data address into the ALR. Then the master sends a RESTART condition followed by a read Device Address (RW=1).

– **Sequential address read:** This mode is similar to the current and random address reads, except that the master DOES acknowledge the data byte for the DDC1/2B Interface to output the next byte in sequence. To terminate the read operation the master must NOT acknowledge the last data byte and must generate a STOP condition.

The data output are from consecutive memory addresses. The internal address counter is incremented automatically after each byte. If the counter is pointing to the top of the structure, it rolls over to the bottom since the incrementation is performed only on the 7 or 8 LSB's of the counter depending on the selected data structure size.

DDC INTERFACE (Cont'd)

Figure 66. Read sequences



**DDC INTERFACE** (Cont'd)**4.8.5.2 DDC/CI - Factory Alignment Interface****4.8.5.2.1 Functional Description**

Refer to the CR, SR1 and SR2 registers in Section 4.8.6. for the bit definitions.

The DDC/CI interface works as an I/O interface between the microcontroller and the DDC2Bi, EDDC or Factory alignment protocols. It receives and transmits data in Slave I<sup>2</sup>C mode using an interrupt or polled handshaking.

The interface is connected to the I<sup>2</sup>C bus by a data pin (SDAD) and a clock pin (SCLD) configured as open drain.

The DDC/CI interface has five internal register locations.

Two of them are used for initialization of the interface:

- Own Address Register OAR
- Control register CR

The following four registers are used during data transmission/reception:

- Data Register DR
- Control Register CR
- Status Register 1 SR1
- Status Register 2 SR2

The interface decodes an I<sup>2</sup>C or DDC2Bi address stored by software in the OAR register and/or the EDDC address (60h/61h) as its default hardware address.

After a reset, the interface is disabled.

**4.8.5.2.2 I<sup>2</sup>C Modes****■ General description**

In I<sup>2</sup>C mode, the interface can operate in the following modes:

- Slave transmitter/receiver  
Both start and stop conditions are generated by the master. The I<sup>2</sup>C clock (SCL) is always received by the interface from a master, but the interface is able to stretch the clock line.

The interface is capable of recognizing both its own programmable address (7-bit) and its default hardware address (Enhanced DDC address: 60h/61h). The Enhanced DDC address detection may be enabled or disabled by software. It never recognizes the Start byte (01h) whatever its own address is.

**■ Slave Mode**

As soon as a start condition is detected, the address is received from the SDA line and sent to the shift register; then it is compared with the programmable address of the interface or the Enhanced DDC address (if selected by software).

**Address not matched:** the interface ignores it and waits for another Start condition.

**Address matched:** the following events occur in sequence:

- Acknowledge pulse is generated if the ACK bit is set.
- EVF and ADSL bits are set.
- An interrupt is generated if the ITE bit is set. Then the interface waits for a read of the SR1 register, **holding the SCL line low** (see Figure 67 Transfer sequencing EV1).

Next, the DR register must be read to determine from the least significant bit if the slave must enter Receiver or Transmitter mode.

**DDC INTERFACE (Cont'd)****Slave Receiver**

Following the address reception and after SR1 register has been read, the slave receives bytes from the SDA line into the DR register via the internal shift register. After each byte, the following events occur in sequence:

- Acknowledge pulse is generated if the ACK bit is set.
- EVF and BTF bits are set.
- An interrupt is generated if the ITE bit is set.

Then the interface waits for a read of the SR1 register followed by a read of the DR register, **holding the SCL line low** (see Figure 67 Transfer sequencing EV2).

**Slave Transmitter**

Following the address reception and after SR1 register has been read, the slave sends bytes from the DR register to the SDA line via the internal shift register.

The slave waits for a read of the SR1 register followed by a write in the DR register, **holding the SCL line low** (see Figure 67 Transfer sequencing EV3).

When the acknowledge pulse is received:

- EVF and BTF bits are set.
- An interrupt is generated if the ITE bit is set.

**Closing slave communication**

After the last data byte is transferred, a Stop Condition is generated by the master. The interface detects this condition and in this case:

- EVF and STOPF bits are set.
- An interrupt is generated if the ITE bit is set.

Then the interface waits for a read of the SR2 register (see Figure 67 Transfer sequencing EV4).

**Error Cases**

- **BERR**: Detection of a Stop or a Start condition during a byte transfer. In this case, the EVF and the BERR bits are set and an interrupt is generated if the ITE bit is set.  
If it is a Stop then the interface discards the data, releases the lines and waits for another Start condition.  
If it is a Start then the interface discards the data and waits for the next slave address on the bus.
- **AF**: Detection of a non-acknowledge bit. In this case, the EVF and AF bits are set and an interrupt is generated if the ITE bit is set.

**Note:** In both cases, SCL line is not held low; however, SDA line can remain low due to possible «0» bits transmitted last. It is then necessary to release both lines by software.

**How to release the SDA / SCL lines**

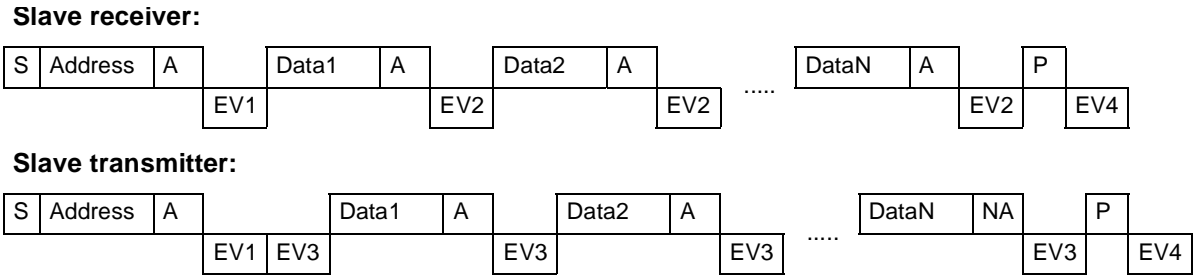
Set and subsequently clear the STOP bit while BTF is set. The SDA/SCL lines are released after the transfer of the current byte.

**Other Events**

- **ADSL**: Detection of a Start condition after an acknowledge time-slot.  
The state machine is reset and starts a new process. The ADSL bit is set and an interrupt is generated if the ITE bit is set. The SCL line is stretched low.
- **STOPF**: Detection of a Stop condition after an acknowledge time-slot.  
The state machine is reset. Then the STOPF flag is set and an interrupt is generated if the ITE bit is set.

DDC INTERFACE (Cont'd)

Figure 67. Transfer Sequencing



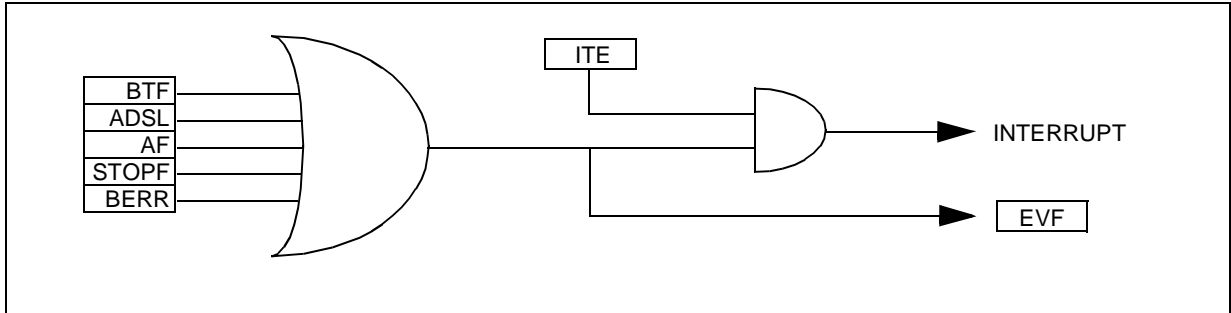
Legend:

S=Start, P=Stop, A=Acknowledge, NA=Non-acknowledge

EVx=Event (with interrupt if ITE=1)

- EV1:** EVF=1, ADSL=1, cleared by reading SR1 register.
- EV2:** EVF=1, BTF=1, cleared by reading SR1 register followed by reading DR register.
- EV3:** EVF=1, BTF=1, cleared by reading SR1 register followed by writing DR register.
- EV4:** EVF=1, STOPF=1, cleared by reading SR2 register.

Figure 68. Event Flags and Interrupt Generation



DDC INTERFACE (Cont'd)

4.8.6 Register Description  
DDC CONTROL REGISTER (CR)

Read / Write

Reset Value: 0000 0000 (00h)

|   |   |    |            |   |     |      |     |
|---|---|----|------------|---|-----|------|-----|
| 7 |   |    |            |   |     |      | 0   |
| 0 | 0 | PE | EDDC<br>EN | 0 | ACK | STOP | ITE |

Bit 7:6 = Reserved. Forced to 0 by hardware.

Bit 5 = **PE** *Peripheral enable*.

This bit is set and cleared by software.

0: Peripheral disabled

1: Slave capability

Notes:

- When PE=0, all the bits of the CR register and the SR register are reset. All outputs are released while PE=0
- When PE=1, the corresponding I/O pins are selected by hardware as alternate functions.
- To enable the I<sup>2</sup>C interface, write the CR register **TWICE** with PE=1 as the first write only activates the interface (only PE is set).

Bit 4 = **EDDCEN** *Enhanced DDC address detection enabled*.

This bit is set and cleared by software. It is also cleared by hardware when the interface is disabled (PE=0). The 60h/61h Enhanced DDC address is acknowledged.

0: Enhanced DDC address detection disabled

1: Enhanced DDC address detection enabled

Bit 3 = Reserved. Forced to 0 by hardware.

Bit 2 = **ACK** *Acknowledge enable*.

This bit is set and cleared by software. It is also cleared by hardware when the interface is disabled (PE=0).

0: No acknowledge returned

1: Acknowledge returned after an address byte or a data byte is received

Bit 1 = **STOP** *Release I2C bus*.

This bit is set and cleared by software or when the interface is disabled (PE=0).

- Slave Mode:

0: Nothing

1: Release the SCL and SDA lines after the current byte transfer (BTF=1). The STOP bit has to be cleared by software.

Bit 0 = **ITE** *Interrupt enable*.

This bit is set and cleared by software and cleared by hardware when the interface is disabled (PE=0).

0: Interrupts disabled

1: Interrupts enabled

Refer to Figure 68 for the relationship between the events and the interrupt. SCL is held low when the BTF or ADSL is detected.

## DDC INTERFACE (Cont'd)

### DDC STATUS REGISTER 1 (SR1)

Read Only

Reset Value: 0000 0000 (00h)

|     |   |     |      |     |      |   |   |
|-----|---|-----|------|-----|------|---|---|
| 7   |   |     |      |     |      |   | 0 |
| EVF | 0 | TRA | BUSY | BTF | ADSL | 0 | 0 |

Bit 7 = **EVF** *Event flag*.

This bit is set by hardware as soon as an event occurs. It is cleared by software reading SR2 register in case of error event or as described in Figure 67. It is also cleared by hardware when the interface is disabled (PE=0).

- 0: No event
- 1: One of the following events has occurred:
  - BTF=1 (Byte received or transmitted)
  - ADSL=1 (Address matched in Slave mode while ACK=1)
  - AF=1 (No acknowledge received after byte transmission if ACK=1)
  - STOPF=1 (Stop condition detected in Slave mode)
  - BERR=1 (Bus error, misplaced Start or Stop condition detected)

Bit 6 = Reserved. Forced to 0 by hardware.

Bit 5 = **TRA** *Transmitter/Receiver*.

When BTF is set, TRA=1 if a data byte has been transmitted. It is cleared automatically when BTF is cleared. It is also cleared by hardware after detection of Stop condition (STOPF=1) or when the interface is disabled (PE=0).

- 0: Data byte received (if BTF=1)
- 1: Data byte transmitted

Bit 4 = **BUSY** *Bus busy*.

This bit is set by hardware on detection of a Start condition and cleared by hardware on detection of a Stop condition. It indicates a communication in progress on the bus. This information is still updated when the interface is disabled (PE=0).

- 0: No communication on the bus
- 1: Communication ongoing on the bus

Bit 3 = **BTF** *Byte transfer finished*.

This bit is set by hardware as soon as a byte is correctly received or transmitted with interrupt generation if ITE=1. It is cleared by software reading SR1 register followed by a read or write of DR register. It is also cleared by hardware when the interface is disabled (PE=0).

- Following a byte transmission, this bit is set after reception of the acknowledge clock pulse. BTF is cleared by reading SR1 register followed by writing the next byte in DR register.
- Following a byte reception, this bit is set after transmission of the acknowledge clock pulse if ACK=1. BTF is cleared by reading SR1 register followed by reading the byte from DR register. The SCL line is held low while BTF=1.

- 0: Byte transfer not done
- 1: Byte transfer succeeded

Bit 2 = **ADSL** *Address matched (Slave mode)*. This bit is set by hardware as soon as the received slave address matched with the OAR register content or the Enhanced DDC address is recognized. An interrupt is generated if ITE=1. It is cleared by software reading SR1 register or by hardware when the interface is disabled (PE=0).

The SCL line is held low while ADSL=1.

- 0: Address mismatched or not received
- 1: Received address matched

Bit 1:0 = Reserved. Forced to 0 by hardware.

## ST72774/ST727754/ST72734

### DDC INTERFACE (Cont'd) DDC STATUS REGISTER 2 (SR2)

Read Only

Reset Value: 0000 0000 (00h)

|   |   |   |    |       |   |      |       |
|---|---|---|----|-------|---|------|-------|
| 7 |   |   |    |       |   |      | 0     |
| 0 | 0 | 0 | AF | STOPF | 0 | BERR | EDDCF |

Bit 7:5 = Reserved. Forced to 0 by hardware.

Bit 4 = **AF** *Acknowledge failure.*

This bit is set by hardware when no acknowledge is returned. An interrupt is generated if ITE=1. It is cleared by software reading SR2 register or by hardware when the interface is disabled (PE=0).

The SCL line is not held low while AF=1.

- 0: No acknowledge failure
- 1: Acknowledge failure

Bit 3 = **STOPF** *Stop detection.*

This bit is set by hardware when a Stop condition is detected on the bus after an acknowledge (if ACK=1). An interrupt is generated if ITE=1. It is cleared by software reading SR2 register or by hardware when the interface is disabled (PE=0).

