

W78E378/W78C378/W78C374



MONITOR MICROCONTROLLER

GENERAL DESCRIPTION

The W78E378, W78C378 and W78C374B are ASIC which is a stand-alone high-performance microcontroller specially designed for monitor control applications. The device integrates the embedded 80C31 microcontroller core, on-chip Flash EPROM or Mask ROM, 576 bytes of RAM, and a number of dedicated hardware monitor functions. Additional special function registers are incorporated to control the on-chip peripheral hardware. The chip is used to control the interface signal of other devices in the monitor and to process the video sync signals. Because of the highly integration and Flash cell for program memory, the device can offer users the competitive advantages of low cost and reduced development time.

FEATURES

- 80C31 MCU Core Embedded
- 32K Bytes Flash EPROM(W78E378)
- 32K Bytes Mask-ROM (W78C378)
- 16K Bytes Mask-ROM (W78C374B)
- Total 576 Bytes of On-chip Data RAM
 - 256 bytes accessed as in the 80C32
 - 320 bytes accessed as external data memory via "MOVX @Ri"
- PWM DACs
 - Eight 8-bit Static PWM DACs: DAC0–DAC8
 - Three 8-bit Dynamic PWM DACs: DAC9–DAC10
- Sync Processor
 - Horizontal & Vertical Polarity Detector
 - Sync Separator for Composite Sync
 - 12-bit Horizontal & Vertical Frequency Counter
 - Programmable Dummy Frequency Generator
 - Programmable H-clamp Pulse Output
 - SOA Interrupt
 - Hsync/2 Output
- Serial Ports:
 - DDC1 Port- support DDC1
 - SIO1 & SIO2 Ports - each can support DDC2B/2B+/2Bi/2AB (each has 2 slave addresses)
- Two 16-bit Timer/Counters (8031's Timer0 & Timer1)
- One External Interrupt Input (8031's $\overline{\text{INT0}}$)
- One Parabola Interrupt Generator
- One ADC with 7 Multiplexed Analog Inputs
- Two 12 mA(min) Output Pins for Driving LEDs
- Watchdog Timer ($2^{22}/F_{osc} = 0.42s @F_{osc} = 10 \text{ MHz}$)
- Power Low Reset
- Frequency: 10 MHz max. (with the same performance as a normal 8051 that uses 20 MHz)
- Packaged in 40/32-pin 600 mil DIP & 44-pin PLCC

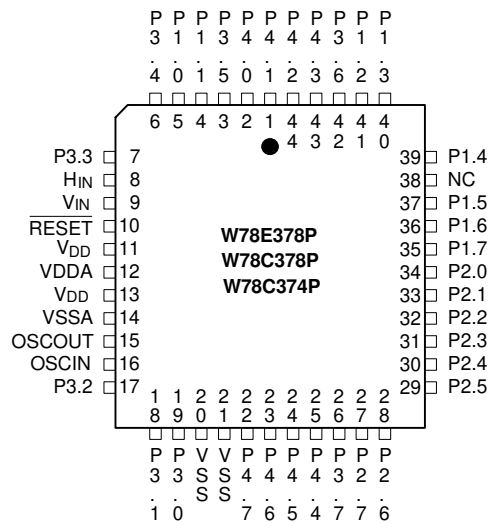
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PIN CONFIGURATIONS

| 40-pin DIP: | W78E378E | | 40-pin DIP | | | |
|-------------|----------|------------------|------------|------------|---------|---------------------|
| | W78C378E | P4.1 | 1 | | 40 P4.2 | |
| | W78C374E | P4.0 (HFI) | 2 | 32-pin DIP | 39 P4.3 | |
| | | P3.5 (ADC4, T0)* | 3 | 1 | 32 | 38 P3.6 (ADC5, T1)* |
| | | P1.1 (DAC1)* | 4 | 2 | 31 | 37 P1.2 (DAC2)* |
| 32-pin DIP: | W78E378 | P1.0 (DAC0)* | 5 | 3 | 30 | 36 P1.3 (DAC3)* |
| | W78C378 | P3.4 (VOUT) | 6 | 4 | 29 | 35 P1.4 (DAC4)* |
| | W78C374 | P3.3 (HOUT) | 7 | 5 | 28 | 34 P1.5 (DAC5)* |
| | | H _{IN} | 8 | 6 | 27 | 33 P1.6 (DAC6)* |
| | | V _{IN} | 9 | 7 | 26 | 32 P1.7 (DAC7)* |
| | | RESET | 10 | 8 | 25 | 31 P2.0 (DAC8) |
| | | V _{DD} | 11 | 9 | 24 | 30 P2.1 (DAC9) |
| | | V _{SSA} | 12 | 10 | 23 | 29 P2.2 (DAC10) |
| | | OSCOUT | 13 | 11 | 22 | 28 P2.3 (Hclamp) |
| | | OSCIN | 14 | 12 | 21 | 27 P2.4 (ADC0) |
| | | P3.2 (INT0) | 15 | 13 | 20 | 26 P2.5 (ADC1) |
| | | P3.1 (SCL)* | 16 | 14 | 19 | 25 P2.6 (ADC2) |
| | | P3.0 (SDA)* | 17 | 15 | 18 | 24 P2.7 (ADC3) |
| | | V _{SS} | 18 | 16 | 17 | 23 P3.7 (ADC6)* |
| | | P4.7 (HFO) | 19 | | | 22 P4.4 (SCL2)* |
| | | P4.6 | 20 | | | 21 P4.5 (SDA2)* |

44-pin PLCC



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PIN DESCRIPTION

| PIN NAME | I/O | DESCRIPTION |
|-------------|-----|--|
| RESET | I/O | Chip reset input (active low) input & Internal reset output (generated by WDT or power low) TTL Schmitt trigger input, internal pull-up ~30 KΩ IOL = +12 mA @VOL = 0.45V |
| VDD | - | Positive power supply |
| VSS | - | Ground |
| VSS | - | Ground |
| OSCOU | O | Output from the inverting oscillator amplifier |
| OSCI | I | Input to the inverting oscillator amplifier, 10 MHz max. |
| HIN | I | Hsync input TTL Schmitt trigger input , w/o PMOS VIH/VIL = 2.0V/0.8V, V+ / V- = ~1.6V/ 1.1V |
| VIN | I | Vsync input TTL Schmitt trigger input, w/o PMOS VIH/VIL = 2.0V/0.8V, V+ / V- = ~1.6V/ 1.1V |
| P1.0 (DAC0) | I/O | General purpose I/O, DAC0 special function output Open-drain output , sink current: 15 mA |
| P1.1 (DAC1) | I/O | General purpose I/O, DAC1 special function output Open-drain output , sink current: 15 mA |
| P1.2 (DAC2) | I/O | General purpose I/O, DAC2 special function output Open-drain output , sink current: 4 mA |
| P1.3 (DAC3) | I/O | General purpose I/O, DAC3 special function output Open-drain output , sink current: 4 mA |
| P1.4 (DAC4) | I/O | General purpose I/O, DAC4 special function output Open-drain output , sink current: 4 mA |
| P1.5 (DAC5) | I/O | General purpose I/O, DAC5 special function output Open-drain output , sink current: 4 mA |
| P1.6 (DAC6) | I/O | General purpose I/O, DAC6 special function output Open-drain output , sink current: 4 mA |
| P1.7 (DAC7) | I/O | General purpose I/O, DAC7 special function output Open-drain output , sink current: 4 mA |

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Pin Description, Continued

| PIN NAME | I/O | DESCRIPTION |
|----------------------------|-----|---|
| P2.0 (DAC8) | I/O | General purpose I/O, DAC8 Special Function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P2.1 (DAC9) | I/O | General purpose I/O, DAC9 Special Function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P2.2 (DAC10) | I/O | General purpose I/O, DAC10 Special Function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P2.3 (Hclamp) | I/O | General purpose I/O, Hclamp Special Function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P2.4 (ADC0) | I/O | General purpose I/O, ADC input channel 0 Sink/Source current: 4 mA/-100 μ A |
| P2.5 (ADC1) | I/O | General purpose I/O, ADC input channel 1 Sink/Source current: 4 mA/-100 μ A |
| P2.6 (ADC2) | I/O | General purpose I/O, ADC input channel 2 Sink/Source current: 4 mA/-100 μ A |
| P2.7 (ADC3) | I/O | General purpose I/O, ADC input channel 3 Sink/Source current: 4 mA/-100 μ A |
| P3.0 (SDA) | I/O | General purpose I/O, DDC port serial data I/O Schmitt trigger input $V_{IH}/V_{IL} = 0.7 V_{DD}/0.3 V_{DD}$, $V_{+}/V_{-} = \sim 0.6 V_{DD}/0.4 V_{DD}$ Open-drain output , sink current: 8 mA |
| P3.1 (SCL) | I/O | General purpose I/O, DDC port serial clock I/O Schmitt trigger input $V_{IH}/V_{IL} = 0.7 V_{DD}/0.3 V_{DD}$, $V_{+}/V_{-} = \sim 0.6 V_{DD}/0.4 V_{DD}$ Open-drain output , sink current: 8 mA |
| P3.2 ($\overline{INT0}$) | I/O | General purpose I/O, $\overline{INT0}$ input Sink/Source current: 1 mA/ -100 μ A |
| P3.3 (HOUT) | I/O | General purpose I/O, HOUT special function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P3.4 (VOUT) | I/O | General purpose I/O, VOUT special function output Sink/Source current: 4 mA/-100 μ A (-4 mA for SF output) |
| P3.5 (ADC4, T0) | I/O | General purpose I/O, ADC input channel 4 Open-drain output , sink current: 4 mA |
| P3.6 (ADC5, T1) | I/O | General purpose I/O, ADC input channel 5 Open-drain output , sink current: 4 mA |
| P3.7 (ADC6) | I/O | General purpose I/O, ADC input channel 6 Open-drain output , sink current: 4 mA |

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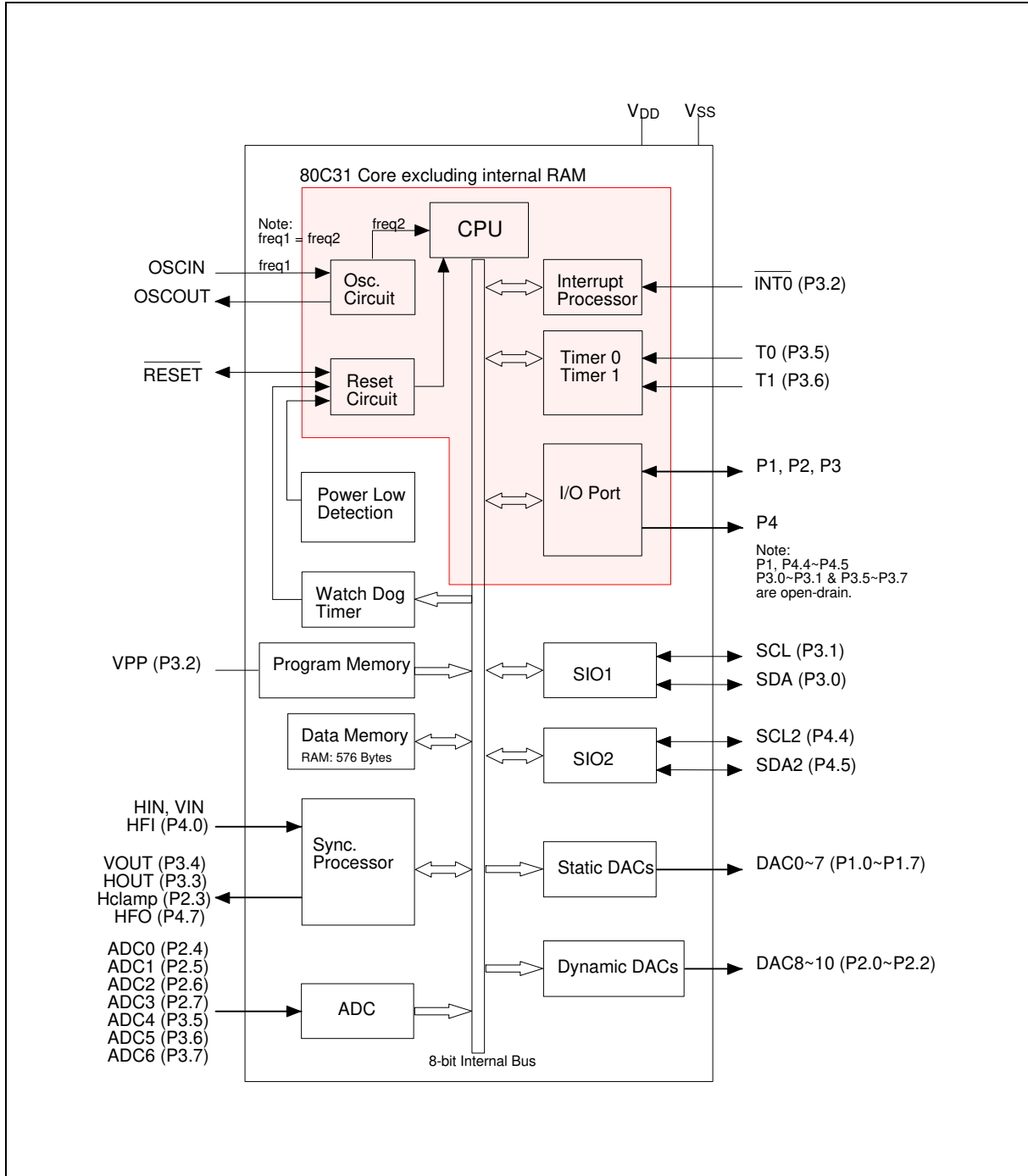
Pin Description, Continued