The SCL line is not held low while STOPF=1.

- 0: No Stop condition detected
- 1: Stop condition detected

Bit 2 = Reserved. Forced to 0 by hardware.

Bit 1 = **BERR** *Bus error.*

This bit is set by hardware when the interface detects a misplaced Start or Stop condition. An interrupt is generated if ITE=1. It is cleared by software reading SR2 register or by hardware when the interface is disabled (PE=0).

The SCL line is not held low while BERR=1.

- 0: No misplaced Start or Stop condition
- 1: Misplaced Start or Stop condition

Bit 0 = **EDDCF** *Enhanced DDC address detected.*

This bit is set by hardware when the Enhanced DDC address (60h/61h) is detected on the bus while EDDCEN=1. It is cleared by hardware when a Start or a Stop condition (STOPF=1) is detected, or when the interface is disabled (PE=0).

- 0: No Enhanced DDC address detected on bus
- 1: Enhanced DDC address detected on bus



**DDC INTERFACE (Cont'd)**  
**DDC DATA REGISTER (DR)**

Read / Write

Reset Value: 0000 0000 (00h)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 7  |    |    |    |    |    |    | 0  |
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

Bit 7:0 = **D7-D0** 8-bit Data Register.

These bits contain the byte to be received or transmitted on the bus.

- Transmitter mode: Byte transmission start automatically when the software writes in the DR register.
- Receiver mode: the first data byte is received automatically in the DR register using the least significant bit of the address.  
Then, the next data bytes are received one by one after reading the DR register.

**DDC OWN ADDRESS REGISTER (OAR)**

Read / Write

Reset Value: 0000 0000 (00h)

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| 7    |      |      |      |      |      |      | 0    |
| ADD7 | ADD6 | ADD5 | ADD4 | ADD3 | ADD2 | ADD1 | ADD0 |

Bit 7:1 = **ADD7-ADD1** Interface address.

These bits define the I<sup>2</sup>C bus programmable address of the interface. They are not cleared when the interface is disabled (PE=0).

Bit 0 = **ADD0**.

This bit is Don't Care, the interface acknowledges either 0 or 1. It is not cleared when the interface is disabled (PE=0).

**Note:** Address 01h is always ignored.

## ST72774/ST727754/ST72734

### DDC INTERFACE (Cont'd) DDC1/2B CONTROL REGISTER (DCR)

Read / Write

Reset Value: 0000 0000 (00h)

|   |     |     |     |     |     |    |      |
|---|-----|-----|-----|-----|-----|----|------|
| 7 |     |     |     |     |     |    | 0    |
| 0 | CF2 | EDF | EDE | CF1 | CF0 | WP | HWPE |

Bit 7 = Reserved.

Forced by hardware to 0.

Bit 5 = **EDF** *End of Download interrupt Flag*.

This bit is set by hardware and cleared by software.

- 0: Download not started or not completed yet.
- 1: Download completed. Last byte of data structure (relative address 7Fh or FFh) has been stored in RAM.

Bit 4 = **EDE** *End of Download interrupt Enable*.

This bit is set and cleared by software.

- 0: Interrupt disabled.
- 1: A DDC1/2B interrupt is generated if EDF bit is set.

Bits 6, 3:2 = **CF[2:0]** *Configuration bits*.

These bits are set and cleared by software only when the peripheral is disabled (HWPE = 0). They define which EDID structure version is used and which Device Addresses are recognized as shown in the following table:

| CF[2:0] Bit Values | EDID version used | DDC1 Mode support / Transition Mode support | DDC2B Addresses Recognized                |
|--------------------|-------------------|---------------------------------------------|-------------------------------------------|
| 000                | DDC v2            | Yes (128b EDID) / Yes                       | 128b-EDID @A0h/A1h                        |
| 001                | P&D               | No                                          | 256b-EDID @ A2h/A3h                       |
| 010                | v2 + P&D          | Yes (128b EDID) / Yes                       | 128b-EDID @A0h/A1h<br>256b-EDID @ A2h/A3h |
| 011                | FPDI-2            | No                                          | 256b-EDID @ A6h/A7h                       |
| 100                | DDC v2            | No                                          | 128b-EDID @A0h/A1h                        |
| 101                |                   | Reserved                                    |                                           |
| 110                | v2 + P&D          | No                                          | 128b-EDID @A0h/A1h<br>256b-EDID @ A2h/A3h |
| 111                |                   | Reserved                                    |                                           |

Bit 1 = **WP** *Write Protect*.

This bit is set and cleared by software.

- 0: Enable writes to the RAM.
- 1: Disable DMA write transfers and protect the RAM content. CPU writes to the RAM are not affected.

Bit 0 = **HWPE** *Peripheral Enable*.

This bit is set and cleared by software.

- 0: Release the SDA port pin and ignore Vsync and SCL port pins. The other bits of the DCR and the content of the AHR are left unchanged.
- 1: Enable the DDC Interface and respond to the DDC1/DDC2B protocol.

### ADDRESS POINTER HIGH REGISTER (AHR)

Read / Write

Reset Value: see Register Map

|     |  |  |  |  |  |  |     |
|-----|--|--|--|--|--|--|-----|
| 7   |  |  |  |  |  |  | 0   |
| MSB |  |  |  |  |  |  | LSB |

**AHR** contains the 8 MSB's of the 16-bit address pointer. It therefore defines the location of the 256-byte block containing the data structure within the CPU address space.

**Note:** AHR0 is ignored when CF[1:0] = 10 (P&D+ v2 mode) to allow non-overlapping 128-byte and 256-byte data structures.

## DDC INTERFACE (Cont'd)

Table 26. DDC Register Map and Reset Values

| Address (Hex.) | Register Name             | 7         | 6         | 5         | 4           | 3          | 2         | 1         | 0          |
|----------------|---------------------------|-----------|-----------|-----------|-------------|------------|-----------|-----------|------------|
| 50             | <b>CR</b><br>Reset Value  | 0         | 0         | PE<br>0   | EDDCEN<br>0 | 0          | ACK<br>0  | STOP<br>0 | ITE<br>0   |
| 51             | <b>SR1</b><br>Reset Value | EVF<br>0  | 0         | TRA<br>0  | BUSY<br>0   | BTF<br>0   | ADSL<br>0 | 0         | 0          |
| 52             | <b>SR2</b><br>Reset Value | 0         | 0         | 0         | AF<br>0     | STOPF<br>0 | 0         | BERR<br>0 | EDDCF<br>0 |
| 54             | <b>OAR</b><br>Reset Value | ADD7<br>0 | ADD6<br>0 | ADD5<br>0 | ADD4<br>0   | ADD3<br>0  | ADD2<br>0 | ADD1<br>0 | ADD0<br>0  |
| 56             | <b>DR</b><br>Reset Value  | D7<br>0   | D6<br>0   | D5<br>0   | D4<br>0     | D3<br>0    | D2<br>0   | D1<br>0   | D0<br>0    |
|                |                           |           |           |           |             |            |           |           |            |
| 0C             | <b>DCR</b><br>Reset Value | 0         | CF2<br>0  | EDF<br>0  | EDE<br>0    | CF1<br>0   | CF0<br>0  | WP<br>0   | HWPE<br>0  |
| 0D             | <b>AHR</b><br>Reset Value | AHR7<br>0 | AHR6<br>0 | AHR5<br>0 | AHR4<br>0   | AHR3<br>0  | AHR2<br>0 | AHR1<br>0 | AHR0<br>0  |

## 4.9 PWM/BRM GENERATOR (DAC)

### 4.9.1 Introduction

This PWM/BRM peripheral includes two types of PWM/BRM outputs, with differing step resolutions based on the Pulse Width Modulator (PWM) and Binary Rate Multiplier (BRM) Generator technique are available. It allows the digital to analog conversion (DAC) when used with external filtering.

### 4.9.2 Main Features

- Fixed frequency:  $f_{CPU}/64$
- Resolution:  $T_{CPU}$
- 10-Bit PWM/BRM generator with a step of  $V_{DD}/2^{10}$  (5mV if  $V_{DD}=5V$ )

### 4.9.3 Functional Description

#### 4.9.3.1 PWM/BRM

The 10 bits of the 10-bit PWM/BRM are distributed as 6 PWM bits and 4 BRM bits. The generator consists of a 12-bit counter (common for all channels), a comparator and the PWM/BRM generation logic.

### PWM Generation

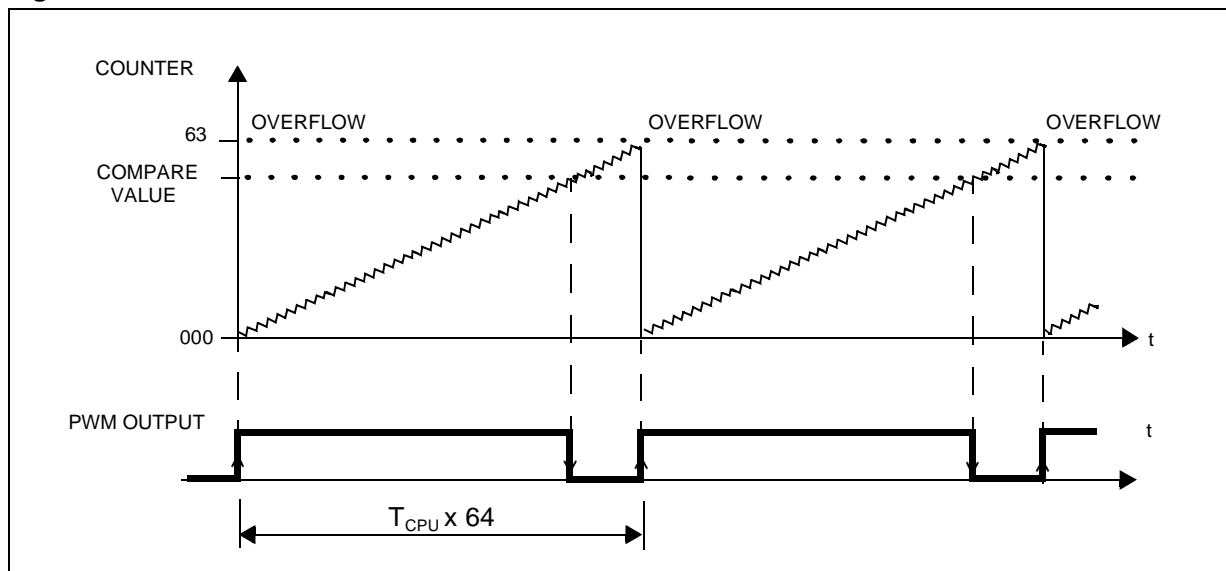
The counter increments continuously, clocked at internal CPU clock. Whenever the 6 least significant bits of the counter (defined as the PWM counter) overflow, the output level for all active channels is set.

The state of the PWM counter is continuously compared to the PWM binary weight for each channel, as defined in the relevant PWM register, and when a match occurs the output level for that channel is reset.

This Pulse Width modulated signal must be filtered, using an external RC network placed as close as possible to the associated pin. This provides an analog voltage proportional to the average charge passed to the external capacitor. Thus for a higher mark/space ratio (High time much greater than Low time) the average output voltage is higher. The external components of the RC network should be selected for the filtering level required for control of the system variable.

Each output may individually have its polarity inverted by software, and can also be used as a logical output.

Figure 69. PWM Generation



**PWM/BRM Outputs (Cont'd)**

**PWM/BRM Outputs**

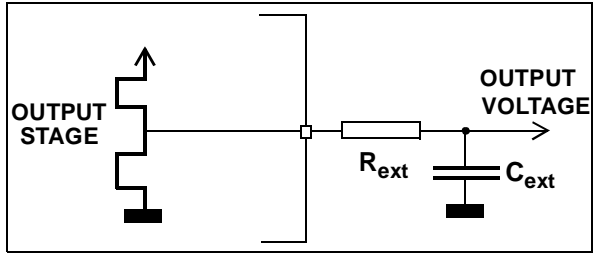
The PWM/BRM outputs are assigned to dedicated pins.

The RC filter time must be higher than TCPUX64.

**Table 27. 6-Bit PWM Ripple After Filtering**

| $C_{ext}$ ( $\mu F$ ) | V RIPPLE (mV) |
|-----------------------|---------------|
| 0.128                 | 78            |
| 1.28                  | 7.8           |
| 12.8                  | 0.78          |

**Figure 70. Typical PWM Output Filter**



With RC filter (R=1K $\Omega$ ),

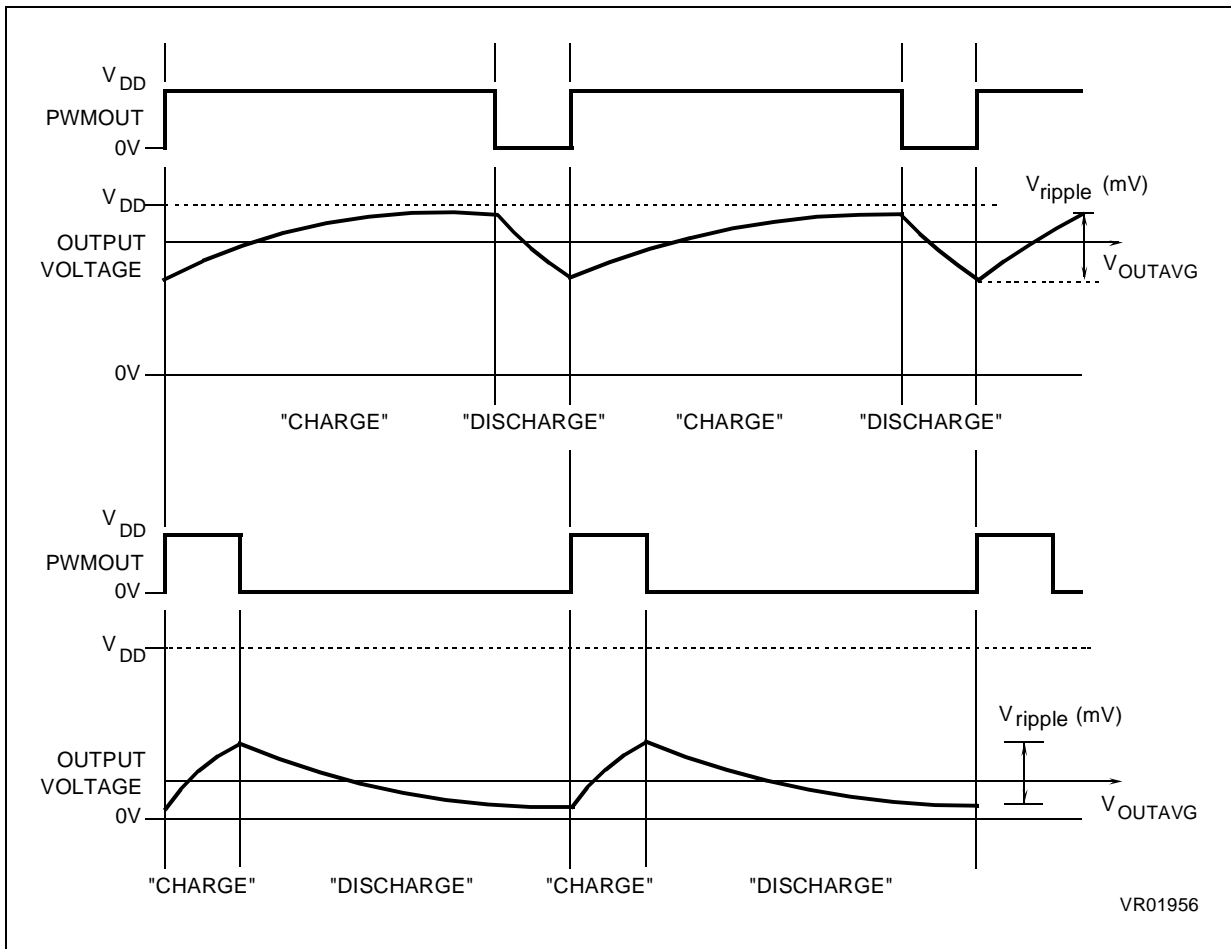
$f_{CPU} = 8$  MHz

$V_{DD} = 5V$

PWM Duty Cycle 50%

R=R<sub>ext</sub>.

**Figure 71. PWM Simplified Voltage Output After Filtering**



**PWM/BRM GENERATOR (Cont'd)**  
**BRM Generation**

The BRM bits allow the addition of a pulse to widen a standard PWM pulse for specific PWM cycles. This has the effect of “fine-tuning” the PWM Duty cycle (without modifying the base duty cycle), thus, with the external filtering, providing additional fine voltage steps.

The incremental pulses (with duration of  $T_{CPU}$ ) are added to the beginning of the original PWM pulse. The PWM intervals which are added to are specified in the 4-bit BRM register and are encoded as shown in the following table. The BRM values shown may be combined together to provide a summation of the incremental pulse intervals specified.

The pulse increment corresponds to the PWM resolution.

For example,if

- Data 18h is written to the PWM register
- Data 06h (00000110b) is written to the BRM register
- with a 8MHz internal clock (125ns resolution)

Then 3.0  $\mu$ s-long pulse will be output at 8  $\mu$ s intervals, except for cycles numbered 2,4,6,10,12,14, where the pulse is broadened to 3.125  $\mu$ s.

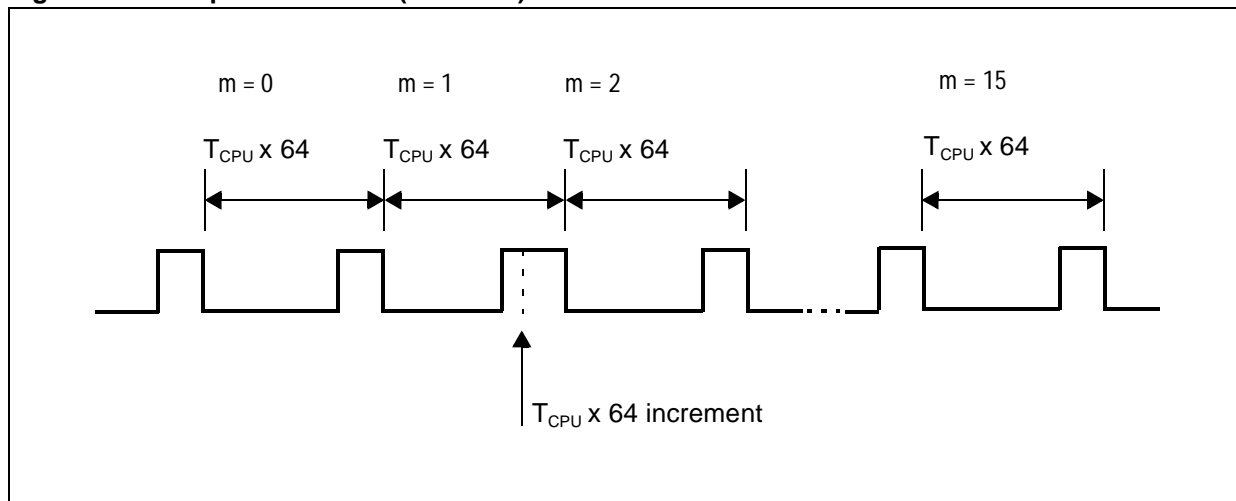
**Note:** If 00h is written to both PWM and BRM registers, the generator output will remain at “0”. Conversely, if both registers hold data 3Fh and 0Fh, respectively, the output will remain at “1” for all intervals #1 to #15, but it will return to zero at interval #0 for an amount of time corresponding to the PWM resolution ( $T_{CPU}$ ).

An output can be set to a continuous “1” level by clearing the PWM and BRM values and setting POL = “1” (inverted polarity) in the PWM register. This allows a PWM/BRM channel to be used as an additional I/O pin if the DAC function is not required.

**Table 28. Bit BRM Added Pulse Intervals (Interval #0 not selected).**

| BRM 4 - Bit Data | Incremental Pulse Intervals |
|------------------|-----------------------------|
| 0000             | none                        |
| 0001             | i = 8                       |
| 0010             | i = 4,12                    |
| 0100             | i = 2,6,10,14               |
| 1000             | i = 1,3,5,7,9,11,13,15      |

**Figure 72. BRM pulse addition (PWM > 0)**



PWM/BRM GENERATOR (Cont'd)

Figure 73. Simplified Filtered Voltage Output Schematic with BRM added

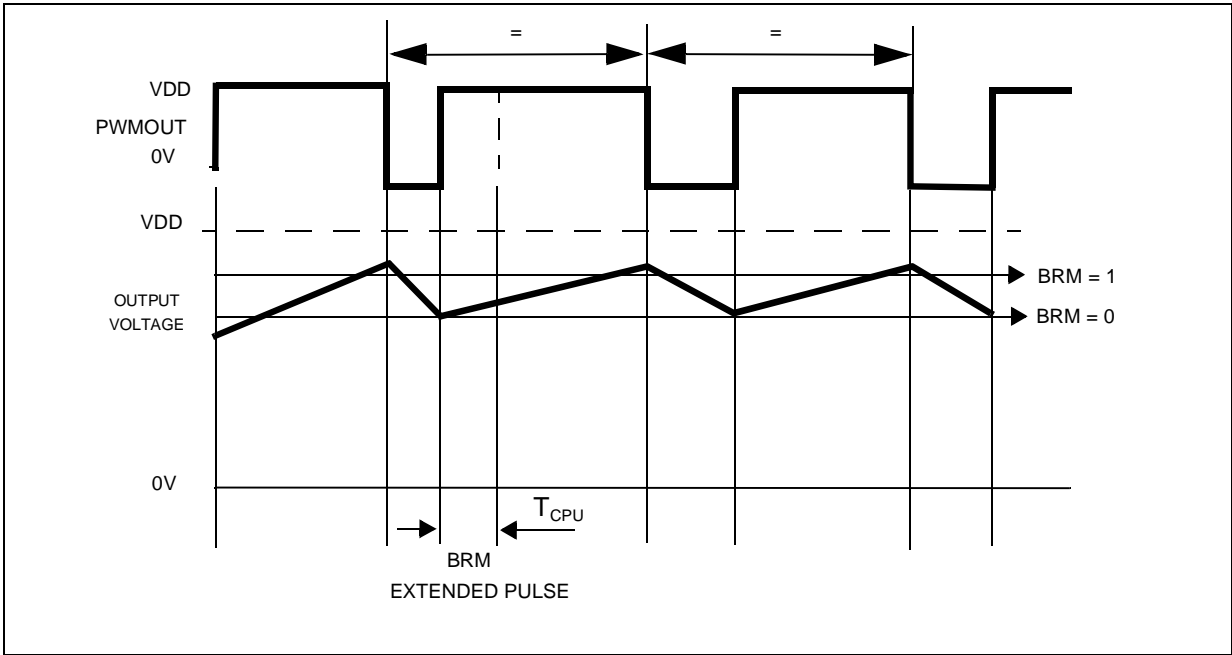
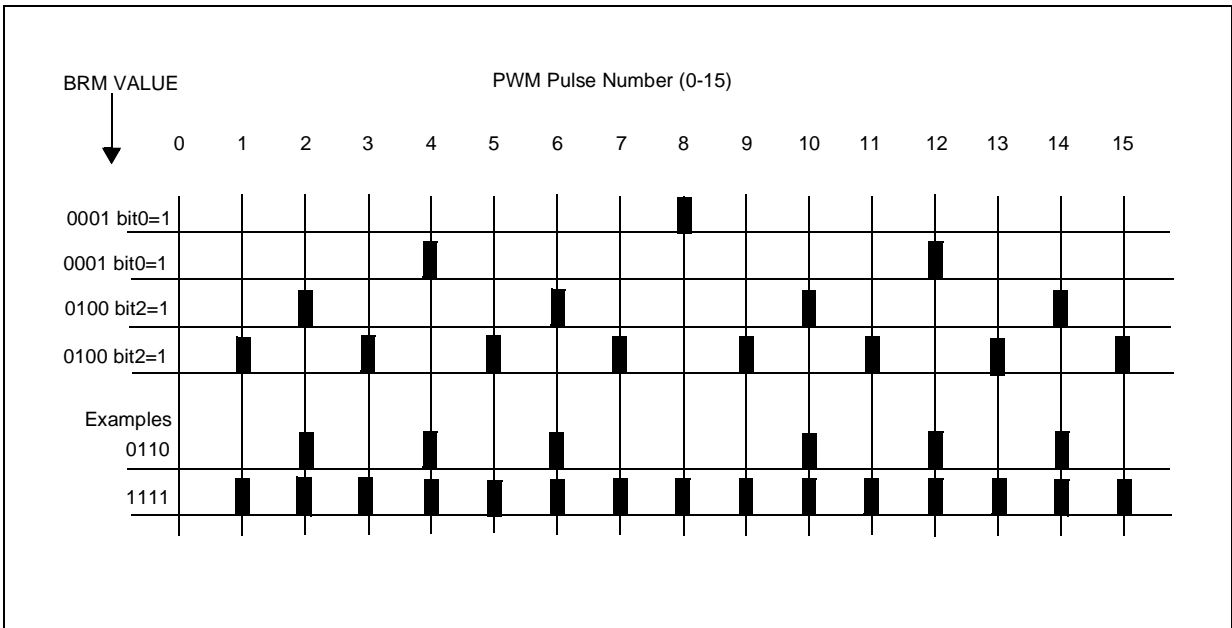


Figure 74. Graphical Representation of 4-Bit BRM Added Pulse Positions



PWM/BRM GENERATOR (Cont'd)

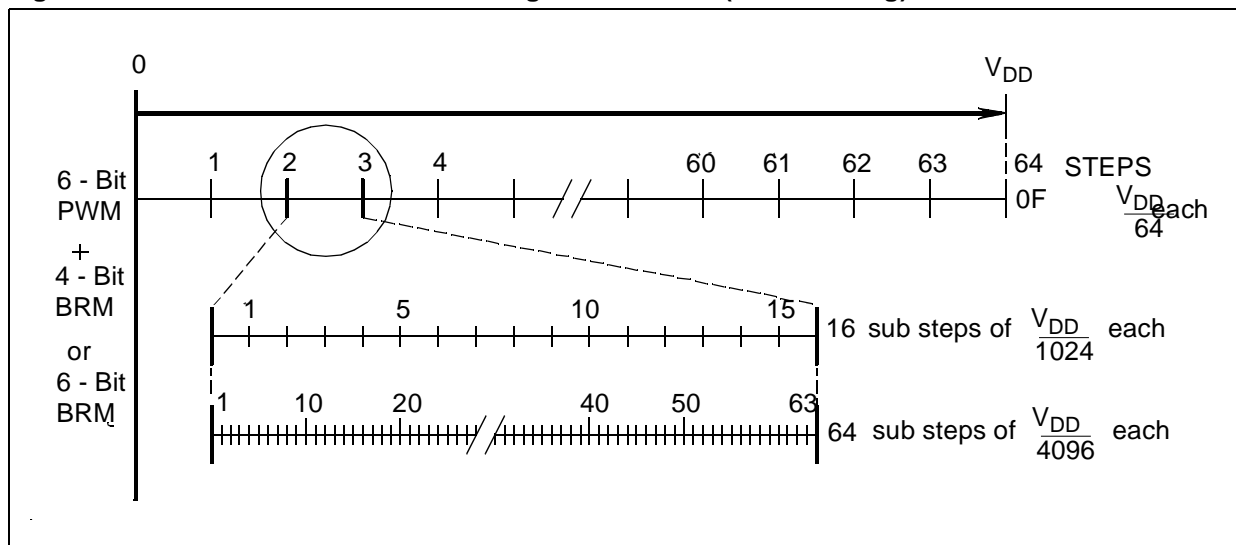
4.9.3.2 PWM/BRM OUTPUTS

The PWM/BRM outputs are assigned to dedicated pins.

If necessary, these pins can be used in push-pull or open-drain modes under software control.

In these pins, the PWM/BRM outputs are connected to a serial resistor which must be taken into account to calculate the RC filter.

Figure 75. Precision for PWM/BRM Tuning for VOUTEFF (After filtering)





**PWM/BRM GENERATOR (Cont'd)****4.9.4 Register Description****4.9.4.1 PWM/BRM REGISTERS**

On a channel basis, the 10 bits are separated into two data registers:

- A 6-bit PWM register corresponding to the binary weight of the PWM pulse.
- A 4-bit BRM register defining the intervals where an incremental pulse is added to the beginning of the original PWM pulse. Two BRM channel values share the same register.