| PIN NAME | I/O | DESCRIPTION |
|-------------|-----|--|
| P4.0 (HFI) | I/O | P4.0 Output, HFI Input Sink/Source current: 4 mA/-4 mA |
| P4.1 | O | P4.1 Output Sink/Source current: 4 mA/-4 mA |
| P4.2 | O | P4.2 Output Sink/Source current: 4 mA/-4 mA |
| P4.3 | O | P4.3 Output Sink/Source current: 4 mA/-4 mA |
| P4.4 (SCL2) | I/O | P4.4 Output, SIO2 port serial clock I/O Schmitt trigger input $V_{IH}/V_{IL} = 0.7 V_{DD}/0.3 V_{DD}$, $V_{+}/V_{-} = \sim 0.6 V_{DD}/0.4 V_{DD}$ Open-drain output , sink current: 8 mA |
| P4.5 (SDA2) | I/O | P4.5 Output, SIO2 port serial data I/O Schmitt trigger input $V_{IH}/V_{IL} = 0.7 V_{DD}/0.3 V_{DD}$, $V_{+}/V_{-} = \sim 0.6 V_{DD}/0.4 V_{DD}$ Open-drain output , sink current: 8 mA |
| P4.6 | O | P4.6 Output Sink/Source current: 4 mA/-4 mA |
| P4.7 (HFO) | O | P4.7 Output, HFO Output Sink/Source current: 4 mA/-4 mA |

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BLOCK DIAGRAM

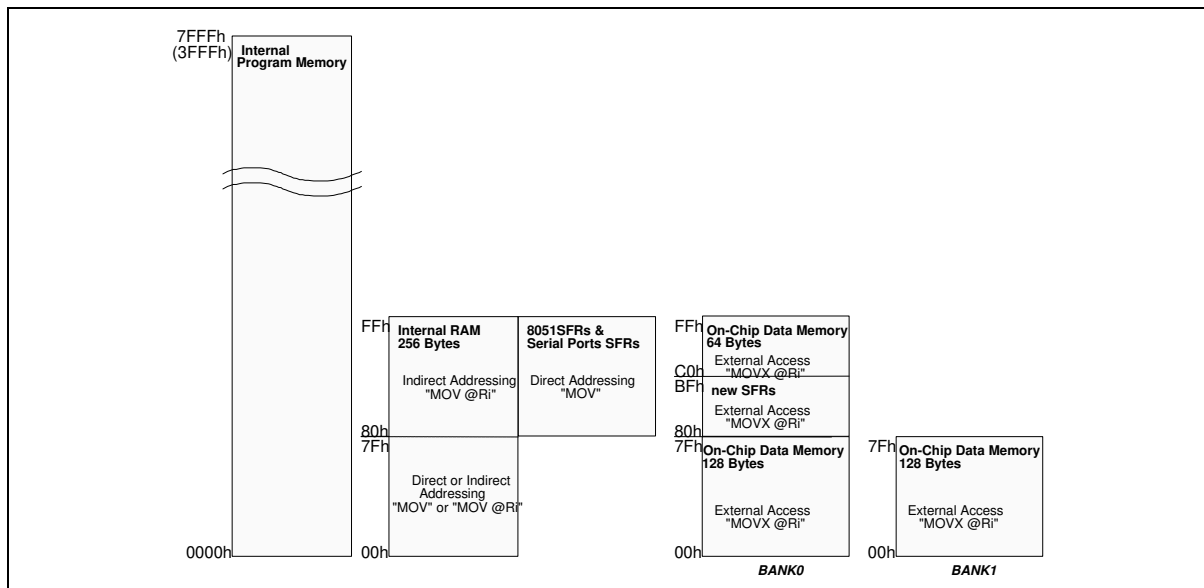


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FUNCTIONAL DESCRIPTION

Address Space



Program/Data/SFRs Address Space

SFRs accessed using 'Direct Addressing'

| | REGISTER | ADDRESS | BITS | POWER ON RESET | RESET | R/W |
|----|----------|---------|------|----------------|-------|-----|
| 1 | A* | E0h | 8 | 00h | 00h | R/W |
| 2 | B* | F0h | 8 | 00h | 00h | R/W |
| 3 | PSW* | D0h | 8 | 00h | 00h | R/W |
| 4 | SP | 81h | 8 | 00h | 00h | R/W |
| 5 | DPL | 82h | 8 | 00h | 00h | R/W |
| 6 | DPH | 83h | 8 | 00h | 00h | R/W |
| 7 | IE* | A8h | 8 | 00h | 00h | R/W |
| 8 | IP* | B8h | 8 | 00h | 00h | R/W |
| 9 | TCON* | 88h | 8 | 00h | 00h | R/W |
| 10 | TMOD | 89h | 8 | 00h | 00h | R/W |
| 11 | TL0 | 8Ah | 8 | 00h | 00h | R/W |
| 12 | TH0 | 8Ch | 8 | 00h | 00h | R/W |
| 13 | TL1 | 8Bh | 8 | 00h | 00h | R/W |
| 14 | TH1 | 8Dh | 8 | 00h | 00h | R/W |
| 15 | PCON | 87h | 8 | 00h | x0h | R/W |

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SFRs accessed using 'Direct Addressing', continued

| | REGISTER | ADDRESS | BITS | POWER ON RESET | RESET | R/W |
|----|----------|---------|------|----------------|-------|-----|
| 16 | P1* | 90h | 8 | 00h | 00h | R/W |
| 17 | P2* | A0h | 8 | FFh | FFh | R/W |
| 18 | P3* | B0h | 8 | 1Fh | 1Fh | R/W |
| 19 | TMREG* | C0h | 3 | 00h | xxh | R/W |
| 20 | S1CON* | D8h | 8 | 00h | 00h | R/W |
| 21 | S1STA | D9h | 8 | F8h | F8h | R |
| 22 | S1DAT | DAh | 8 | FFh | FFh | R/W |
| 23 | S1ADR1 | DBh | 8 | 00h | 00h | R/W |
| 24 | S1ADR2 | DCh | 8 | 00h | 00h | R/W |
| 25 | S2CON* | E8h | 8 | 00h | 00h | R/W |
| 26 | S2STA | E9h | 8 | F8h | F8h | R |
| 27 | S2DAT | EAh | 8 | FFh | FFh | R/W |
| 28 | S2ADR1 | EBh | 8 | 00h | 00h | R/W |
| 28 | S2ADR2 | ECh | 8 | 00h | 00h | R/W |

Notes:

1. The SFRs marked with an asterisk (*) are both bit- and byte-addressable.
2. Port 1 and P3.5–P3.7 outputs low during & after reset.
3. "x" means no reset action.
4. The SFRs in the shaded region are new-defined.

* Modified *PCON*

| BIT | NAME | FUNCTION |
|-----|---------|---|
| 0 | ADCS2 | ADC channel Select bit 2 |
| 1 | PD | Power Down bit |
| 2 | GF0 | General purpose flag bit |
| 3 | GF1 | General purpose flag bit |
| 4 | TEST0 | Test purpose flag bit |
| 5 | TEST1 | Test purpose flag bit |
| 6 | ADCcal | Set 0/1 to select 1.0V/3.0V for ADC calibration |
| 7 | CPUhalt | Set to let CPU halt when the chip runs internally |

* *TMREG*: Test Mode Register

| BIT | NAME | FUNCTION |
|-----|------|------------|
| 0 | TM1 | Test Mode1 |
| 1 | TM2 | Test Mode2 |
| 2 | TM3 | Test Mode3 |

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SFRs accessed using 'MOVX @Ri'

| | REGISTER | ADDRESS | BITS | POWER ON RESET | RESET | R/W TYPE |
|----|----------|---------|------|----------------|-------|----------|
| 1 | CTRL1 | 80h | 8 | 00h | 00h | W |
| 2 | CTRL2 | 81h | 8 | 00h | 00h | W |
| 3 | P1SF | 82h | 8 | 00h | xxh | W |
| 4 | P2SF | 83h | 8 | 00h | xxh | W |
| 5 | P3SF | 84h | 8 | 00h | 00h | W |
| 6 | PARAL | 85h | 8 | 00h | 00h | R/W |
| 7 | PARAH | 86h | 5 | 00h | 00h | R/W |
| 8 | HFCOUNTL | 87h | 8 | x | x | R |
| 9 | HFCOUNTH | 88h | 8 | x | x | R |
| 10 | VFCOUNTL | 89h | 8 | x | x | R |
| 11 | VFCOUNTH | 8Ah | 8 | x | x | R |
| 12 | WDTCLR | 8Bh | - | x | x | W |
| 13 | SOARL | 8Ch | 8/6 | x | x | R/W |
| 14 | SOARH | 8Dh | 8/6 | x | x | R/W |
| 15 | SOACL | 8Eh | - | x | x | W |
| 16 | INTMSK | 8Fh | 6 | 00h | 00h | R/W |
| 17 | INTVECT | 90h | 6 | 00h | 00h | R |
| 18 | INTCLR | 91h | 6 | x | x | W |
| 19 | DDC1 | 92h | 8 | x | x | W |
| 20 | ADC | 93h | 8 | x | x | R |
| 21 | DAC0 | 94h | 8 | 00h | x | R/W |
| 22 | DAC1 | 95h | 8 | 00h | x | R/W |
| 23 | DAC2 | 96h | 8 | 00h | x | R/W |
| 24 | DAC3 | 97h | 8 | 00h | x | R/W |
| 25 | DAC4 | 98h | 8 | 00h | x | R/W |
| 26 | DAC5 | 99h | 8 | 00h | x | R/W |
| 27 | DAC6 | 9Ah | 8 | 00h | x | R/W |
| 28 | DAC7 | 9Bh | 8 | 00h | x | R/W |
| 29 | DAC8 | 9Ch | 8 | 00h | x | R/W |
| 30 | DAC9 | 9Dh | 8 | 00h | x | R/W |
| 31 | DAC10 | 9Eh | 8 | 00h | x | R/W |
| 32 | P4 | 9Fh | 8 | FFh | FFh | W |
| 33 | CTRL3 | A0h | 0 | 00h | 00h | W |

Note: "x" means no reset action.