**Note:** The number of PWM and BRM channels available depends on the device. Refer to the device pin description and register map.

**PWM[1:8] REGISTERS**

Read/Write

Reset Value 1000 0000 (80h)

|   |     |    |    |    |    |    |    |
|---|-----|----|----|----|----|----|----|
| 7 |     |    |    |    |    |    | 0  |
| 1 | POL | P5 | P4 | P3 | P2 | P1 | P0 |

Bit 7 = Reserved (read as "1")

Bit 6 = **POL** *Polarity Bit*.

When POL is set, output signal polarity is inverse; otherwise, no change occurs.

Bits 5:0 = **P[5:0]** PWM Pulse Binary Weight for channel *i*.

For example (10-bit)

|   |     |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|-----|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | POL | P | P | P | P | P | P | P | P | + | B | B | B | B |
|---|-----|---|---|---|---|---|---|---|---|---|---|---|---|---|

Effective (with external RC filtering) DAC value

|   |     |   |   |   |   |   |   |   |   |   |   |   |   |
|---|-----|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | POL | P | P | P | P | P | P | P | P | B | B | B | B |
|---|-----|---|---|---|---|---|---|---|---|---|---|---|---|

**BRM REGISTERS**

**BRM21 (Channels 2 + 1)**

**BRM43 (Channels 4 + 3)**

**BRM65 (Channels 6 + 5)**

**BRM87 (Channels 8 + 7)**

Read/Write

Reset Value: 0000 0000 (00h)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 7  |    |    |    |    |    |    | 0  |
| B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 |

Bits 7:4 = **B[7:4]** *BRM Bits (channel  $i+1$ )*

Bits 3:0 = **B[3:0]** *BRM Bits (channel  $i$ )*

**4.9.4.2 OUTPUT ENABLE REGISTER**

Read/Write

Reset Value 1000 0000 (80h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 7   |     |     |     |     |     |     | 0   |
| OE7 | OE6 | OE5 | OE4 | OE3 | OE2 | OE1 | OE0 |

Bit 7:0 = **OE[7:0]** *Output Enable Bit*.

When OE<sub>*i*</sub> is set, PWM output function is enabled.

0: PWM output is disabled

1: PWM output is enabled

**Note:** From the programmer's point of view, the PWM and BRM registers can be regarded as being combined to give one data value.

**ST72774/ST727754/ST72734**

**Table 29. PWM Register Map**

| Address (Hex.) | Register Name | 7             | 6   | 5       | 4 | 3             | 2 | 1 | 0 |
|----------------|---------------|---------------|-----|---------|---|---------------|---|---|---|
| 32             | PWM1          |               | POL | P5 ..P0 |   |               |   |   |   |
| 33             | BRM21         | BRM Channel 2 |     |         |   | BRM Channel 1 |   |   |   |
| 34             | PWM2          |               | POL | P5 ..P0 |   |               |   |   |   |
| 35             | PWM3          |               | POL | P5 ..P0 |   |               |   |   |   |
| 36             | BRM43         | BRM Channel 4 |     |         |   | BRM Channel 3 |   |   |   |
| 37             | PWM4          |               | POL | P5 ..P0 |   |               |   |   |   |
| 38             | PWM5          |               | POL | P5 ..P0 |   |               |   |   |   |
| 39             | BRM65         | BRM Channel 6 |     |         |   | BRM Channel 5 |   |   |   |
| 3A             | PWM6          |               | POL | P5 ..P0 |   |               |   |   |   |
| 3B             | PWM7          |               | POL | P5 ..P0 |   |               |   |   |   |
| 3C             | BRM87         | BRM Channel 8 |     |         |   | BRM Channel 7 |   |   |   |
| 3D             | PWM8          |               | POL | P5 ..P0 |   |               |   |   |   |
| 3E             | PWMCR         | OE7 ..OE0     |     |         |   |               |   |   |   |

## 4.10 8-BIT A/D CONVERTER (ADC)

### 4.10.1 Introduction

The on-chip Analog to Digital Converter (ADC) peripheral is a 8-bit, successive approximation converter with internal sample and hold circuitry. This peripheral has up to 16 multiplexed analog input channels (refer to device pin out description) that allow the peripheral to convert the analog voltage levels from up to 16 different sources.

The result of the conversion is stored in a 8-bit Data Register. The A/D converter is controlled through a Control/Status Register.

### 4.10.2 Main Features

- 8-bit conversion
- Up to 16 channels with multiplexed input
- Linear successive approximation
- Data register (DR) which contains the results
- Conversion complete status flag
- On/off bit (to reduce consumption)

The block diagram is shown in Figure 76.

### 4.10.3 Functional Description

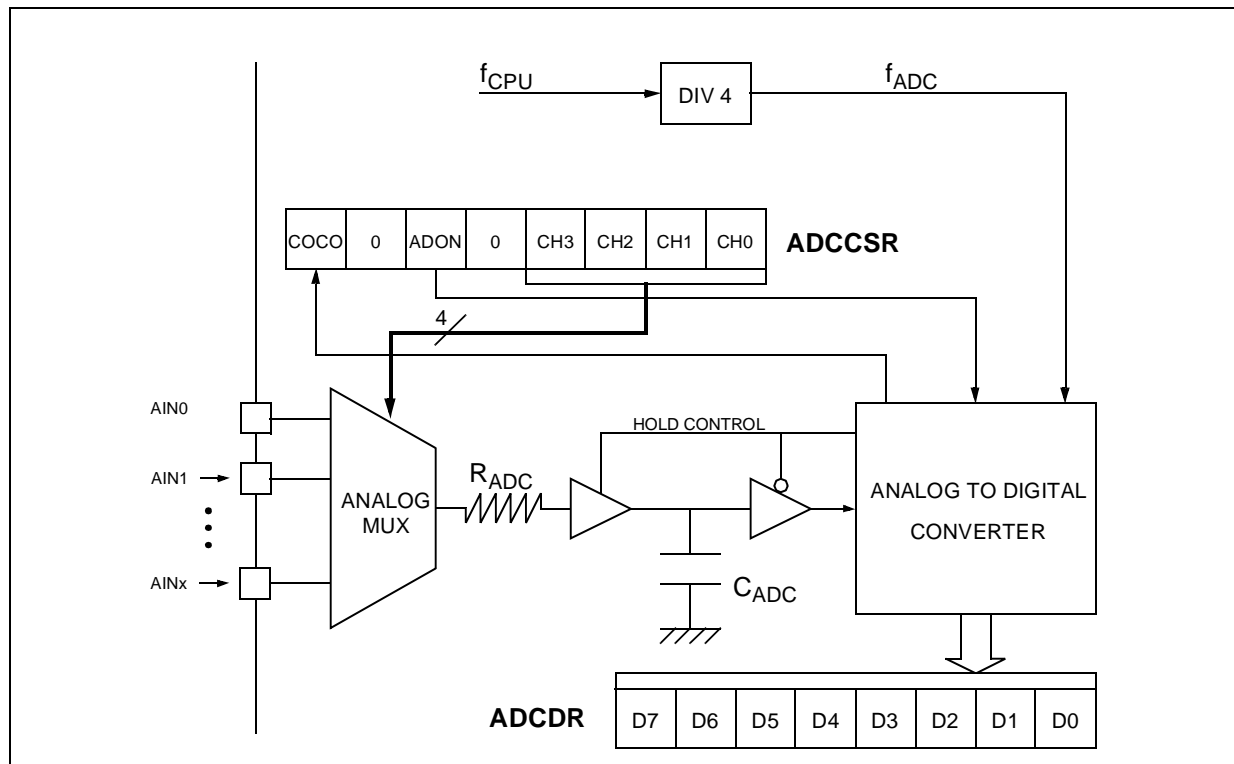
#### 4.10.3.1 Analog Power Supply

$V_{DDA}$  and  $V_{SSA}$  are the high and low level reference voltage pins. In some devices (refer to device pin out description) they are internally connected to the  $V_{DD}$  and  $V_{SS}$  pins.

Conversion accuracy may therefore be impacted by voltage drops and noise in the event of heavily loaded or badly decoupled power supply lines.

See electrical characteristics section for more details.

Figure 76. ADC Block Diagram



### 4.10.3.2 Digital A/D Conversion Result

The conversion is monotonic, meaning that the result never decreases if the analog input does not and never increases if the analog input does not.

If the input voltage ( $V_{AIN}$ ) is greater than or equal to  $V_{DDA}$  (high-level voltage reference) then the conversion result in the DR register is FFh (full scale) without overflow indication.

If input voltage ( $V_{AIN}$ ) is lower than or equal to  $V_{SSA}$  (low-level voltage reference) then the conversion result in the DR register is 00h.

The A/D converter is linear and the digital result of the conversion is stored in the ADCDR register. The accuracy of the conversion is described in the parametric section.

$R_{AIN}$  is the maximum recommended impedance for an analog input signal. If the impedance is too high, this will result in a loss of accuracy due to leakage and sampling not being completed in the allotted time.

### 4.10.3.3 A/D Conversion Phases

The A/D conversion is based on two conversion phases as shown in Figure 77:

- Sample capacitor loading [duration:  $t_{LOAD}$ ]  
During this phase, the  $V_{AIN}$  input voltage to be measured is loaded into the  $C_{ADC}$  sample capacitor.
- A/D conversion [duration:  $t_{CONV}$ ]  
During this phase, the A/D conversion is computed (8 successive approximations cycles) and the  $C_{ADC}$  sample capacitor is disconnected from the analog input pin to get the optimum analog to digital conversion accuracy.

While the ADC is on, these two phases are continuously repeated.

At the end of each conversion, the sample capacitor is kept loaded with the previous measurement load. The advantage of this behaviour is that it minimizes the current consumption on the analog pin in case of single input channel measurement.

### 4.10.3.4 Software Procedure

Refer to the control/status register (CSR) and data register (DR) in Section 4.10.6 for the bit definitions and to Figure 77 for the timings.

### ADC Configuration

The total duration of the A/D conversion is 12 ADC clock periods ( $1/f_{ADC}=4/f_{CPU}$ ).

The analog input ports must be configured as input, no pull-up, no interrupt. Refer to the «I/O ports» chapter. Using these pins as analog inputs does not affect the ability of the port to be read as a logic input.

In the CSR register:

- Select the CH[3:0] bits to assign the analog channel to be converted.

### ADC Conversion

In the CSR register:

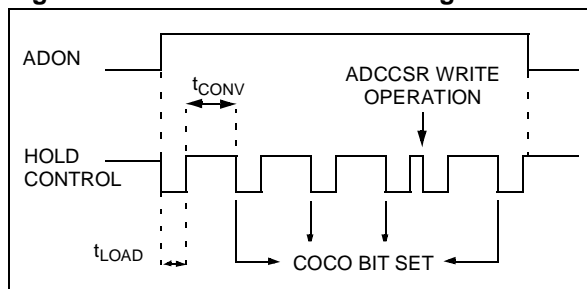
- Set the ADON bit to enable the A/D converter and to start the first conversion. From this time on, the ADC performs a continuous conversion of the selected channel.

When a conversion is complete

- The COCO bit is set by hardware.
- No interrupt is generated.
- The result is in the DR register and remains valid until the next conversion has ended.

A write to the CSR register (with ADON set) aborts the current conversion, resets the COCO bit and starts a new conversion.

Figure 77. ADC Conversion Timings



### 4.10.4 Low Power Mode

| Mode | Description                |
|------|----------------------------|
| WAIT | No effect on A/D Converter |

**Note:** The A/D converter is disabled by resetting the ADON bit. With this feature, power consumption is reduced when no conversion is needed and between single shot conversions.

### 4.10.5 Interrupts

None

**8-BIT A/D CONVERTER (ADC) (Cont'd)**

**4.10.6 Register Description**

**CONTROL/STATUS REGISTER (CSR)**

Read/Write

Reset Value: 0000 0000 (00h)

|      |   |      |   |     |     |     |     |
|------|---|------|---|-----|-----|-----|-----|
| 7    |   |      |   |     |     |     | 0   |
| COCO | 0 | ADON | 0 | CH3 | CH2 | CH1 | CH0 |

Bit 7 = **COCO** *Conversion Complete*

This bit is set by hardware. It is cleared by software reading the result in the DR register or writing to the CSR register.

- 0: Conversion is not complete
- 1: Conversion can be read from the DR register

Bit 6 = **Reserved**. *must always be cleared.*

Bit 5 = **ADON** *A/D Converter On*

This bit is set and cleared by software.

- 0: A/D converter is switched off
- 1: A/D converter is switched on

Bit 4 = **Reserved**. *must always be cleared.*

Bit 3:0 = **CH[3:0]** *Channel Selection*

These bits are set and cleared by software. They select the analog input to convert.

**Note:** The number of pins AND the channel selection varies according to the device. Refer to the device pinout.

| Channel Pin* | CH3 | CH2 | CH1 | CH0 |
|--------------|-----|-----|-----|-----|
| AIN0         | 0   | 0   | 0   | 0   |
| AIN1         | 0   | 0   | 0   | 1   |
| AIN2         | 0   | 0   | 1   | 0   |
| AIN3         | 0   | 0   | 1   | 1   |
| AIN4         | 0   | 1   | 0   | 0   |
| AIN5         | 0   | 1   | 0   | 1   |
| AIN6         | 0   | 1   | 1   | 0   |
| AIN7         | 0   | 1   | 1   | 1   |
| AIN8         | 1   | 0   | 0   | 0   |
| AIN9         | 1   | 0   | 0   | 1   |
| AIN10        | 1   | 0   | 1   | 0   |
| AIN11        | 1   | 0   | 1   | 1   |
| AIN12        | 1   | 1   | 0   | 0   |
| AIN13        | 1   | 1   | 0   | 1   |
| AIN14        | 1   | 1   | 1   | 0   |
| AIN15        | 1   | 1   | 1   | 1   |

**DATA REGISTER (DR)**

Read Only

Reset Value: 0000 0000 (00h)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 7  |    |    |    |    |    |    | 0  |
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

Bit 7:0 = **D[7:0]** *Analog Converted Value*

This register contains the converted analog value in the range 00h to FFh.

**Note:** Reading this register reset the COCO flag.

**Table 30. ADC Register Map**

| Address (Hex.) | Register Name         | 7         | 6       | 5         | 4       | 3        | 2        | 1        | 0        |
|----------------|-----------------------|-----------|---------|-----------|---------|----------|----------|----------|----------|
| 0A             | ADCDR<br>Reset Value  | D7<br>0   | D6<br>0 | D5<br>0   | D4<br>0 | D3<br>0  | D2<br>0  | D1<br>0  | D0<br>0  |
| 0B             | ADCCSR<br>Reset Value | COCO<br>0 | -<br>0  | ADON<br>0 | -<br>0  | CH3<br>0 | CH2<br>0 | CH1<br>0 | CH0<br>0 |

## 5 INSTRUCTION SET

### 5.1 ST7 ADDRESSING MODES

The ST7 Core features 17 different addressing modes which can be classified in 7 main groups:

| Addressing Mode | Example         |
|-----------------|-----------------|
| Inherent        | nop             |
| Immediate       | ld A,#\$55      |
| Direct          | ld A,\$55       |
| Indexed         | ld A,(\$55,X)   |
| Indirect        | ld A,([\$55],X) |
| Relative        | jrne loop       |
| Bit operation   | bset byte,#5    |

The ST7 Instruction set is designed to minimize the number of bytes required per instruction: To do

so, most of the addressing modes may be subdivided in two sub-modes called long and short:

- Long addressing mode is more powerful because it can use the full 64 Kbyte address space, however it uses more bytes and more CPU cycles.
  - Short addressing mode is less powerful because it can generally only access page zero (0000h - 00FFh range), but the instruction size is more compact, and faster. All memory to memory instructions use short addressing modes only (CLR, CPL, NEG, BSET, BRES, BTJT, BTJF, INC, DEC, RLC, RRC, SLL, SRL, SRA, SWAP)
- The ST7 Assembler optimizes the use of long and short addressing modes.

**Table 31. ST7 Addressing Mode Overview**

| Mode      |          | Syntax      | Destination/<br>Source | Pointer<br>Address<br>(Hex.) | Pointer<br>Size<br>(Hex.) | Length<br>(Bytes)                              |     |
|-----------|----------|-------------|------------------------|------------------------------|---------------------------|------------------------------------------------|-----|
| Inherent  |          | nop         |                        |                              |                           | + 0                                            |     |
| Immediate |          | ld A,#\$55  |                        |                              |                           | + 1                                            |     |
| Short     | Direct   | ld A,\$10   | 00..FF                 |                              |                           | + 1                                            |     |
| Long      | Direct   | ld A,\$1000 | 0000..FFFF             |                              |                           | + 2                                            |     |
| No Offset | Direct   | Indexed     | ld A,(X)               | 00..FF                       |                           | + 0 (with X register)<br>+ 1 (with Y register) |     |
| Short     | Direct   | Indexed     | ld A,(\$10,X)          | 00..1FE                      |                           | + 1                                            |     |
| Long      | Direct   | Indexed     | ld A,(\$1000,X)        | 0000..FFFF                   |                           | + 2                                            |     |
| Short     | Indirect |             | ld A,[\$10]            | 00..FF                       | 00..FF                    | byte                                           | + 2 |
| Long      | Indirect |             | ld A,[\$10.w]          | 0000..FFFF                   | 00..FF                    | word                                           | + 2 |
| Short     | Indirect | Indexed     | ld A,([\$10],X)        | 00..1FE                      | 00..FF                    | byte                                           | + 2 |
| Long      | Indirect | Indexed     | ld A,([\$10.w],X)      | 0000..FFFF                   | 00..FF                    | word                                           | + 2 |
| Relative  | Direct   |             | jrne loop              | PC-128/PC+127 <sup>1)</sup>  |                           | + 1                                            |     |
| Relative  | Indirect |             | jrne [\$10]            | PC-128/PC+127 <sup>1)</sup>  | 00..FF                    | byte                                           | + 2 |
| Bit       | Direct   |             | bset \$10,#7           | 00..FF                       |                           | + 1                                            |     |
| Bit       | Indirect |             | bset [\$10],#7         | 00..FF                       | 00..FF                    | byte                                           | + 2 |
| Bit       | Direct   | Relative    | btjt \$10,#7,skip      | 00..FF                       |                           | + 2                                            |     |
| Bit       | Indirect | Relative    | btjt [\$10],#7,skip    | 00..FF                       | 00..FF                    | byte                                           | + 3 |

Note 1. At the time the instruction is executed, the Program Counter (PC) points to the instruction following JRxx.

**ST7 ADDRESSING MODES (Cont'd)****5.1.1 Inherent**

All Inherent instructions consist of a single byte. The opcode fully specifies all the required information for the CPU to process the operation.

| Inherent Instruction    | Function                            |
|-------------------------|-------------------------------------|
| NOP                     | No operation                        |
| TRAP                    | S/W Interrupt                       |
| WFI                     | Wait For Interrupt (Low Power Mode) |
| HALT                    | <b>Disabled, forces a RESET</b>     |
| RET                     | Sub-routine Return                  |
| IRET                    | Interrupt Sub-routine Return        |
| SIM                     | Set Interrupt Mask                  |
| RIM                     | Reset Interrupt Mask                |
| SCF                     | Set Carry Flag                      |
| RCF                     | Reset Carry Flag                    |
| RSP                     | Reset Stack Pointer                 |
| LD                      | Load                                |
| CLR                     | Clear                               |
| PUSH/POP                | Push/Pop to/from the stack          |
| INC/DEC                 | Increment/Decrement                 |
| TNZ                     | Test Negative or Zero               |
| CPL, NEG                | 1 or 2 Complement                   |
| MUL                     | Byte Multiplication                 |
| SLL, SRL, SRA, RLC, RRC | Shift and Rotate Operations         |
| SWAP                    | Swap Nibbles                        |

**5.1.2 Immediate**

Immediate instructions have two bytes, the first byte contains the opcode, the second byte contains the operand value.

| Immediate Instruction | Function              |
|-----------------------|-----------------------|
| LD                    | Load                  |
| CP                    | Compare               |
| BCP                   | Bit Compare           |
| AND, OR, XOR          | Logical Operations    |
| ADC, ADD, SUB, SBC    | Arithmetic Operations |

**5.1.3 Direct**

In Direct instructions, the operands are referenced by their memory address.

The direct addressing mode consists of two sub-modes:

**Direct (short)**

The address is a byte, thus requires only one byte after the opcode, but only allows 00 - FF addressing space.

**Direct (long)**

The address is a word, thus allowing 64 Kbyte addressing space, but requires 2 bytes after the opcode.

**5.1.4 Indexed (No Offset, Short, Long)**

In this mode, the operand is referenced by its memory address, which is defined by the unsigned addition of an index register (X or Y) with an offset.

The indirect addressing mode consists of three sub-modes:

**Indexed (No Offset)**

There is no offset, (no extra byte after the opcode), and allows 00 - FF addressing space.

**Indexed (Short)**

The offset is a byte, thus requires only one byte after the opcode and allows 00 - 1FE addressing space.

**Indexed (long)**

The offset is a word, thus allowing 64 Kbyte addressing space and requires 2 bytes after the opcode.

**5.1.5 Indirect (Short, Long)**

The required data byte to do the operation is found by its memory address, located in memory (pointer).

The pointer address follows the opcode. The indirect addressing mode consists of two sub-modes:

**Indirect (short)**

The pointer address is a byte, the pointer size is a byte, thus allowing 00 - FF addressing space, and requires 1 byte after the opcode.

**Indirect (long)**

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The pointer address is a byte, the pointer size is a word, thus allowing 64 Kbyte addressing space, and requires 1 byte after the opcode.

### 5.1.6 Indirect Indexed (Short, Long)

This is a combination of indirect and short indexed addressing modes. The operand is referenced by its memory address, which is defined by the unsigned addition of an index register value (X or Y) with a pointer value located in memory. The pointer address follows the opcode.

The indirect indexed addressing mode consists of two sub-modes:

#### Indirect Indexed (Short)

The pointer address is a byte, the pointer size is a byte, thus allowing 00 - 1FE addressing space, and requires 1 byte after the opcode.

#### Indirect Indexed (Long)

The pointer address is a byte, the pointer size is a word, thus allowing 64 Kbyte addressing space, and requires 1 byte after the opcode.

**Table 32. Instructions Supporting Direct, Indexed, Indirect and Indirect Indexed Addressing Modes**

| Long and Short Instructions | Function                                   |
|-----------------------------|--------------------------------------------|
| LD                          | Load                                       |
| CP                          | Compare                                    |
| AND, OR, XOR                | Logical Operations                         |
| ADC, ADD, SUB, SBC          | Arithmetic Addition/subtraction operations |
| BCP                         | Bit Compare                                |

| Short Instructions Only | Function                     |
|-------------------------|------------------------------|
| CLR                     | Clear                        |
| INC, DEC                | Increment/Decrement          |
| TNZ                     | Test Negative or Zero        |
| CPL, NEG                | 1 or 2 Complement            |
| BSET, BRES              | Bit Operations               |
| BTJT, BTJF              | Bit Test and Jump Operations |
| SLL, SRL, SRA, RLC, RRC | Shift and Rotate Operations  |
| SWAP                    | Swap Nibbles                 |
| CALL, JP                | Call or Jump subroutine      |

### 5.1.7 Relative mode (Direct, Indirect)

This addressing mode is used to modify the PC register value, by adding an 8-bit signed offset to it.

| Available Relative Direct/Indirect Instructions | Function         |
|-------------------------------------------------|------------------|
| JRxx                                            | Conditional Jump |
| CALLR                                           | Call Relative    |

The relative addressing mode consists of two sub-modes:

#### Relative (Direct)

The offset follows the opcode.

#### Relative (Indirect)

The offset is defined in memory, of which the address follows the opcode.



## 5.2 INSTRUCTION GROUPS

The ST7 family devices use an Instruction Set consisting of 63 instructions. The instructions may be subdivided into 13 main groups as illustrated in the following table:

|                                  |      |      |      |     |      |       |     |     |
|----------------------------------|------|------|------|-----|------|-------|-----|-----|
| Load and Transfer                | LD   | CLR  |      |     |      |       |     |     |
| Stack operation                  | PUSH | POP  | RSP  |     |      |       |     |     |
| Increment/Decrement              | INC  | DEC  |      |     |      |       |     |     |
| Compare and Tests                | CP   | TNZ  | BCP  |     |      |       |     |     |
| Logical operations               | AND  | OR   | XOR  | CPL | NEG  |       |     |     |
| Bit Operation                    | BSET | BRES |      |     |      |       |     |     |
| Conditional Bit Test and Branch  | BTJT | BTJF |      |     |      |       |     |     |
| Arithmetic operations            | ADC  | ADD  | SUB  | SBC | MUL  |       |     |     |
| Shift and Rotates                | SLL  | SRL  | SRA  | RLC | RRC  | SWAP  | SLA |     |
| Unconditional Jump or Call       | JRA  | JRT  | JRF  | JP  | CALL | CALLR | NOP | RET |
| Conditional Branch               | JRxx |      |      |     |      |       |     |     |
| Interrupt management             | TRAP | WFI  | IRET |     |      |       |     |     |
| Code Condition Flag modification | SIM  | RIM  | SCF  | RCF |      |       |     |     |

### Using a pre-byte

The instructions are described with one to four bytes.

In order to extend the number of available opcodes for an 8-bit CPU (256 opcodes), three different prebyte opcodes are defined. These prebytes modify the meaning of the instruction they precede.

The whole instruction becomes:

PC-2            End of previous instruction  
 PC-1            Prebyte  
 PC              opcode  
 PC+1           Additional word (0 to 2) according to the number of bytes required to compute the effective address

These prebytes enable instruction in Y as well as indirect addressing modes to be implemented. They precede the opcode of the instruction in X or the instruction using direct addressing mode. The prebytes are:

PDY 90        Replace an X based instruction using immediate, direct, indexed, or inherent addressing mode by a Y one.

PIX 92        Replace an instruction using direct, direct bit, or direct relative addressing mode to an instruction using the corresponding indirect addressing mode.

It also changes an instruction using X indexed addressing mode to an instruction using indirect X indexed addressing mode.

PIY 91        Replace an instruction using X indirect indexed addressing mode by a Y one.