* **CTRL1:** Control Register 1 (Write Only)

| BIT | NAME | FUNCTION |
|-----|---------|--|
| 0 | ADCSTRT | A-to-D Conversion START control Set by S/W to start conversion. Cleared by H/W while conversion completed (read SOARH.6 to check). |
| 1 | ADCS0 | ADC channel Select bit 0 |
| 2 | ADCS1 | ADC channel Select bit 1 |
| 3 | ENDDC1 | Enable DDC1 |
| 4 | HCES | H-Clamp Edge Select 0: Select leading edge of restored Hsync 1: Select trailing edge of restored Hsync |
| 5 | HCWS | H-Clamp Width Select bit |
| 6 | DUMMYEN | Dummy signal Enable |
| 7 | VSDIS | Vsync Separator Disable, 0: Enable, 1: Disable |

* **CTRL2:** Control Register 2 (Write Only)

| BIT | NAME | FUNCTION |
|-----|---------|---|
| 0 | HSPS | HSync Polarity Select 0: Positive, 1: Negative |
| 1 | VSPS | VSynC Polarity Select 0: Positive, 1: Negative |
| 2 | HDUMS0 | H Dummy frequency Select 0 |
| 3 | VDUMS | V Dummy frequency Select |
| 4 | DDC1B9 | Bit 9 in DDC1 mode |
| 5 | WDTEN | Enable Watch Dog Timer |
| 6 | SOAHDIS | Disable SOA low to high detection |
| 7 | OSCHI | OSC freq. Higher than 10 MHz |

* **CTRL3:** Control Register 3 (Write Only)

| BIT | NAME | FUNCTION |
|-----|----------|---|
| 0 | ENHFO | Enable HF input/output for P4.0/P4.7, respectively 0: Disable, 1: Enable |
| 1 | HDUMS1 | H Dummy frequency Select 1 |
| 2 | HFO_POL | Select HFO polarity 0: Positive, 1: Negative |
| 3 | HFO_HALF | Select HFO output freq. 0: the same as HFI, 1: half of the HFI |
| 4 | ENBNK1 | Select on-chip ext. RAM bank 0: Bank 0, 1: Bank 1 |
| 5-7 | - | - |

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***P1SF:** Port1 special function output enable register (Write Only)

| BIT | NAME | FUNCTION |
|-----|-------|--|
| 0 | P10SF | Port 1.0 Special Function enable (DAC0 output) |
| 1 | P11SF | Port 1.1 Special Function enable (DAC1 output) |
| 2 | P12SF | Port 1.2 Special Function enable (DAC2 output) |
| 3 | P13SF | Port 1.3 Special Function enable (DAC3 output) |
| 4 | P14SF | Port 1.4 Special Function enable (DAC4 output) |
| 5 | P15SF | Port 1.5 Special Function enable (DAC5 output) |
| 6 | P16SF | Port 1.6 Special Function enable (DAC6 output) |
| 7 | P17SF | Port 1.7 Special Function enable (DAC7 output) |

***P2SF:** Port2 special function output enable register (Write Only)

| BIT | NAME | FUNCTION |
|-----|-------|--|
| 0 | P20SF | Port 2.0 Special Function enable (DAC8 output) |
| 1 | P21SF | Port 2.1 Special Function enable (DAC9 output) |
| 2 | P22SF | Port 2.2 Special Function enable (DAC10 output) |
| 3 | P23SF | Port 2.3 Special Function enable (Hclamp output) |
| 4 | P24SF | Port 2.4 Special Function enable (ADC0 input) |
| 5 | P25SF | Port 2.5 Special Function enable (ADC1 input) |
| 6 | P26SF | Port 2.6 Special Function enable (ADC2 input) |
| 7 | P27SF | Port 2.7 Special Function enable (ADC3 input) |

***P3SF:** Port3 special function output enable register (Write Only)

| BIT | NAME | FUNCTION |
|-----|-------|---|
| 0-2 | - | - |
| 3 | P33SF | Port 3.3 Special Function enable (HOUT) |
| 4 | P34SF | Port 3.4 Special Function enable (VOUT) |
| 5-7 | - | - |

***HFCOUNTL:** Horizontal frequency counter register, low byte (Read Only)

| BIT | NAME | FUNCTION |
|-----|------|-------------------------|
| 0 | HF0 | H frequency count bit 0 |
| 1 | HF1 | H frequency count bit 1 |
| 2 | HF2 | H frequency count bit 2 |
| 3 | HF3 | H frequency count bit 3 |
| 4 | HF4 | H frequency count bit 4 |
| 5 | HF5 | H frequency count bit 5 |
| 6 | HF6 | H frequency count bit 6 |
| 7 | HF7 | H frequency count bit 7 |

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***HFCOUNTH:** Horizontal frequency counter register, high byte (Read Only)

| BIT | NAME | FUNCTION |
|-----|------|--|
| 0 | HF8 | H frequency count bit 8 |
| 1 | HF9 | H frequency count bit 9 |
| 2 | HF10 | H frequency count bit 10 |
| 3 | HF11 | H frequency count bit 11 |
| 4-5 | - | - |
| 6 | NOH | Set by hardware if no Hin signal |
| 7 | HPOL | Hin polarity. 0: Positive, 1: Negative |

***VFCOUNTL:** Vertical frequency counter register, low byte (Read Only)

| BIT | NAME | FUNCTION |
|-----|------|-------------------------|
| 0 | VF0 | V frequency count bit 0 |
| 1 | VF1 | V frequency count bit 1 |
| 2 | VF2 | V frequency count bit 2 |
| 3 | VF3 | V frequency count bit 3 |
| 4 | VF4 | V frequency count bit 4 |
| 5 | VF5 | V frequency count bit 5 |
| 6 | VF6 | V frequency count bit 6 |
| 7 | VF7 | V frequency count bit 7 |

***VFCOUNTH:** Vertical frequency counter register, high byte (Read Only)

| BIT | NAME | FUNCTION |
|-----|------|--|
| 0 | VF8 | V frequency count bit 8 |
| 1 | VF9 | V frequency count bit 9 |
| 2 | VF10 | V frequency count bit 10 |
| 3 | VF11 | V frequency count bit 11 |
| 4-5 | - | - |
| 6 | NOV | Set by hardware if no VIN signal |
| 7 | VPOL | VIN polarity. 0: Positive, 1: Negative |

***INTVECT:** Interrupt Vector Register (Read Only)

| BIT | NAME | FUNCTION |
|-----|---------|---|
| 0 | SCLINT | SCL pin pulled low detected |
| 1 | ADCINT | ADC conversion completed |
| 2 | DDC1INT | DDC1 port buffer empty |
| 3 | SOAINT | SOA condition happen |
| 4 | VEVENT | Vsync pulse detected or NOV = 1 (V counter overflow) (The VEVENT is designed to be generated only 'one' time if no Vsync input.) |
| 5 | PARAINT | Parabola Interrupt generated |



* **INTMSK**: Interrupt Mask Register (Read/Write)

| BIT | NAME | FUNCTION |
|-----|----------|-------------------------------------|
| 0 | MSCLINT | Set/clear to enable/disable SCLINT |
| 1 | MADCINT | Set/clear to enable/disable ADCINT |
| 2 | MDDC1INT | Set/clear to enable/disable DDC1INT |
| 3 | MSOAINT | Set/clear to enable/disable SOAINT |
| 4 | MVEVENT | Set/clear to enable/disable VEVENT |
| 5 | MPARAINT | Set/clear to enable/disable PARAINT |

* **INTCLR** (Write Only)

| BIT | NAME | FUNCTION |
|-----|----------|---|
| 0 | CSCLINT | Write 1 to this bit to clear SCLINT in INTVECT |
| 1 | CADCINT | Write 1 to this bit to clear ADCINT in INTVECT |
| 2 | CDDC1INT | Write 1 to this bit to clear DDC1INT in INTVECT |
| 3 | CSOAINT | Write 1 to this bit to clear SOAINT in INTVECT |
| 4 | CVEVENT | Write 1 to this bit to clear VEVENT in INTVECT |
| 5 | CPARAINT | Write 1 to this bit to clear PARAINT in INTVECT |

***PARAL**: Parabola interrupt generator register, low byte (Read/Write)

| BIT | NAME | FUNCTION |
|-----|-------|-------------------------------|
| 0 | PARA0 | PARAINT period register bit 0 |
| 1 | PARA1 | PARAINT period register bit 1 |
| 2 | PARA2 | PARAINT period register bit 2 |
| 3 | PARA3 | PARAINT period register bit 3 |
| 4 | PARA4 | PARAINT period register bit 4 |
| 5 | PARA5 | PARAINT period register bit 5 |
| 6 | PARA6 | PARAINT period register bit 6 |
| 7 | PARA7 | PARAINT period register bit 7 |

***PARAH**: Parabola interrupt generator register, high byte (Read/Write)

| BIT | NAME | FUNCTION |
|-----|--------|--------------------------------|
| 0 | PARA8 | PARAINT period register bit 8 |
| 1 | PARA9 | PARAINT period register bit 9 |
| 2 | PARA10 | PARAINT period register bit 10 |
| 3 | PARA11 | PARAINT period register bit 11 |
| 4 | PARA12 | PARAINT period register bit 12 |



***SOARL:** SOA register, low byte (Read/Write)

| BIT | NAME | FUNCTION |
|-----|-------|---|
| 0 | SL0 | SOA Low register bit 0 |
| 1 | SL1 | SOA Low register bit 1 |
| 2 | SL2 | SOA Low register bit 2 |
| 3 | SL3 | SOA Low register bit 3 |
| 4 | SL4 | SOA Low register bit 4 |
| 5 | SL5 | SOA Low register bit 5 |
| 6 | (OVL) | OVL = 1: current H count larger than SOARL, for test |
| 7 | (OVH) | OVH = 1: current H count smaller than SOARH, for test |