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**INSTRUCTION GROUPS (Cont'd)**

| Mnemo | Description                | Function/Example    | Dst    | Src | H | I | N | Z | C |
|-------|----------------------------|---------------------|--------|-----|---|---|---|---|---|
| ADC   | Add with Carry             | A = A + M + C       | A      | M   | H |   | N | Z | C |
| ADD   | Addition                   | A = A + M           | A      | M   | H |   | N | Z | C |
| AND   | Logical And                | A = A . M           | A      | M   |   |   | N | Z |   |
| BCP   | Bit compare A, Memory      | tst (A . M)         | A      | M   |   |   | N | Z |   |
| BRES  | Bit Reset                  | bres Byte, #3       | M      |     |   |   |   |   |   |
| BSET  | Bit Set                    | bset Byte, #3       | M      |     |   |   |   |   |   |
| BTJF  | Jump if bit is false (0)   | btjf Byte, #3, Jmp1 | M      |     |   |   |   |   | C |
| BTJT  | Jump if bit is true (1)    | btjt Byte, #3, Jmp1 | M      |     |   |   |   |   | C |
| CALL  | Call subroutine            |                     |        |     |   |   |   |   |   |
| CALLR | Call subroutine relative   |                     |        |     |   |   |   |   |   |
| CLR   | Clear                      |                     | reg, M |     |   |   | 0 | 1 |   |
| CP    | Arithmetic Compare         | tst(Reg - M)        | reg    | M   |   |   | N | Z | C |
| CPL   | One Complement             | A = FFH-A           | reg, M |     |   |   | N | Z | 1 |
| DEC   | Decrement                  | dec Y               | reg, M |     |   |   | N | Z |   |
| IRET  | Interrupt routine return   | Pop CC, A, X, PC    |        |     | H | I | N | Z | C |
| INC   | Increment                  | inc X               | reg, M |     |   |   | N | Z |   |
| JP    | Absolute Jump              | jp [TBL.w]          |        |     |   |   |   |   |   |
| JRA   | Jump relative always       |                     |        |     |   |   |   |   |   |
| JRT   | Jump relative              |                     |        |     |   |   |   |   |   |
| JRF   | Never jump                 | jrf *               |        |     |   |   |   |   |   |
| JRIH  | Jump if ext. interrupt = 1 |                     |        |     |   |   |   |   |   |
| JRIL  | Jump if ext. interrupt = 0 |                     |        |     |   |   |   |   |   |
| JRH   | Jump if H = 1              | H = 1 ?             |        |     |   |   |   |   |   |
| JRNH  | Jump if H = 0              | H = 0 ?             |        |     |   |   |   |   |   |
| JRM   | Jump if I = 1              | I = 1 ?             |        |     |   |   |   |   |   |
| JRNM  | Jump if I = 0              | I = 0 ?             |        |     |   |   |   |   |   |
| JRMI  | Jump if N = 1 (minus)      | N = 1 ?             |        |     |   |   |   |   |   |
| JRPL  | Jump if N = 0 (plus)       | N = 0 ?             |        |     |   |   |   |   |   |
| JREQ  | Jump if Z = 1 (equal)      | Z = 1 ?             |        |     |   |   |   |   |   |
| JRNE  | Jump if Z = 0 (not equal)  | Z = 0 ?             |        |     |   |   |   |   |   |
| JRC   | Jump if C = 1              | C = 1 ?             |        |     |   |   |   |   |   |
| JRNC  | Jump if C = 0              | C = 0 ?             |        |     |   |   |   |   |   |
| JRULT | Jump if C = 1              | Unsigned <          |        |     |   |   |   |   |   |
| JRUGE | Jump if C = 0              | Jmp if unsigned >=  |        |     |   |   |   |   |   |
| JRUGT | Jump if (C + Z = 0)        | Unsigned >          |        |     |   |   |   |   |   |

## INSTRUCTION GROUPS (Cont'd)

| Mnemo | Description            | Function/Example        | Dst       | Src     | H | I | N | Z | C |
|-------|------------------------|-------------------------|-----------|---------|---|---|---|---|---|
| JRULE | Jump if (C + Z = 1)    | Unsigned <=             |           |         |   |   |   |   |   |
| LD    | Load                   | dst <= src              | reg, M    | M, reg  |   |   | N | Z |   |
| MUL   | Multiply               | X, A = X * A            | A, X, Y   | X, Y, A | 0 |   |   |   | 0 |
| NEG   | Negate (2's compl)     | neg \$10                | reg, M    |         |   |   | N | Z | C |
| NOP   | No Operation           |                         |           |         |   |   |   |   |   |
| OR    | OR operation           | A = A + M               | A         | M       |   |   | N | Z |   |
| POP   | Pop from the Stack     | pop reg<br>pop CC       | reg<br>CC | M<br>M  |   |   |   |   |   |
| PUSH  | Push onto the Stack    | push Y                  | M         | reg, CC | H | I | N | Z | C |
| RCF   | Reset carry flag       | C = 0                   |           |         |   |   |   |   | 0 |
| RET   | Subroutine Return      |                         |           |         |   |   |   |   |   |
| RIM   | Enable Interrupts      | I = 0                   |           |         |   | 0 |   |   |   |
| RLC   | Rotate left true C     | C <= Dst <= C           | reg, M    |         |   |   | N | Z | C |
| RRC   | Rotate right true C    | C => Dst => C           | reg, M    |         |   |   | N | Z | C |
| RSP   | Reset Stack Pointer    | S = Max allowed         |           |         |   |   |   |   |   |
| SBC   | Subtract with Carry    | A = A - M - C           | A         | M       |   |   | N | Z | C |
| SCF   | Set carry flag         | C = 1                   |           |         |   |   |   |   | 1 |
| SIM   | Disable Interrupts     | I = 1                   |           |         |   | 1 |   |   |   |
| SLA   | Shift left Arithmetic  | C <= Dst <= 0           | reg, M    |         |   |   | N | Z | C |
| SLL   | Shift left Logic       | C <= Dst <= 0           | reg, M    |         |   |   | N | Z | C |
| SRL   | Shift right Logic      | 0 => Dst => C           | reg, M    |         |   |   | 0 | Z | C |
| SRA   | Shift right Arithmetic | Dst7 => Dst => C        | reg, M    |         |   |   | N | Z | C |
| SUB   | Subtraction            | A = A - M               | A         | M       |   |   | N | Z | C |
| SWAP  | SWAP nibbles           | Dst[7..4] <=> Dst[3..0] | reg, M    |         |   |   | N | Z |   |
| TNZ   | Test for Neg & Zero    | tnz  b 1                |           |         |   |   | N | Z |   |
| TRAP  | S/W trap               | S/W interrupt           |           |         |   | 1 |   |   |   |
| WFI   | Wait for Interrupt     |                         |           |         |   | 0 |   |   |   |
| XOR   | Exclusive OR           | A = A XOR M             | A         | M       |   |   | N | Z |   |

## 6 ELECTRICAL CHARACTERISTICS

The ST727x4 device contains circuitry to protect the inputs against damage due to high static voltage or electric field. Nevertheless it is advised to take normal precautions and to avoid applying to this high impedance voltage circuit any voltage higher than the maximum rated voltages. It is recommended for proper operation that  $V_{IN}$  and  $V_{OUT}$  be constrained to the range:

$$V_{SS} \leq (V_{IN} \text{ or } V_{OUT}) \leq V_{DD}$$

To enhance reliability of operation, it is recommended to connect unused inputs to an appropriate logic voltage level such as  $V_{SS}$  or  $V_{DD}$ . All the voltages in the following table, are referenced to  $V_{SS}$ .

**Table 33. Absolute Maximum Ratings**

| Symbol    | Ratings                                                              | Value                            | Unit |
|-----------|----------------------------------------------------------------------|----------------------------------|------|
| $V_{DD}$  | Recommended Supply Voltage                                           | -0.3 to +6.0                     | V    |
| $V_{IN}$  | Input Voltage                                                        | $V_{SS} - 0.3$ to $V_{DD} + 0.3$ | V    |
| $V_{AIN}$ | Analog Input Voltage (A/D Converter)                                 | $V_{SS} - 0.3$ to $V_{DD} + 0.3$ | V    |
| $V_{OUT}$ | Output Voltage                                                       | $V_{SS} - 0.3$ to $V_{DD} + 0.3$ | V    |
| $I_{IN}$  | Input Current                                                        | -10.....+10                      | mA   |
| $I_{OUT}$ | Output Current                                                       | -10.....+10                      | mA   |
| $I_{INJ}$ | Accumulated injected current of all I/O pins ( $V_{DD}$ , $V_{SS}$ ) | 40                               | mA   |
| $T_A$     | Operating Temperature Range                                          | 0 to +70                         | °C   |
| $T_{STG}$ | Storage Temperature Range                                            | -65 to +150                      | °C   |
| $T_J$     | Junction Temperature                                                 | 150                              | °C   |
| PD        | Power Dissipation                                                    | TBD                              | mW   |
| ESD       | ESD susceptibility                                                   | 2000                             | V    |

## 6.1 POWER CONSIDERATIONS

The average chip-junction temperature,  $T_J$ , in degrees Celsius, may be calculated using the following equation:

$$T_J = T_A + (P_D \times \theta_{JA}) \quad (1)$$

Where:

- $T_A$  is the Ambient Temperature in °C,
- $\theta_{JA}$  is the Package Junction-to-Ambient Thermal Resistance, in °C/W,
- $P_D$  is the sum of  $P_{INT}$  and  $P_{I/O}$ ,
- $P_{INT}$  is the product of  $I_{DD}$  and  $V_{DD}$ , expressed in Watts. This is the Chip Internal Power
- $P_{I/O}$  represents the Power Dissipation on Input and Output Pins; User Determined.

For most applications  $P_{I/O} < P_{INT}$  and may be neglected.  $P_{I/O}$  may be significant if the device is configured to drive Darlington bases or sink LED Loads.

An approximate relationship between  $P_D$  and  $T_J$  (if  $P_{I/O}$  is neglected) is given by:

$$P_D = K \div (T_J + 273^\circ\text{C}) \quad (2)$$

Therefore:

$$K = P_D \times (T_A + 273^\circ\text{C}) + \theta_{JA} \times P_D^2 \quad (3)$$

Where:

- $K$  is a constant for the particular part, which may be determined from equation (3) by measuring  $P_D$  (at equilibrium) for a known  $T_A$ . Using this value of  $K$ , the values of  $P_D$  and  $T_J$  may be obtained by solving equations (1) and (2) iteratively for any value of  $T_A$ .

**Table 34. Thermal Characteristics**

| Symbol        | Package | Value | Unit |
|---------------|---------|-------|------|
| $\theta_{JA}$ | PSDIP42 | 95    | °C/W |
| $\theta_{JA}$ | TQFP44  | 95    | °C/W |

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### 6.2 AC/DC ELECTRICAL CHARACTERISTICS

( $T_A = 0$  to  $+70^\circ\text{C}$  unless otherwise specified)

| GENERAL  |                               |                                                                                                     |     |      |     |      |
|----------|-------------------------------|-----------------------------------------------------------------------------------------------------|-----|------|-----|------|
| Symbol   | Parameter                     | Conditions                                                                                          | Min | Typ. | Max | Unit |
| $V_{DD}$ | Operating Supply Voltage      | RUN & WAIT mode                                                                                     | 4.0 | 5    | 5.5 | V    |
| $I_{DD}$ | CPU RUN mode                  | I/O in input mode<br>$V_{DD} = 5\text{V}$<br>$f_{CPU} = 8\text{ MHz}$ ,<br>$T_A = 20^\circ\text{C}$ |     | 14   | 18  | mA   |
|          | CPU WAIT mode                 |                                                                                                     |     | 12   | 18  | mA   |
|          | CPU HALT mode (see Note 1)    |                                                                                                     | N/A |      |     |      |
|          | USB Suspend mode (see Note 2) |                                                                                                     | N/A |      |     |      |

Note 1: HALT mode no longer exists.

Note 2: The USB cell must be put in suspend mode as well as the MCU in HALT mode. Since the latter no longer exists for enhanced arcing protection, the measurement of the USB suspend consumption parameter is no longer relevant.

| CONTROL TIMING         |                                                                                           |                                                      |            |      |                |                 |
|------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------|------------|------|----------------|-----------------|
| Symbol                 | Parameter                                                                                 | Conditions                                           | Value      |      |                | Unit            |
|                        |                                                                                           |                                                      | Min        | Typ. | Max            |                 |
| $f_{OSC}$<br>$f_{CPU}$ | Frequency of Operation:<br>external frequency<br>internal frequency<br>internal frequency | $f_{OSC} = 24\text{MHz}$<br>$f_{OSC} = 12\text{MHz}$ |            |      | 24<br>8<br>4   | MHz             |
| $t_{BU}$               | Startup Time Built-Up Time                                                                | Crystal Resonator                                    |            | 8    | 20             | ms              |
| $t_{RL}$               | External RESET<br>Input pulse Width                                                       |                                                      | 1000       |      |                | ns              |
| $t_{PORL}$             | Internal Power Reset Duration                                                             |                                                      | 4096       |      |                | $t_{CPU}$       |
| $t_{POWL}$             | Watchdog RESET<br>Output Pulse Width                                                      |                                                      | 500        |      |                | ns              |
| $t_{DOG}$              | Watchdog Time-out                                                                         | $f_{CPU} = 8\text{ MHz}$                             | 49152<br>6 |      | 3145728<br>384 | $t_{CPU}$<br>ms |
| $t_{ILIL}$             | Interrupt Pulse Period                                                                    |                                                      |            | (1)  |                | $t_{CPU}$       |
| $t_{OXOV}$             | Crystal Oscillator<br>Start-up Time                                                       |                                                      |            |      | 50             | ms              |
| $t_{DDR}$              | Power up rise time                                                                        | $V_{DD\text{ min}}$                                  | 1          |      | 100            | ms              |

**Note:** : The minimum period  $t_{ILIL}$  should not be less than the number of cycle times it takes to execute the interrupt service routine plus 21 cycles.

## AC/DC ELECTRICAL CHARACTERISTICS (Cont'd)

| STANDARD I/O PORT PINS |                                                                                                                      |                                                         |                     |     |                     |               |
|------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|---------------------|-----|---------------------|---------------|
| Symbol                 | Parameter                                                                                                            | Conditions                                              | Min                 | Typ | Max                 | Unit          |
| $V_{OL}$               | Output Low Level Voltage<br>Port A[7,2:0], Port B[7:4],<br>Port C[7:0], Port D[6:0]<br>Push Pull                     | $I_{OL} = -1.6\text{mA}$ $V_{DD}=5\text{V}$             | -                   | -   | 0.4                 | V             |
| $V_{OL}$               | Output Low Level Voltage Port A[6:3]<br>Open Drain                                                                   | $I_{OL} = -1.6\text{mA}$ $V_{DD}=5\text{V}$             | -                   | -   | 0.4                 | V             |
| $V_{OL}$               | Output Low Level Voltage<br>Port A and Port C                                                                        | $I_{OL} = -10\text{mA}$ $V_{DD}=5\text{V}$              | -                   | -   | 1.5                 | V             |
| $V_{OL}$               | Output Low Level Voltage Port B[3:0]<br>Open Drain                                                                   | $I_{OL} = -3\text{mA}$ $V_{DD}=5\text{V}$               | -                   | -   | 0.4                 | V             |
| $V_{OH}$               | Output High Level Voltage<br>Port A[7, 2:0], Port B[7:4],<br>Port C [7:0], Port D [6:0]<br>Push Pull                 | $I_{OH} = 1.6\text{mA}$                                 | $V_{DD}-0.8$        | -   | -                   | V             |
| $V_{IH}$               | Input High Level Voltage Port A [7:0],<br>Port B [7:0], Port C [7:0], Port D[6:0],<br>$\overline{\text{RESET}}$      | Leading Edge                                            | $0.7 \times V_{DD}$ |     | $V_{DD}$            | V             |
| $V_{IH}$               | HSYNC, VSYNCl, CSYNCl, HFBACK,<br>VFBACK                                                                             | $V_{DD} = 5\text{V}$                                    | 2.0                 |     |                     | V             |
| $V_{IL}$               | HSYNC, VSYNCl, CSYNCl, HFBACK,<br>VFBACK                                                                             | $V_{DD} = 5\text{V}$                                    |                     |     | 0.8                 | V             |
| $V_{IL}$               | Input Low Voltage Port A [7:0],<br>Port B[7:0], Port C[7:0], Port D [6:0],<br>$\overline{\text{RESET}}$              | Trailing Edge                                           | $V_{SS}$            |     | $0.3 \times V_{DD}$ | V             |
| $I_{IL}$               | I/O Ports Hi-Z Leakage Current<br>Port A [7:0], Port B[7:0], Port C[7:0],<br>Port D [6:0], $\overline{\text{RESET}}$ |                                                         |                     |     | 10                  | $\mu\text{A}$ |
| $C_{OUT}$<br>$C_{IN}$  | Capacitance: Ports (as Input or<br>Output), $\overline{\text{RESET}}$                                                |                                                         |                     |     | 12<br>8             | pF<br>pF      |
| IRPU                   | Pull-up resistor current                                                                                             | $V_{DD}=5\text{V}$ $V_{IN}=V_{SS}$ $T=25^\circ\text{C}$ |                     | 280 |                     | $\mu\text{A}$ |

**Note: Note:** All voltages are referred to  $V_{SS}$  unless otherwise specified.

| POWER ON/OFF Electrical Specifications |                                                     |                            |      |      |     |      |
|----------------------------------------|-----------------------------------------------------|----------------------------|------|------|-----|------|
| Symbol                                 | Parameter                                           | Conditions                 | Min  | Typ  | Max | Unit |
| $V_{TRH}$                              | Power ON/OFF Reset Trigger<br>$V_{DD}$ rising edge  | $V_{DD}$ Variation 50mV/mS | 3.35 | 3.65 | 3.9 | V    |
| $V_{TRL}$                              | Power ON/OFF Reset Trigger<br>$V_{DD}$ falling edge | $V_{DD}$ Variation 50mV/mS | 3.1  | 3.4  | 3.7 | V    |
| $V_{TRM}$                              | $V_{DD}$ minimum for Power ON/OFF Reset<br>active   | $V_{DD}$ Variation 50mV/mS |      | 2.0  | 2.2 | V    |
| $V_{TRHyst}$                           | Power ON/OFF LVD Hysteresis                         | $V_{DD}$ Variation 50mV/mS |      | 250  |     | mV   |

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**AC/DC ELECTRICAL CHARACTERISTICS (Cont'd)**

| 8-bit A/D Converter |                                     |                                             |          |     |             |             |
|---------------------|-------------------------------------|---------------------------------------------|----------|-----|-------------|-------------|
| Symbol              | Parameter                           | Conditions                                  | Min      | Typ | Max         | Unit        |
| $f_{ADC}$           | Analog control frequency            | $V_{DD}=5V$                                 |          |     | 2           | MHz         |
| TUE                 | Total unadjusted error              | $f_{CPU}=8MHz, f_{ADC}=2MHz$<br>$V_{DD}=5V$ |          |     | 2           | LSB         |
| OE                  | Offset error                        |                                             | -1       |     | 1           |             |
| GE                  | Gain error                          |                                             | -1       |     | 1           |             |
| DLE                 | Differential linearity error        |                                             |          |     | 0.5         |             |
| ILE                 | Integral linearity error            |                                             |          |     | 0.5         |             |
| $V_{AIN}$           | Conversion range voltage            |                                             | $V_{SS}$ |     | $V_{DD}$    | V           |
| $I_{ADC}$           | A/D conversion supply current       | $f_{CPU}=8MHz, f_{ADC}=2MHz$<br>$V_{DD}=5V$ |          | 1   |             | mA          |
| $t_{STAB}$          | Stabilization time after enable ADC |                                             |          |     | 1           | $\mu s$     |
| $t_{LOAD}$          | Sample capacitor loading time       |                                             |          | 1   |             | $\mu s$     |
|                     |                                     |                                             |          | 4   |             | $1/f_{ADC}$ |
| $t_{CONV}$          | Conversion time                     |                                             |          | 2   |             | $\mu s$     |
|                     |                                     |                                             | 8        |     | $1/f_{ADC}$ |             |
| $R_{AIN}$           | External input resistor             |                                             |          |     | 15          | $k\Omega$   |
| $R_{ADC}$           | Internal input resistor             |                                             |          | 1.5 |             | $k\Omega$   |
| $C_{SAMPLE}$        | Sample capacitor                    |                                             |          | 6   |             | pF          |

| PWM/BRM Electrical and Timings |                 |                             |     |     |     |      |
|--------------------------------|-----------------|-----------------------------|-----|-----|-----|------|
| Symbol                         | Parameter       | Conditions                  | Min | Typ | Max | Unit |
| $F$                            | Repetition rate | $T_{CPU}=125ns$             |     | 125 |     | kHz  |
| Res                            | Resolution      | $T_{CPU}=125ns$             |     | 125 |     | ns   |
| s                              | Output step     | $V_{DD}=5V, 10\text{ bits}$ |     | 5   |     | mV   |



## AC/DC ELECTRICAL CHARACTERISTICS (Cont'd)

| I2C/DDC-Bus Electrical specifications                                                                                                                                    |           |         |                   |     |               |       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---------|-------------------|-----|---------------|-------|
| Parameter                                                                                                                                                                | Symbol    | Unit    | Standard mode I2C |     | Fast mode I2C |       |
|                                                                                                                                                                          |           |         | Min               | Max | Min           | Max   |
| Hysteresis of Schmitt trigger inputs<br>Fixed input levels<br>$V_{DD}$ -related input levels                                                                             | $V_{HYS}$ | V       | na                | na  | 0.2           |       |
|                                                                                                                                                                          |           |         | na                | na  | $0,05 V_{DD}$ |       |
| Pulse width of spikes which must be suppressed by the input filter                                                                                                       | $T_{SP}$  | ns      | na                | na  | 0 ns          | 50 ns |
| Output fall time from $V_{IH}$ min to $V_{IL}$ max with a bus capacitance from 10 pF to 400 pF with up to 3 mA sink current at VOL1 with up to 6 mA sink current at VOL2 | $T_{OF}$  | ns      | na                | 250 | $20+0.1C_b$   | 250   |
|                                                                                                                                                                          |           |         | na                | na  | $20+0.1C_b$   | 250   |
| Input current each I/O pin with an input voltage between 0.4V and $0.9 V_{DD}$ max                                                                                       | I         | $\mu A$ | - 10              | 10  | -10           | 10    |
| Capacitance for each I/O pin                                                                                                                                             | C         | pF      |                   | 10  |               | 10    |

na = not applicable

 $C_b$  = capacitance of one bus in pF

| I2C/DDC-Bus Timings                                                              |              |      |             |        |              |         |
|----------------------------------------------------------------------------------|--------------|------|-------------|--------|--------------|---------|
| Parameter                                                                        | Standard I2C |      | Fast I2C    |        | Symbol       | Unit    |
|                                                                                  | Min          | Max  | Min         | Max    |              |         |
| Bus free time between a STOP and START condition                                 | 4.7          |      | 1.3         |        | $T_{BUF}$    | ms      |
| Hold time START condition. After this period, the first clock pulse is generated | 4.0          |      | 0.6         |        | $T_{HD:STA}$ | $\mu s$ |
| LOW period of the SCL clock                                                      | 4.7          |      | 1.3         |        | $T_{LOW}$    | $\mu s$ |
| HIGH period of the SCL clock                                                     | 4.0          |      | 0.6         |        | $T_{HIGH}$   | $\mu s$ |
| Set-up time for a repeated START condition                                       | 4.7          |      | 0.6         |        | $T_{SU:STA}$ | $\mu s$ |
| Data hold time                                                                   | 0 (1)        |      | 0 (1)       | 0.9(2) | $T_{HD:DAT}$ | ns      |
| Data set-up time                                                                 | 250          |      | 100         |        | $T_{SU:DAT}$ | ns      |
| Rise time of both SDA and SCL signals                                            |              | 1000 | $20+0.1C_b$ | 300    | $T_R$        | ns      |
| Fall time of both SDA and SCL signals                                            |              | 300  | $20+0.1C_b$ | 300    | TF           | ns      |
| Set-up time for STOP condition                                                   | 4.0          |      | 0.6         |        | $T_{SU:STO}$ | ns      |
| Capacitive load for each bus line                                                |              | 400  |             | 400    | $C_b$        | pF      |

1)The device must internally provide a hold time of at least 300 ns for the SDA signal in order to bridge the undefined region of the falling edge of SCL

2)The maximum hold time of the START condition has only to be met if the interface does not stretch the low period of SCL signal

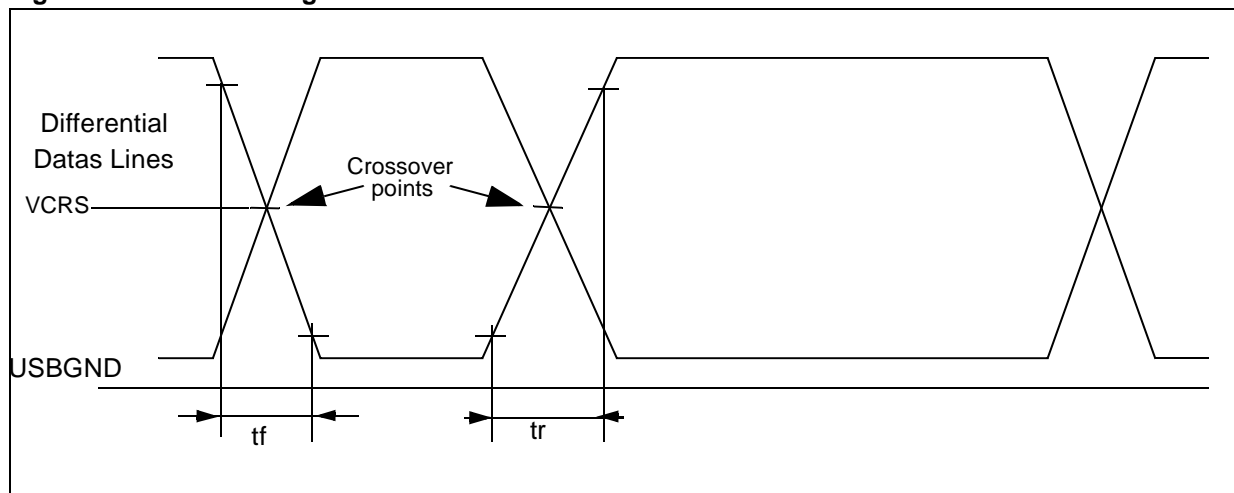
$C_b$  = total capacitance of one bus line in pF

| USB DC Electrical Characteristics |        |                          |      |      |      |
|-----------------------------------|--------|--------------------------|------|------|------|
| Parameter                         | Symbol | Conditions               | Min. | Max. | Unit |
| Inputs Levels:                    |        |                          |      |      |      |
| Differential Input Sensitivity    | VDI    | Absl((D+) - (D-))        | 0.2  |      | V    |
| Differential Common Mode Range    | VCM    | Includes VDI range       | 0.8  | 2.5  | V    |
| Single Ended Receiver Threshold   | VSE    |                          | 0.8  | 2.0  | V    |
| Output Levels                     |        |                          |      |      |      |
| Static Output Low                 | VOL    | RL of 1.5K ohms to 3.6V  |      | 0.3  | V    |
| Static Output High                | VOH    | RL of 15K ohms to USBGND | 2.8  | 3.6  | V    |
| USBVCC: voltage level             | USBV   | V <sub>DD</sub> =5V      | 3    | 3.6  | V    |

**Notes:**

- RL is the load connected on the USB drivers.
- All the voltages are measured from the local ground potential (USBGND).

**Figure 78. USB: Data signal Rise and fall time**



| USB: Low speed electrical characteristics |        |                   |     |     |      |
|-------------------------------------------|--------|-------------------|-----|-----|------|
| Parameter                                 | Symbol | Conditions        | Min | Max | Unit |
| Driver characteristics:                   |        |                   |     |     |      |
| Rise time                                 | tr     | Note 1, CL=50 pF  | 75  |     | ns   |
|                                           |        | Note 1, CL=600 pF |     | 300 | ns   |
| Fall Time                                 | tf     | Note 1, CL=50 pF  | 75  |     | ns   |
|                                           |        | Note 1, CL=600 pF |     | 300 | ns   |
| Rise/ Fall Time matching                  | trfm   | tr/tf             | 80  | 120 | %    |
| Output signal Crossover Voltage           | VCRS   |                   | 1.3 | 2.0 | V    |