***SOARH:** SOA register, high byte (Read/Write)

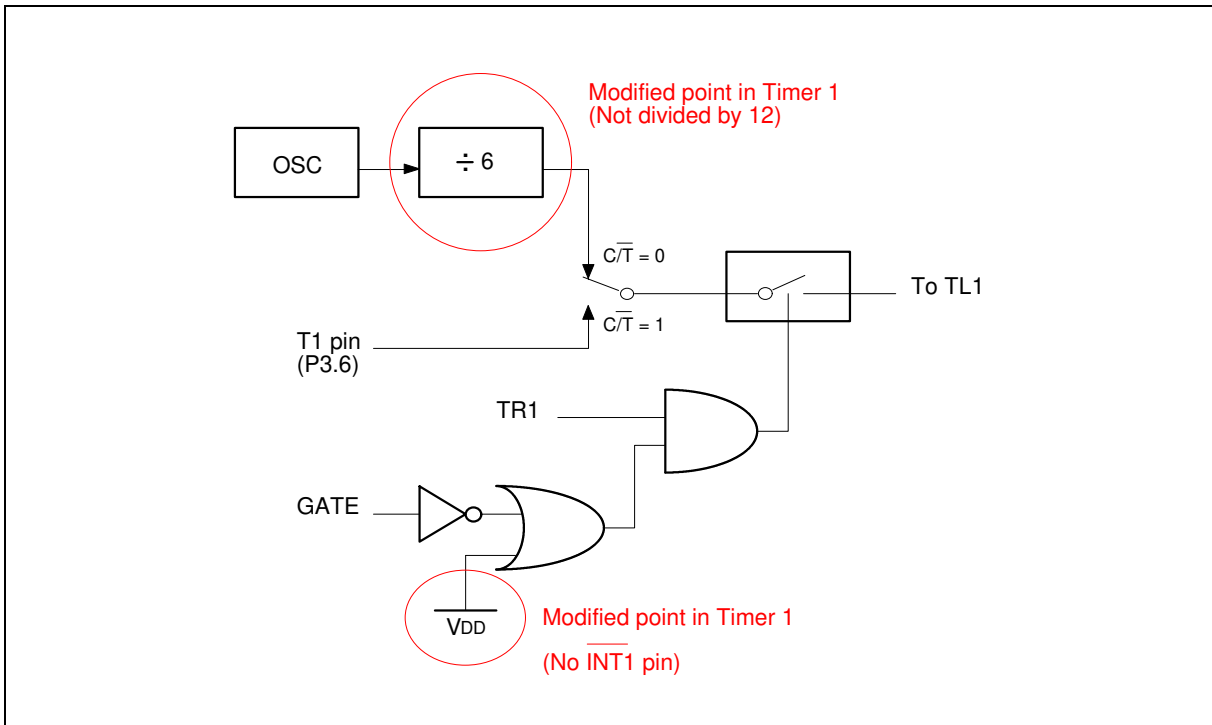
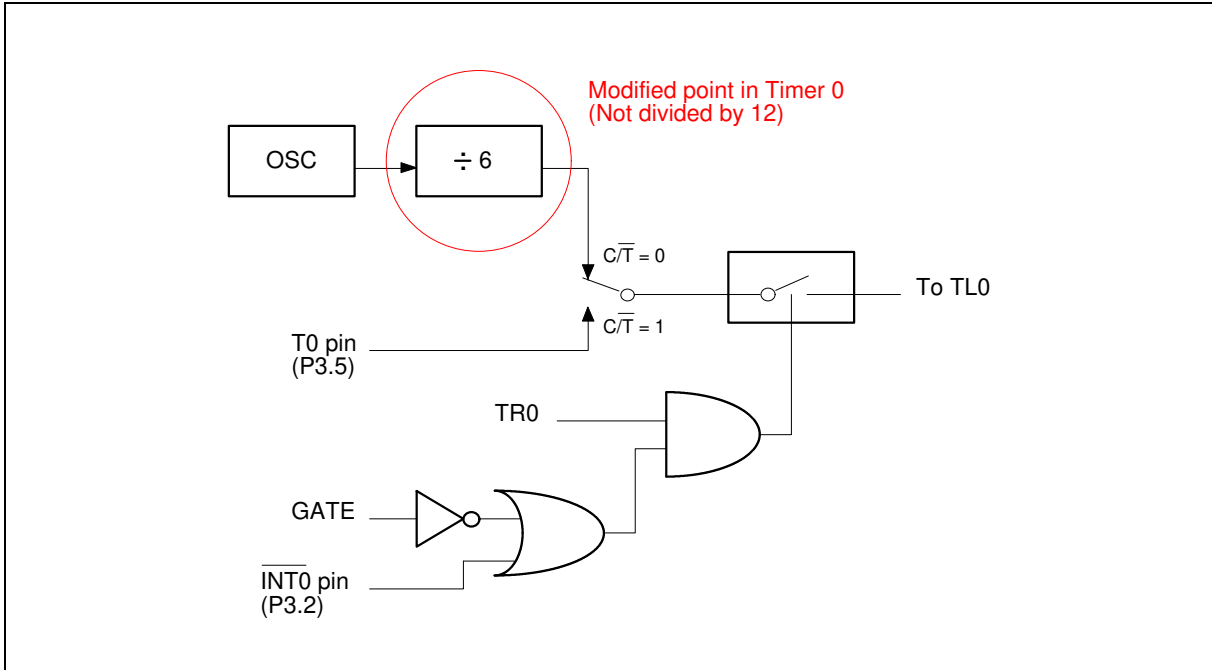
| BIT | NAME | FUNCTION |
|-----|-----------|-----------------------------------|
| 0 | SH0 | SOA High register bit 0 |
| 1 | SH1 | SOA High register bit 1 |
| 2 | SH2 | SOA High register bit 2 |
| 3 | SH3 | SOA High register bit 3 |
| 4 | SH4 | SOA High register bit 4 |
| 5 | SH5 | SOA High register bit 5 |
| 6 | (ADCSTRT) | ADCSTRT bit status, for test |
| 7 | (WDTQ10) | Watch Dog Timer, bit 10, for test |

| | |
|-------------------------|--|
| * ADC | Result of the A-to-D conversion. |
| * DAC0~DAC8 | 8-bit PWM static DAC register. |
| * DAC9~DAC10 | 8-bit PWM dynamic DAC register. |
| * WDTCLR | Watchdog-timer-clear register, without real hardware but an address. Writing any value to WDTCLR will clear the watchdog timer. |
| * SOACLR | Safe-Operation-Area Clear register, without real hardware but an address. Writing any value to SOACLR will clear the SOAINT. |
| * DDC1 | DDC1 latch buffer. |
| * S1CON | SIO1 control register. |
| * S1STA | SIO1 status register. |
| * S1DAT | SIO1 data register. |
| * S1ADR1, S1ADR2 | SIO1 address registers. |
| * S2CON | SIO2 control register. |
| * S2STA | SIO2 status register. |
| * S2DAT | SIO2 data register. |
| * S2ADR1, S2ADR2 | SIO2 address registers. |

W78E378/W78C378/W78C374

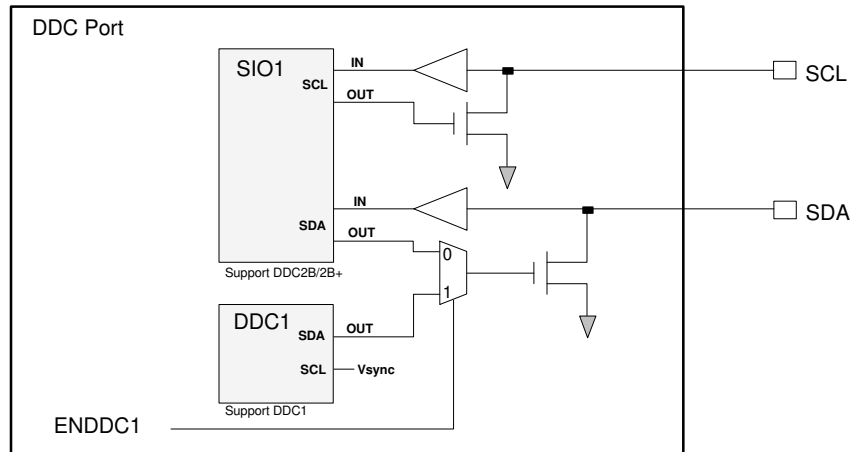


Modified Timer 0 & Timer 1



DDC1/SIO1 and SIO2 Ports

1. DDC1/SIO1 port



- ENDDC1 = 1, used as DDC1 (Display Data Channel) port:
To support DDC1, use Vsync signal for shift clock and P3.0 (SDA) for data output.
- ENDDC1 = 0, used as SIO1 port:
To support DDC2B/2B+/2Bi/2AB, use P3.1 (SCL) for serial clock and P3.0 (SDA) for serial data.

SCLINT interrupt is generated when SCL (P3.1) has a high-to-low transition and then keeps at low for $16 \times 1/F_{osc}$.

| | | |
|---------|-----------|-------------|
| Fosc | 8 MHz | 10 MHz |
| SCL low | 2 μ S | 1.6 μ S |

2. SIO2 port:

- To support DDC2B/2B+/2Bi/2AB, use P4.4 (SCL) for serial clock and P4.5 (SDA) for serial data.

DDC1 Port

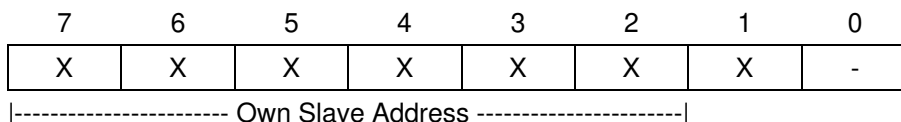
The DDC1 is a serial output port that supports DDC1 communication. To enable the DDC1 port, ENDDC1 (bit 3 of CTRL1) should be set to '1'. Once previous eight data bits in the shift register and one null bit (the 9th bit) are shifted out to the SDA sequentially on each **rising edge** of the VIN signal, the DDC1 control circuit loads the next data byte from the latch buffer (the DDC1 register) to the shift register and generates a DDC1INT signal to the CPU. In the interrupt service routine, the S/W should fetch the next byte of EDID data and write it to the DDC1 register. If ENDDC1 is cleared, the shift register is stopped, and the SDA output is kept high. The bit DDC1B9 (bit 4 of CTRL2) decides the 9th bit in a DDC transmission. If DDC1B9 is set, the 9th bit will be '1', otherwise '0'.



a) Control Registers

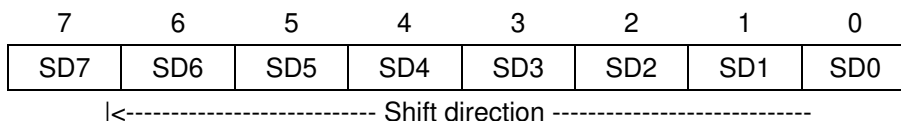
a-1) The Address Registers, S1ADR1, S1ADR2

The SIO1 is equipped with two address registers: S1ADR1 & S1ADR2. The CPU can read from and write to these two 8-bit, directly addressable SFRs. The content of these registers are irrelevant when SIO1 is in master modes. In the slave modes, the seven most significant bits must be loaded with the MCU's own address. The SIO1 hardware will react if either of the addresses is matched.



a-2) The Data Register, S1DAT

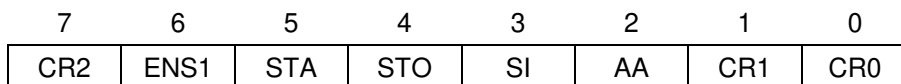
This register contains a byte of serial data to be transmitted or a byte which has just been received. The CPU can read from or write to this 8-bit directly addressable SFR while it is not in the process of shifting a byte. This occurs when SIO1 is in a defined state and the serial interrupt flag (SI) is set. Data in S1DAT remains stable as long as SI is set. While data is being shifted out, data on the bus is simultaneously being shifted in; S1DAT always contains the last data byte present on the bus. Thus, in the event of lost arbitration, the transition from master transmitter to slave receiver is made with the correct data in S1DAT.



S1DAT and the acknowledge bit form a 9-bit shift register, the acknowledge bit is controlled by the SIO1 hardware and cannot be accessed by the CPU. Serial data is shifted through the acknowledge bit into S1DAT on the rising edges of serial clock pulses on the SCL line. When a byte has been shifted into S1DAT, the serial data is available in S1DAT, and the acknowledge bit (ACK or NACK) is returned by the control logic during the ninth clock pulse. Serial data is shifted out from S1DAT on the falling edges of SCL clock pulses, and is shifted into S1DAT on the rising edges of SCL clock pulses.

a-3) The Control Register, S1CON

The CPU can read from and write to this 8-bit, directly addressable SFR. Two bits are affected by the SIO1 hardware: the SI bit is set when a serial interrupt is requested, and the STO bit is cleared when a STOP condition is present on the bus. The STO bit is also cleared when ENS1 = "0".



ENS1, the SIO1 Enable Bit

ENS1 = "0": When ENS1 is "0", the SDA and SCL outputs are in a high impedance state. SDA and SCL input signals are ignored, SIO1 is in the not addressed slave state, and STO bit in S1CON is forced to "0". No other bits are affected. P3.0 (SDA) and P3.1 (SCL) may be used as open drain I/O ports.

ENS1 = "1": When ENS1 is "1", SIO1 is enabled. The P3.0 and P3.1 port latches must be set to logic 1.



STA, the START Flag

STA = "1": When the STA bit is set to enter a master mode, the SIO1 hardware checks the status of I2C bus and generates a START condition if the bus is free. If the bus is not free, then SIO1 waits for a STOP condition and generates a START condition after a delay. If STA is set while SIO1 is already in a master mode and one or more bytes are transmitted or received, SIO1 transmits a repeated START condition. STA may be set at any time. STA may also be set when SIO1 is an addressed slave.

STA = "0": When the STA bit is reset, no START condition or repeated START condition will be generated.

STO, the STOP Flag

STO = "0": When the STO bit is set while SIO1 is in a master mode, a STOP condition is transmitted to the I2C bus. When the STOP condition is detected on the bus, the SIO1 hardware clears the STO flag. In a slave mode, the STO flag may be set to recover from an bus error condition. In this case, no STOP condition is transmitted to the I2C bus. However, the SIO1 hardware behaves as if a STOP condition has been received and switches to the defined not addressed slave receiver mode. The STO flag is automatically cleared by hardware. If the STA and STO bits are both set, then a STOP condition is transmitted to the I2C bus if SIO1 is in a master mode (in a slave mode, SIO1 generates an internal STOP condition which is not transmitted). SIO1 then transmits a START condition.

SI, the Serial Interrupt Flag

SI = "1": When a new SIO1 state is present in the S1STA register, the SI flag is set by hardware, and, if the EA and ES bits (in IE register) are both set, a serial interrupt is requested. The only state that does not cause SI to be set is state F8H, which indicates that no relevant state information is available. When SI is set, the low period of the serial clock on the SCL line is stretched, and the serial transfer is suspended. A high level on the SCL line is unaffected by the serial interrupt flag. SI must be cleared by software.

SI = "0": When the SI flag is reset, no serial interrupt is requested, and there is no stretching on the serial clock on the SCL line.

AA, the Assert Acknowledge Flag

AA = "1": If the AA flag is set, an acknowledge (low level to SDA) will be returned during the acknowledge clock pulse on the SCL line when: 1) The own slave address has been received. 2) A data byte has been received while SIO1 is in the master receiver mode. 3) A data byte has been received while SIO1 is in the addressed slave receiver mode.

AA = "0": If the AA flag is reset, a not acknowledge (high level to SDA) will be returned during the acknowledge clock pulse on SCL when: 1) A data has been received while SIO1 is in the master receiver mode. 2) A data byte has been received while SIO1 is in the addressed slave receiver mode.

CR0, CR1 and CR2, the Clock Rate Bits

These three bits determine the serial clock frequency when SIO1 is in a master mode. It is not important when SIO1 is in a slave mode. In the slave modes, SIO1 will automatically synchronize with any clock frequency up to 100 KHz.



| Bit Freq. (KHz) @Fosc | | | | | |
|-----------------------|-----|-----|-------|--------|-----------------|
| CR2 | CR1 | CR0 | 8 MHz | 10 MHz | Fosc Divided By |
| 0 | 0 | 0 | 31.25 | 39.1 | 256 |
| 0 | 0 | 1 | 35.7 | 44.6 | 224 |
| 0 | 1 | 0 | 41.7 | 52.1 | 192 |
| 0 | 1 | 1 | 50.0 | 62.5 | 160 |
| 1 | 0 | 0 | 8.3 | 10.4 | 960 |
| 1 | 0 | 1 | 66.7 | 83.3 | 120 |
| 1 | 1 | 0 | 133.3 | 166.7 | 60 |

a-4) The Status Register, S1STA

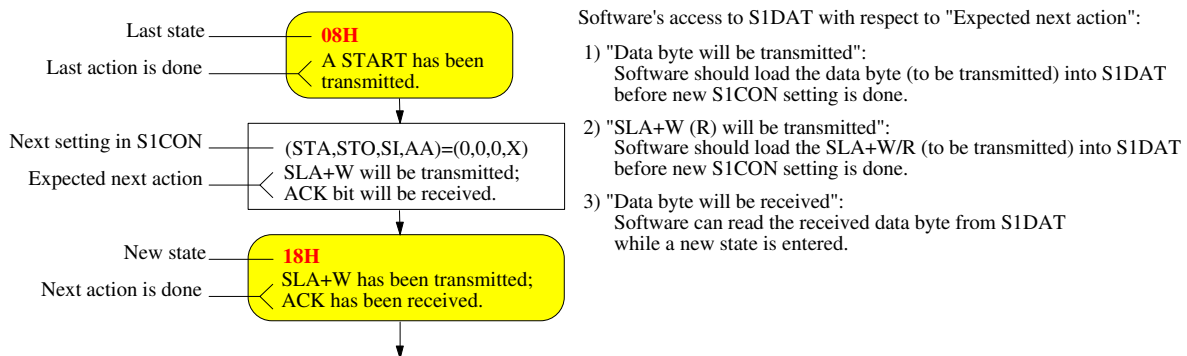
S1STA is an 8-bit read-only register. The three least significant bits are always 0. The five most significant bits contain the status code. There are 23 possible status codes. When S1STA contains F8H, no serial interrupt is requested. All other S1STA values correspond to defined SIO1 states. When each of these states is entered, a status interrupt is requested (SI = 1). A valid status code is present in S1STA one machine cycle after SI is set by hardware and is still present one machine cycle after SI has been reset by software.

In addition, state 00H stands for a Bus Error. A Bus Error occurs when a START or STOP condition is present at an illegal position in the format frame. Examples of illegal positions are during the serial transfer of an address byte, a data byte or an acknowledge bit.

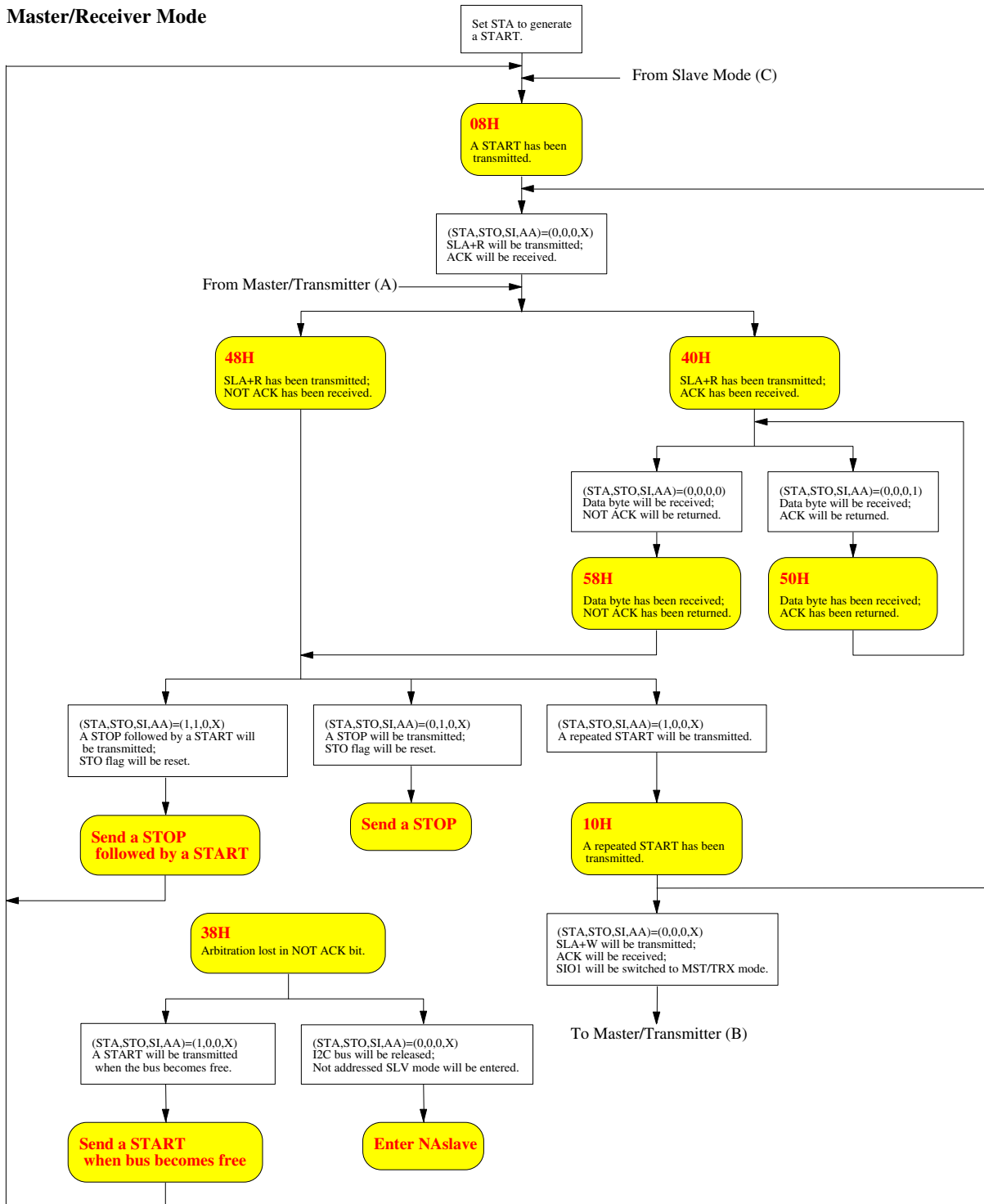
b) Operating Modes

The four operating modes are: Master/Transmitter, Master/Receiver, Slave/Transmitter and Slave/Receiver. Bits STA, STO and AA in S1CON decide the next action the SIO1 hardware will take after SI is cleared. When the next action is completed, a new status code in S1STA will be updated and SI will be set by hardware in the same time. Now, the interrupt service routine is entered (if the SI_interrupt is enabled), the new status code can be used to decide which appropriate service routine the software is to branch. Data transfers in each mode are shown in the following figures.

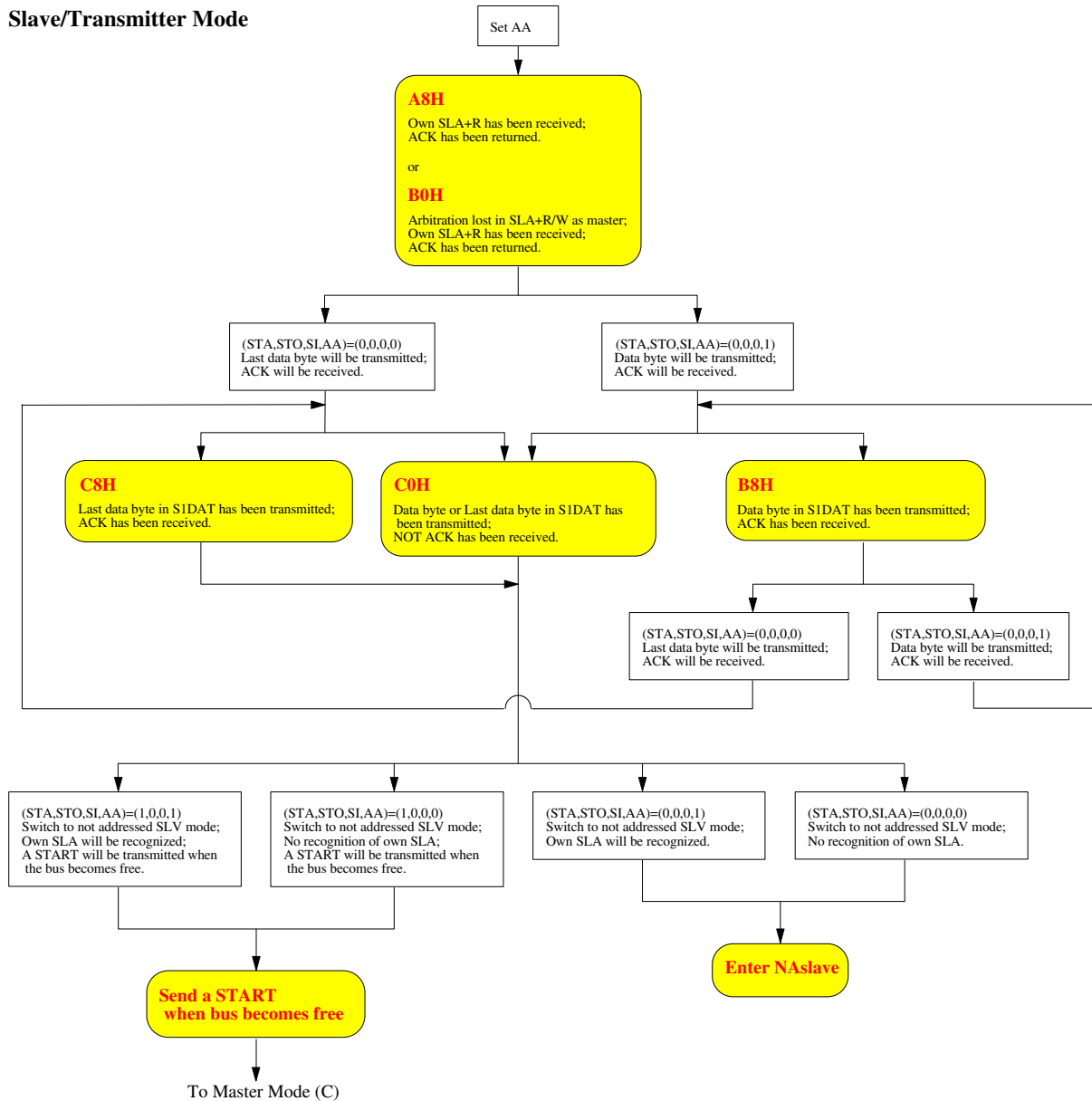
*** Legend for the following four figures:



Master/Receiver Mode



Slave/Transmitter Mode





Parabola Interrupt Generator

The parabola interrupt generator is a 13-bit auto-reload timer, which generates an interrupt to the CPU periodically for software to load the parabola waveform data to the dynamic DACs (DAC8–DAC10). The software should calculate the value of the PARAH and PARAL registers by: $\frac{(V_{count} \times 16)}{\text{segment number}}$. The segment number is the number of integration segments between two V_{sync} pulses. The interrupt interval is programmable:

- Time base = $1/F_{osc}$
- Programmable interrupt period = Time base \times (PARAH \times 256 + PARAL + 1)
- Maximum period = Time base \times 8192

Note: Zero value in [PARAH, PARAL] is inhibited.