**Note1:** Measured from 10% to 90% of the data signal

## 7 GENERAL INFORMATION

### 7.1 PACKAGE MECHANICAL DATA

Figure 79. 42-Pin Shrink Plastic Dual In-Line Package, 600-mil Width

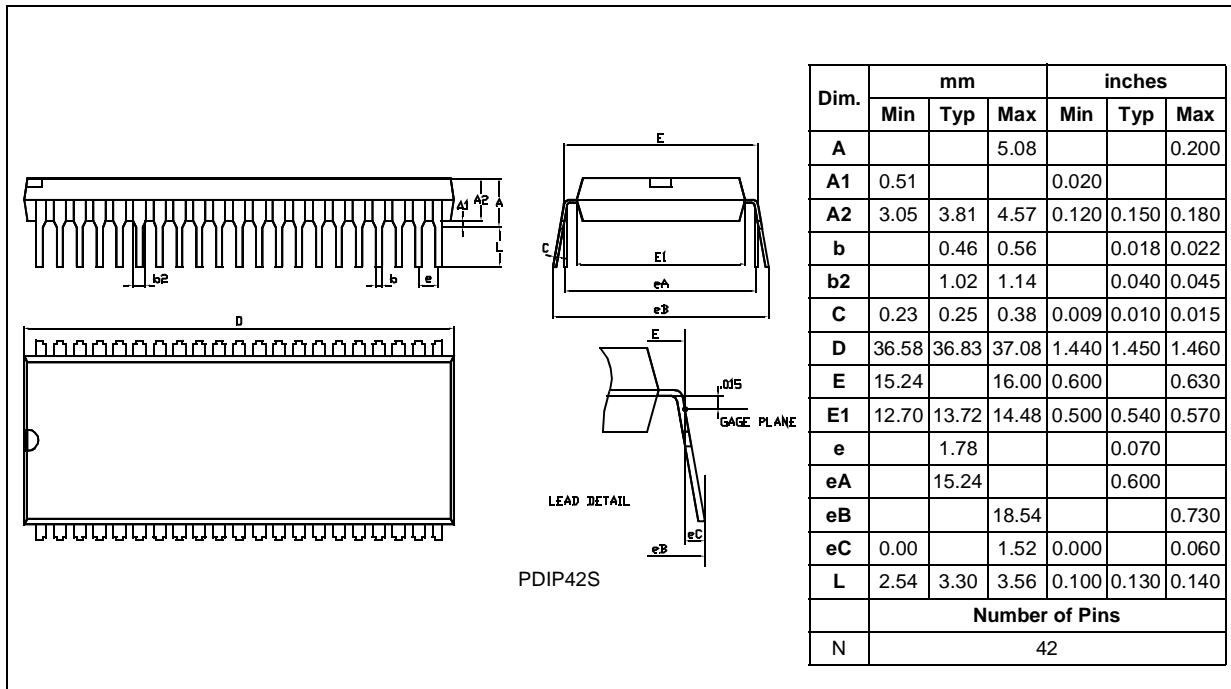
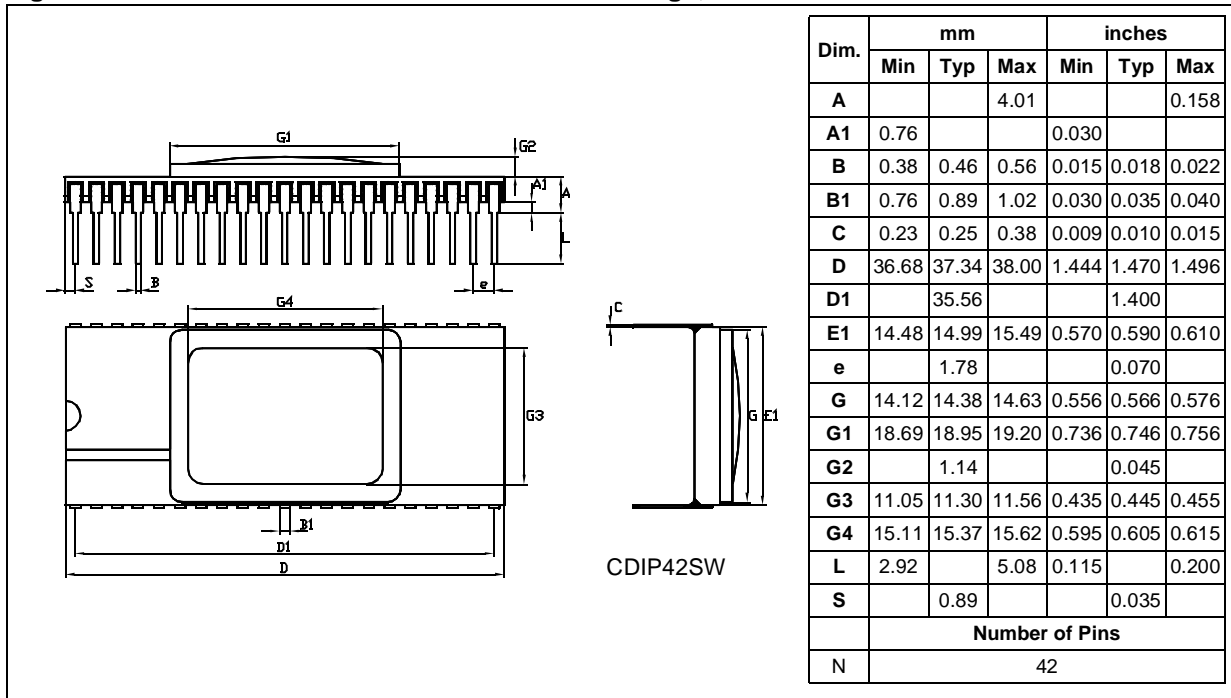
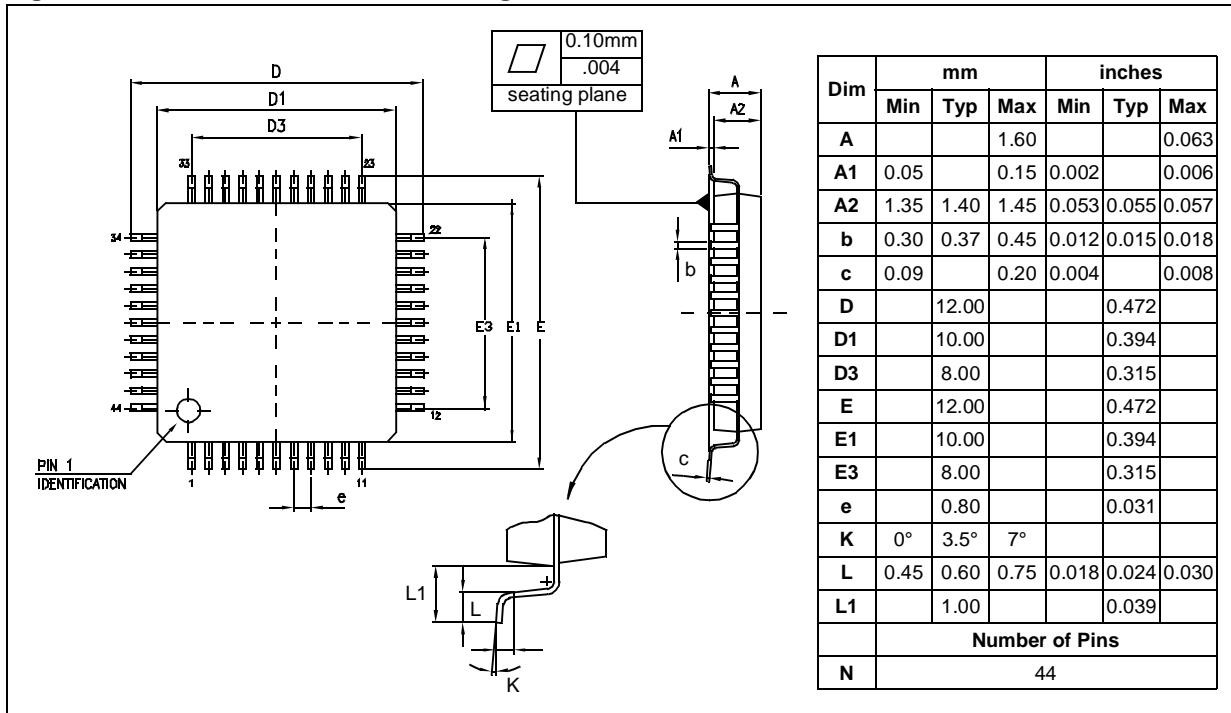


Figure 80. 42-Pin Shrink Ceramic Dual In-Line Package, 600-mil Width



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Figure 81. 44-Pin Thin Quad Flat Package



## 8 ORDERING INFORMATION

The following section deals with the procedure for transfer of customer codes to STMicroelectronics.

### 8.1 Transfer of Customer Code

Customer code is made up of the ROM contents and the list of the selected mask options (if any). The ROM contents are to be sent on diskette, or by electronic means, with the hexadecimal file in .S19 format generated by the development tool. All

unused bytes must be set to 9Dh (opcode for NOP).

The selected mask options are communicated to STMicroelectronics using the correctly completed OPTION LIST appended.

The STMicroelectronics Sales Organization will be pleased to provide detailed information on contractual points.

Figure 82. Sales Type Coding Rules

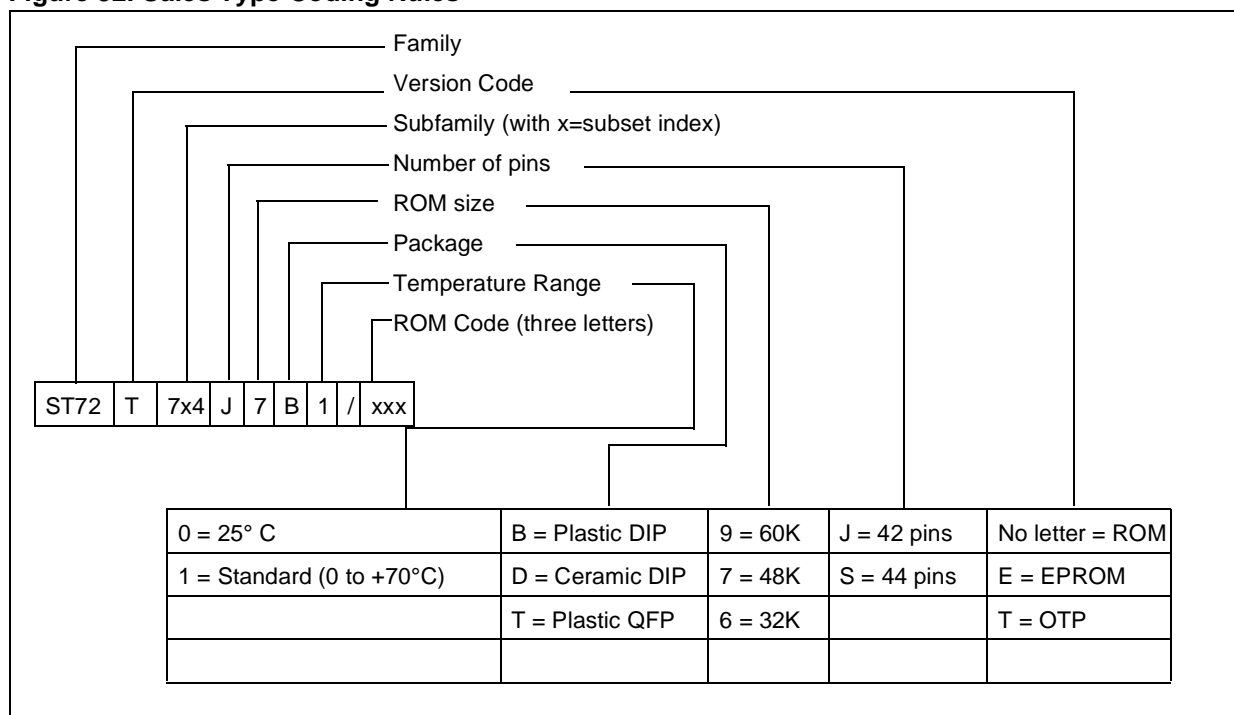


Table 35. Development Tools

| Development Tool       | Sales Type                         | Remarks                                      |
|------------------------|------------------------------------|----------------------------------------------|
| Real time Emulator     | ST727x4-EMU2B                      |                                              |
| EPROM Programmer Board | ST727x4-EPB/xx <sup>1</sup>        | 220V Power Supply EU<br>110V Power Supply US |
| Gang Programmer        | ST72E774-GP/D42<br>ST72E774-GP/Q44 | DIL42<br>PQFP44                              |

<sup>1</sup> xx stands for the power supply code assigned by ST Microelectronics: EU=220V; US=110V

**ST72774/ST727754/ST72734**

**Table 36. Ordering Information**

| Sales Type          | ROM/EPROM (bytes) | RAM (bytes) | TMU | USB | Package |
|---------------------|-------------------|-------------|-----|-----|---------|
| <b>ST72X774 (1)</b> |                   |             |     |     |         |
| ST72E774J9D0        | 60K EPROM         | 1K          | Yes | Yes | CSDIP42 |
| ST72T774J9B1        | 60K OTP           |             |     |     | PSDIP42 |
| ST72774J9B1/xxx     | 60K ROM           |             |     |     |         |
| ST72774J7B1/xxx     | 48K ROM           |             |     |     | TQFP44  |
| ST72774S7T1/xxx     | 48K ROM           |             |     |     |         |
| ST72T774S9T1        | 60K OTP           |             |     |     |         |
| ST72774S9T1/xxx     | 60K ROM           |             |     |     |         |
| <b>ST72X754 (1)</b> |                   |             |     |     |         |
| ST72E754J9D0        | 60K EPROM         | 1K          | Yes | No  | CSDIP42 |
| ST72T754J9B1        | 60K OTP           |             |     |     | PSDIP42 |
| ST72754J9B1/xxx     | 60K ROM           |             |     |     |         |
| ST72754J7B1/xxx     | 48K ROM           |             |     |     | TQFP44  |
| ST72T754S9T1        | 60K OTP           |             |     |     |         |
| ST72754S9T1         | 60K ROM           |             |     |     |         |
| ST72754S7T1/xxx     | 48K ROM           |             |     |     |         |
| <b>ST72X734 (2)</b> |                   |             |     |     |         |
| ST72E734J6D0        | 32K EPROM         | 512         | No  | No  | CSDIP42 |
| ST72T734J6B1/xxx    | 32K OTP           |             |     |     | PSDIP42 |
| ST72734J6B1/xxx     | 32K ROM           |             |     |     |         |

(1) 8 bit ±2 LSB A/D converter

(2) 8 bit ±4 LSB A/D converter

STMicroelectronics OPTION LIST

ST727x4 MICROCONTROLLER FAMILY

Customer: .....  
 Address: .....  
 .....  
 Contact: .....  
 Phone No: .....  
 Reference/ROM Code\* : .....

\*The ROM code name assigned by ST.

STMicroelectronics reference:

- Device (SDIP42):             ST72774J9B1 (60K ROM)
- ST72774J7B1 (48K ROM)
- ST72754J9B1 (60K ROM)
- ST72754J7B1 (48K ROM)
- ST72734J6B1 (32K ROM)
- Device (TQFP44):          ST72774S9T1 (60K ROM)
- ST72774S7T1 (48K ROM)
- ST72754S9T1 (60K ROM)
- ST72754S7T1 (48K ROM)
- Device (CSDIP42):         ST72E774J9D0 (60K EPROM)
- ST72E754J9D0 (60K EPROM)
- ST72E734J6D0 (32K EPROM)
- Software Development:    STMicroelectronics
- Customer
- External laboratory

Special Marking:             No                             Yes "\_\_\_\_\_"

For marking, one line is possible with maximum 16 characters for SDIP42 and 10 characters for TQFP44.

Authorized characters are letters, '!', '!', '/' and spaces only.

Mask Options:                None.

We have checked the ROM code verification file returned to us by STMicroelectronics. It conforms exactly with the ROM code file originally supplied. We therefore authorize STMicroelectronics to proceed with device manufacture.

Signature .....  
 Date .....



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