A-to-D Converter (ref. Application Note in Appendix A.)

One 4-bit Analog-to-Digital Converter.

- Conversion time = $(6/F_{osc}) \times 128 \text{ sec.}$
- 7 channels selected by an analog multiplexer

| | | | | | | | |
|-----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| (ADCS2, ADCS1, ADCS0) | (0, 0, 0) | (0, 0, 1) | (0, 1, 0) | (0, 1, 1) | (1, 0, 0) | (1, 0, 1) | (1, 1, 0) |
| Selected Channel | ADC0 | ADC1 | ADC2 | ADC3 | ADC4 | ADC5 | ADC6 |

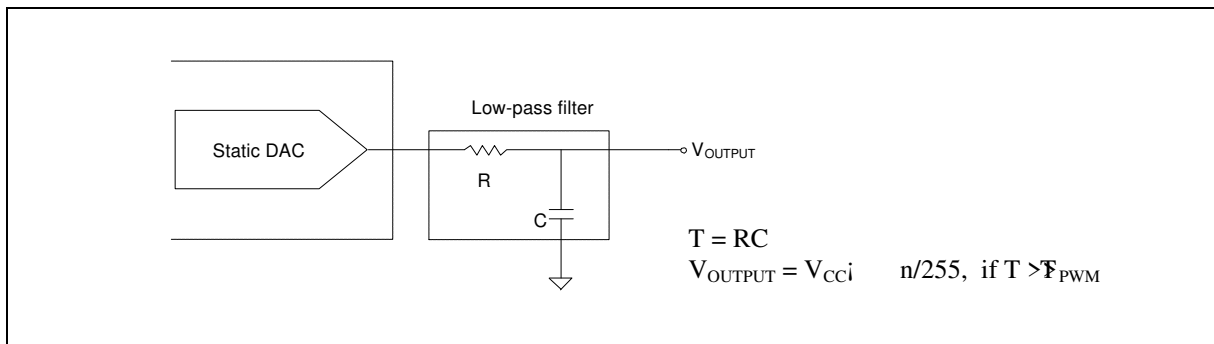
The conversion of the ADC is started by setting bit ADCSTRT in CTRL1 by software. When the conversion is completed, the ADCSTRT bit is cleared by hardware automatically, and the ADCINT bit in INTVECT is set by hardware at the same time if MADCINT in INTMSK is set.

PWM DACs

Eight 8-bit Static DACs: DAC0–DAC7

- The PWM frequency $F_{PWM} = F_{osc} \div 255$
- The duty cycle of the PWM output = Register value $\div 255$
- The DC voltage after the low pass filter = $V_{CC} \times \text{duty cycle}$

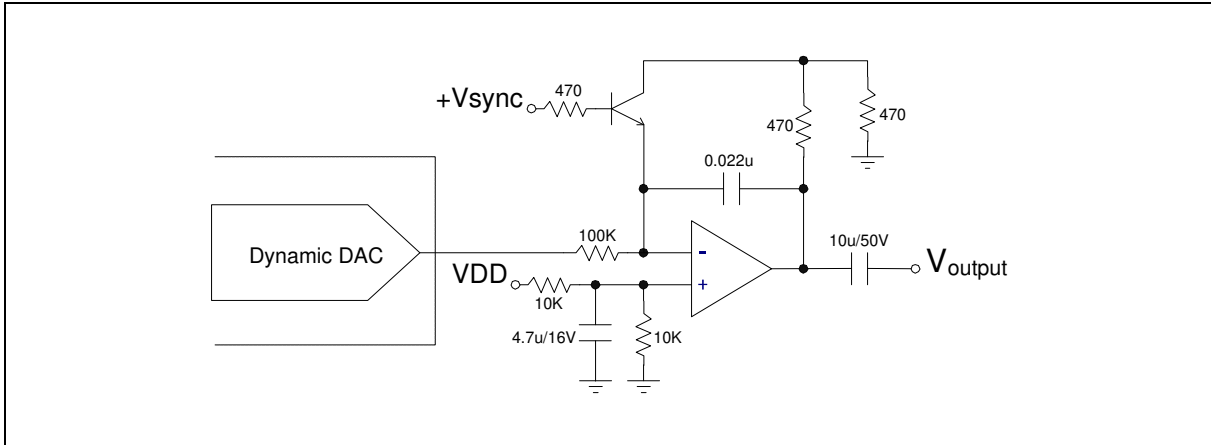
Static DAC application circuit:





Three 8-bit Dynamic DACs: DAC8–DAC10

The dynamic DACs are especially used to generate parabola waveform for geometric compensation, or to be used as static DACs. Dynamic DAC application circuit:



The following types of distortion can be compensated:

1. H size distortion:

a. PinCushion Correction (Amplitude)



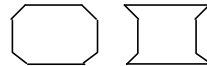
b. Trapezoid (Keystone)



c. CBOW (Quarter Width)



d. PinCushion Correction (Corner)



e. S Curve



The PCC amplitude can be compensated against V size adjustment automatically.

The Trapzoid can be compensated against V center adjustment automatically.

2. H center distortion:

a. Pin balance (Bow)



b. Key balance (Tilt)



c. Corner balance





Sync Processor

Polarity Detector

The H/V polarity is detected automatically and can be known from HPOL bit (HFCOUNTH.7) and VPOL bit (VFCOUNTH.7).

| Fosc | 10 MHz |
|----------------|--|
| Max. H+V width | $(64/Fosc) \times 62$ (counter overflow) = 396.8 μ S |
| Max. V width | $(2048/Fosc) \times 2$ = 409.6 μ S |

Sync Separator

The Vsync is separated from the composite sync automatically, without any software effort.

| Fosc | 10 MHz |
|-----------------------------|------------------------------------|
| Min. V width & Max. H width | $(1/Fosc) \times 64$ = 6.4 μ S |

Horizontal & Vertical Frequency Counter

There are two 12-bit counters which can count H and V frequency automatically. When VEVENT (Vsync frequency counter timeout) interrupt happens, the count value values are latched into the counter registers (HFCOUNTH, HFCOUNTL, VFCOUNTH and VFCOUNTL). And then the S/W may read the count value (H_{COUNT} and V_{COUNT}) from the counter registers to calculate the H and V frequency by the formulas listed below.

V frequency:

The resolution of V frequency counter: $VRESOL = (1/Fosc) \times 64$.

The V frequency: $VFREQ = 1/(VCOUNT \times VRESOL)$.

The lowest V frequency can be detected: $Fosc \div 262144$. (38.1Hz @Fosc =10 MHz)

H frequency:

The resolution of H frequency counter: $HRESOL = (1/Fosc) \div 8$.

The H frequency: $HFREQ = 1/(HCOUNT \times HRESOL)$.

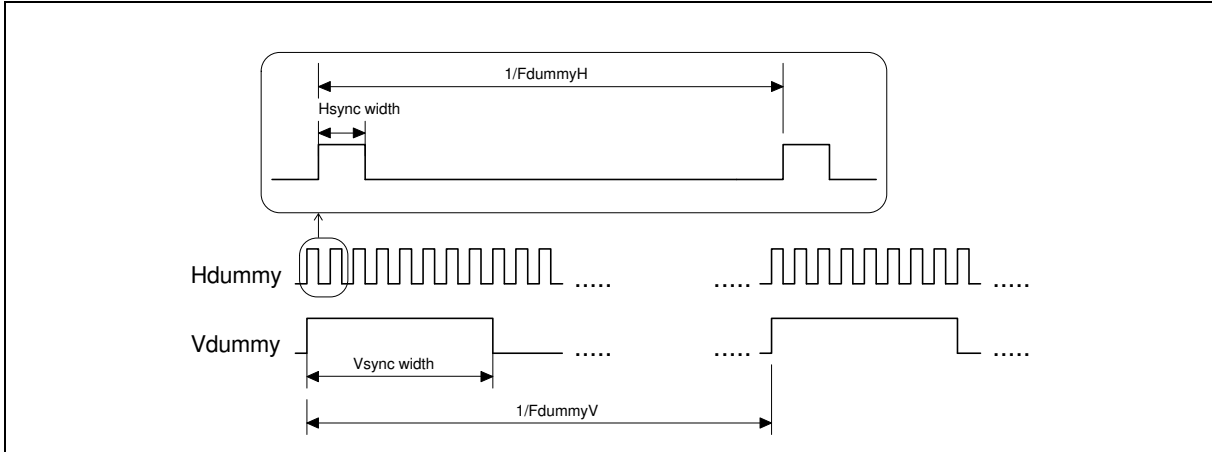
The lowest H frequency can be detected: $Fosc \div 512$. (19.5 KHz @Fosc = 10 MHz)

Dummy Frequency Generator

The Dummy H and V frequencies are generated for factory burn-in or showing warning message while there are no input frequency.

| (HDUMS1, HDUMS0) | (0, 0) | (0, 1) | (1, 0) | (1, 1) |
|------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| FdummyH | $Fosc/(8 \times 4 \times 8)$ | $Fosc/(8 \times 2 \times 8)$ | $Fosc/(8 \times 3 \times 8)$ | $Fosc/(8 \times 5 \times 8)$ |
| Hsync width | $(8 \times 4)/Fosc$ | $(8 \times 2)/Fosc$ | $(8 \times 3)/Fosc$ | $(8 \times 5)/Fosc$ |

| VDUMS | 0 | 1 |
|-------------|---------------|----------------|
| FdummyV | $FdummyH/512$ | $FdummyH/1024$ |
| Vsync width | $8/ FdummyH$ | $16/ FdummyH$ |



For Fosc = 10 MHz:

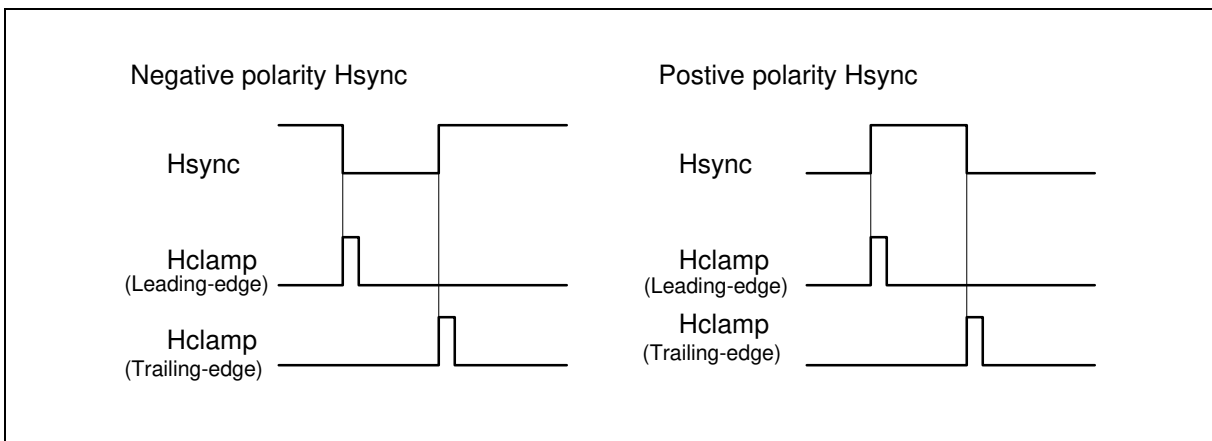
| (HDUMS1, HDUMS0) | (0, 1) | | (1, 0) | | (0, 0) | | (1, 1) | |
|---------------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| | FdummyH | 78.125 KHz | | 52.083 KHz | | 39.063 KHz | | 31.250 KHz |
| Hsync width | 1.6 μ S | | 2.4 μ S | | 3.2 μ S | | 4.0 μ S | |
| VDUMS | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| FdummyV | 152.6 Hz | 76.3 Hz | 101.7 Hz | 50.9 Hz | 76.3 Hz | 38.1 Hz | 61.0 Hz | 30.5 Hz |

H-clamp Pulse Generator

1. Leading edge/Trailing edge selectable.

* HCES = 0: select leading edge

* HCES = 1: select trailing edge





2. Pulse width selectable.

For $F_{osc} = 10 \text{ MHz}$:

| | HCWS = 0 | HCWS = 1 |
|-------------|------------|-------------|
| Pulse Width | 500–600 nS | 900–1000 nS |

Safe Operation Area (SOA) Interrupt

Upper boundary frequency = $F_{osc} / [8 \times \text{SOARH}]$

Lower boundary frequency = $F_{osc} / [8 \times (\text{SOARL} + 1)]$

Function description:

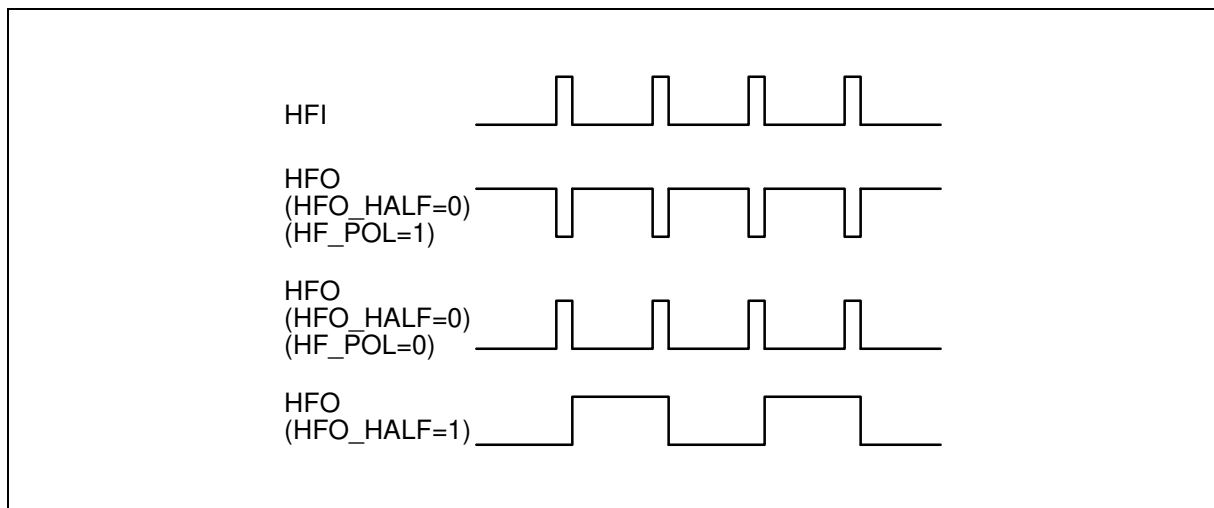
- If the condition, H_{FREQ} lower than the lower boundary freq. or higher than the upper boundary freq., happens twice continuously, the SOAINT will be activated.
- If the HIN is stopped for a certain period, the SOAINT will also be generated.

The no Hsync response time is $512/F_{osc}$. (e.x., 51.2us for 10 MHz)

- If SOAHDIS = 1, then no upper boundary frequency.

Half Hsync Output

When ENHFO (bit 0 of CTRL3) is set, P4.7 (HFO) will output the same or half frequency from P4.0 (HFI). The divide-by-two operation is done at the falling edge of HFI signal when HFO_HALF (bit 3 of CTRL3) is set. The polarity of HFO is specified by HF_POL (bit 2 of CTRL3).





Interrupts

The five interrupt sources are listed as below.

| | SOURCE | VECTOR ADDRESS | DESCRIPTON | PRIORITY WITHIN A LEVEL |
|---|---------|----------------|--|-------------------------|
| 1 | IE0 | 0003H | Interrupt 0 edge detected | Highest |
| 2 | TF0 | 000BH | Timer 0 overflow | |
| 3 | IE1 | 0013H | Miscellaneous interrupts ^{*1} | |
| 4 | TF1 | 001BH | Timer 1 overflow | |
| 5 | SI1+SI2 | 002BH | SIO1 or SIO2 interrupt | Lowest |

Note: *1: SCLINT + ADCINT + DDC1INT + SOAINT + VEVENT + PARAINIT.

The miscellaneous interrupts at vector address 0013H is driven by the following six sources, which are:

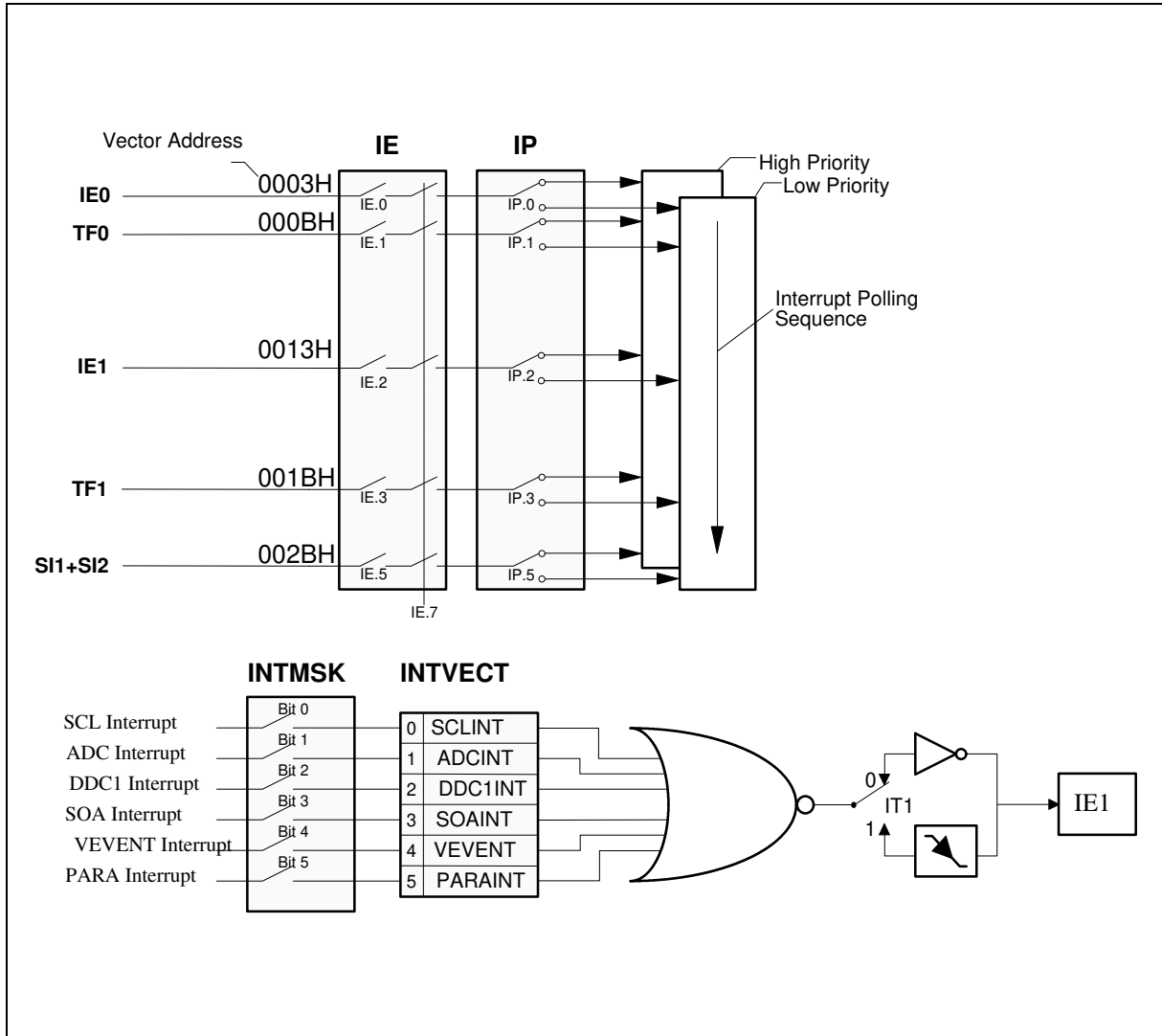
- (1) SCLINT: when high-to-low transition on SCL-pin,
- (2) ADCINT: when A-to-D conversion completion,
- (3) DDC1INT: when DDC1 data byte transmitted (after 9 clock pulses from VIN) in the DDC port,
- (4) SOAINT: when SOA activated,
- (5) VEVENT: on every Vsync pulse or vertical frequency counter overflow,
- (6) PARAINIT: when parabola timer timeout.

If IE1 interrupt occurs, it is necessary for the programmer to read the INTVECT register to tell where the interrupt request comes. These sources can be masked individually by clearing their corresponding bits in the INTMSK register. To clear any of these interrupt flags, just write a '1' to the corresponding bit in the INTCLR.

The interrupt enable bits and priority control bits for these five main sources are listed as below.

| | INTERRUPT FLAG | ENABLE BIT | PRIORITY CONTROL BIT |
|---|----------------|-------------|----------------------|
| 1 | IE0 | IE.0 & IE.7 | IP.0 |
| 2 | TF0 | IE.1 & IE.7 | IP.1 |
| 3 | IE1 | IE.2 & IE.7 | IP.2 |
| 4 | TF1 | IE.3 & IE.7 | IP.3 |
| 5 | SI+SI2 | IE.5 & IE.7 | IP.5 |

W78E378/W78C378/W78C374

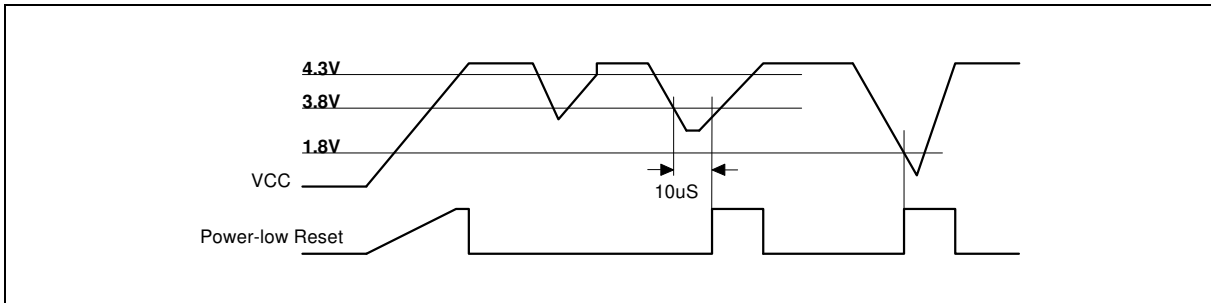


Reset Circuit- Power-low Detector & Watchdog Timer

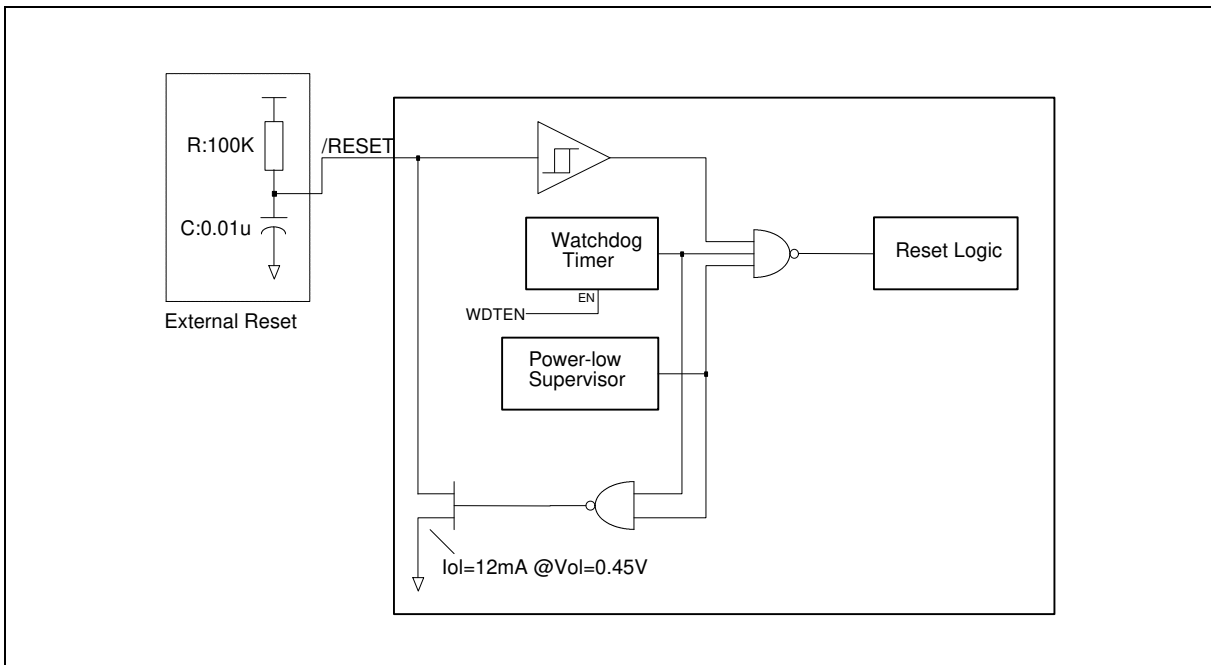
The reset signals come from the following three sources:

1. External reset input (active low)
2. Power low detect
3. Hardware Watchdog Timer

The power-low detection circuit generates a reset signal once the VCC falls below **3.5V** for above 10 μS or falls below **1.8V**, and the reset signal is released after VCC goes up to **4.3V**.



The purpose of a watchdog timer is to reset the CPU if the user program fails to reload the watchdog timer within a reasonable period of time known as the "watchdog interval". The clock source of the watchdog timer comes from the internal system clock. It can be enabled/disabled by set/clear WD TEN (bit 5 of CTRL2). For debug purpose, if the WDT reset or power low reset occur, the $\overline{\text{RESET}}$ pin will be pulled low internally. The pulled-low duration due to WDT reset is about $60/F_{\text{osc}}$ sec. The block diagram of the reset circuitry is shown as below.



W78E378/W78C378/W78C374



ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings

| PARAMETER | SYMBOL | MIN. | MAX. | UNIT |
|-----------------------|--------|----------|----------|------|
| DC Power Supply | VDD | -0.3 | +7.0 | V |
| Input Voltage | VIN | VSS -0.3 | VDD +0.3 | V |
| Input Current | IIN | -100 | +100 | mA |
| Operating Temperature | TA | 0 | 70 | °C |
| Storage Temperature | TST | -55 | 150 | °C |

Note: Exposure to conditions beyond those listed under Absolute Maximum Ratings may adversely affect the life and reliability of the device.

D.C. Characteristics

VDD-VSS= 5V ± 10%, TA = 25°C, Fosc = 10 MHz, unless otherwise specified.

| PARAMETER | SYM. | SPECIFICATION | | | UNIT | TEST CONDITIONS |
|--|------|---------------|------|------|------|----------------------------|
| | | MIN. | TYP. | MAX. | | |
| Operating Voltage | VDD | 4.5 | 5 | 5.5 | V | All function must pass! |
| Operating Current | IDD | - | - | 30 | mA | No load, VDD = 5.5V |
| Power-down Current | IPD | - | - | 100 | μA | No load, VDD = 5.5V |
| Input | | | | | | |
| Input Current P2, P3.2–P3.4, P4.0 | IIN1 | -75 | - | -10 | μA | VDD = 5.5V, VIN = 0V |
| | | -10 | - | +10 | | VDD = 5.5V, VIN = 5.5V |
| Input Current $\overline{\text{RESET}}$ | IIN2 | -300 | - | -100 | μA | VDD = 5.5V, VIN = 0V |
| | | -10 | - | +10 | | VDD = 5.5V, VIN = 5.5V |
| Input Leakage Current P1, P2.4–P2.7(S.F. enabled) P3.0, P3.1, P3.5–P3.7, P4.4, P4.5 HIN, VIN | ILK | -10 | - | +10 | μA | VDD = 5.5V, 0V < VIN < VDD |
| Logical 1-to-0 Transition Current P2, P3.2–P3.4 | ITL | -650 | - | -100 | μA | VDD = 5.5V, VIN = 2.0V |
| Input Low Voltage P1, P2, P3 (except P3.0 & P3.1), P4.0, HIN, VIN, $\overline{\text{RESET}}$, OSCIN | VIL1 | 0 | - | 0.8 | V | VDD = 4.5V |

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D.C. Characteristics, continued

| PARAMETER | SYM. | SPECIFICATION | | | UNIT | TEST CONDITIONS |
|---|------------------|---------------------|------|----------------------|------|---|
| | | MIN. | TYP. | MAX. | | |
| Input Low Voltage P3.0, P3.1, P4.4, P4.5 | V _{IL2} | 0 | - | 0.3 V _{DD} | V | V _{DD} = 4.5V |
| Input High Voltage P1, P2, P3 (except P3.0 & P3.1), P4.0, H _{IN} , V _{IN} , RESET | V _{IH1} | 2.0 | - | V _{DD} +0.2 | V | V _{DD} = 5.5V |
| Input High Voltage P3.0, P3.1, P4.4, P4.5 | V _{IH2} | 0.7 V _{DD} | - | V _{DD} +0.2 | V | V _{DD} = 5.5V |
| Input High Voltage OSCIN | V _{IH3} | 3.5 | - | V _{DD} +0.2 | V | V _{DD} = 5.5V |
| Output | | | | | | |
| Output Low Voltage P1.0, P1.1, RESET | V _{OL1} | - | - | 0.45 | V | V _{DD} = 4.5V I _{OL} = +12 mA |
| Output Low Voltage P3.0, P3.1, P4.4, P4.5 | V _{OL2} | - | - | 0.45 | V | V _{DD} = 4.5V I _{OL} = +8 mA |
| Output Low Voltage P1 (except P1.0 & P1.1) P2, P3 (except P3.0–P3.2) P4 (except P4.4 & P4.5) | V _{OL3} | - | - | 0.45 | V | V _{DD} = 4.5V I _{OL} = +4 mA |
| Output Low Voltage P3.2, OSCOUT | V _{OL4} | - | - | 0.45 | V | V _{DD} = 4.5V I _{OL} = +0.8 mA |
| Output High Voltage P2, P3.2–P3.4 | V _{OH1} | 2.4 | - | - | V | V _{DD} = 4.5V I _{OH} = -100 μA |
| Output High Voltage P4 (except P4.4 & P4.5) | V _{OH2} | 2.4 | - | - | V | V _{DD} = 4.5V I _{OH} = -4 mA |
| Special Function Output High Voltage P2.0–P2.3, P3.3, P3.4 | V _{OH3} | 2.4 | - | - | V | V _{DD} = 4.5V I _{OH} = -4 mA |
| Output High Voltage OSCOUT | V _{OH4} | 2.4 | - | - | V | V _{DD} = 4.5V I _{OH} = -3 mA |

Notes:

*1. RESET has an internal pull-up resistor of about 30 KΩ.

*2. P2 and P3.2–P3.4 can source a transition current when they are being externally driven from 1 to 0. The transition current reaches its maximum value when V_{IN} is approximately 2V.

*3. P3.0, P3.1, P4.4, P4.5, H_{IN}, V_{IN} and RESET are Schmitt trigger inputs.



Appendix A. Application Note for Usage of ADC

To use the ADC, users should pay attention to the following points:

- (1) According to the absolute maximum ratings, the input voltage should not exceed $V_{DD} + 0.3V$, especially for the ADC channel pins (P2.4–P2.7 & P3.5–P3.7). If a voltage over $V_{DD} + 0.3V$ exists on any of these ADC channel pins, the AD conversion will fail.
- (2) Owing to the CMOS process, the ADC curve of some chip might differ from those of the others. So, before using the ADC, the S/W should do the ADC calibration described below.

Step 1. Set (ADCS2, ADCS1, ADCS0, ADCcal) = (1, 1, 1, 0) and then do AD conversion to get the ADC value for the on-chip **0.948V** input. Suppose it is **A**.

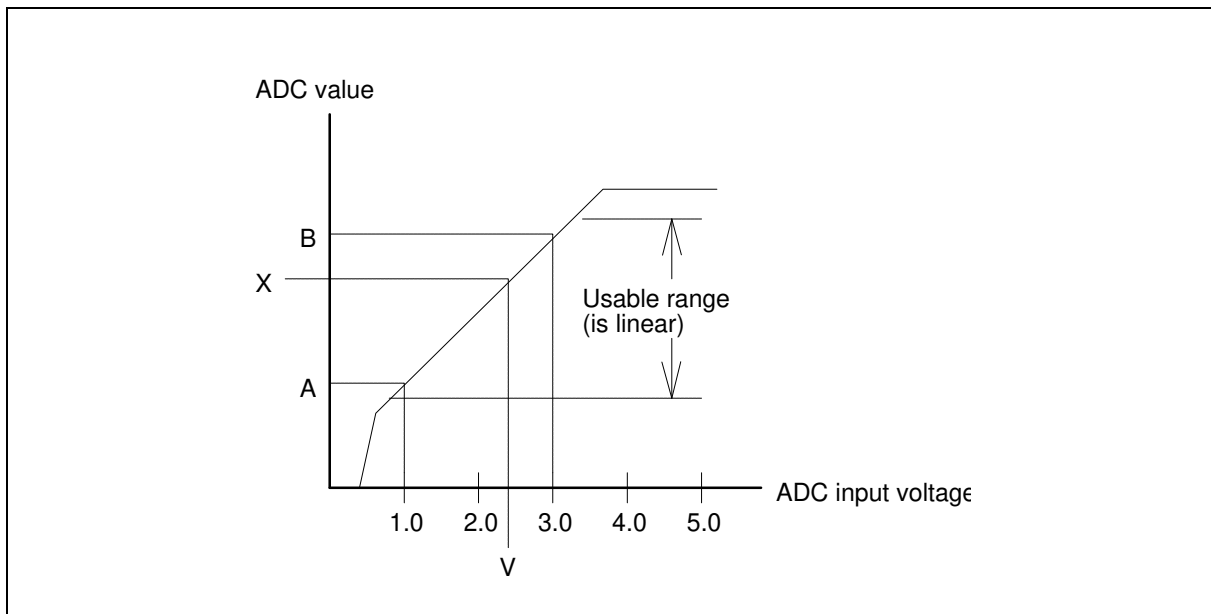
Step 2. Set (ADCS2, ADCS1, ADCS0, ADCcal) = (1, 1, 1, 1) and then do AD conversion to get the ADC value for the on-chip **2.924V** input. Suppose it is **B**.

Step 3. Because the ADC curve in the usable range is linear, any **V** and **X** should meet the formula:

$$(X-A)/(V-0.948) = (B-A)/(2.924-0.948),$$

where **V** is the key voltage (designed by users and thus known) and **X** is its predicted ADC value. Then, we can get $X = A + (V-0.948)(B-A)/(2.924-0.948)$, regardless of $V > 0.948V$ or $< 0.948V$. (Of course, some effort should be paid in S/W to find **X**.)

Step 4. Suppose there are N keys used, the N predicted ADC values for these keys can be found.



After finding these N predicted ADC values, the S/W can recognize which key is pressed by comparing the ADC value of this key with the set of predicted values (found previously).

**** Note: To get the exact on-chip calibration voltages (0.948V and 2.924V), the V_{DD} should be 5.0V as close as possible.**

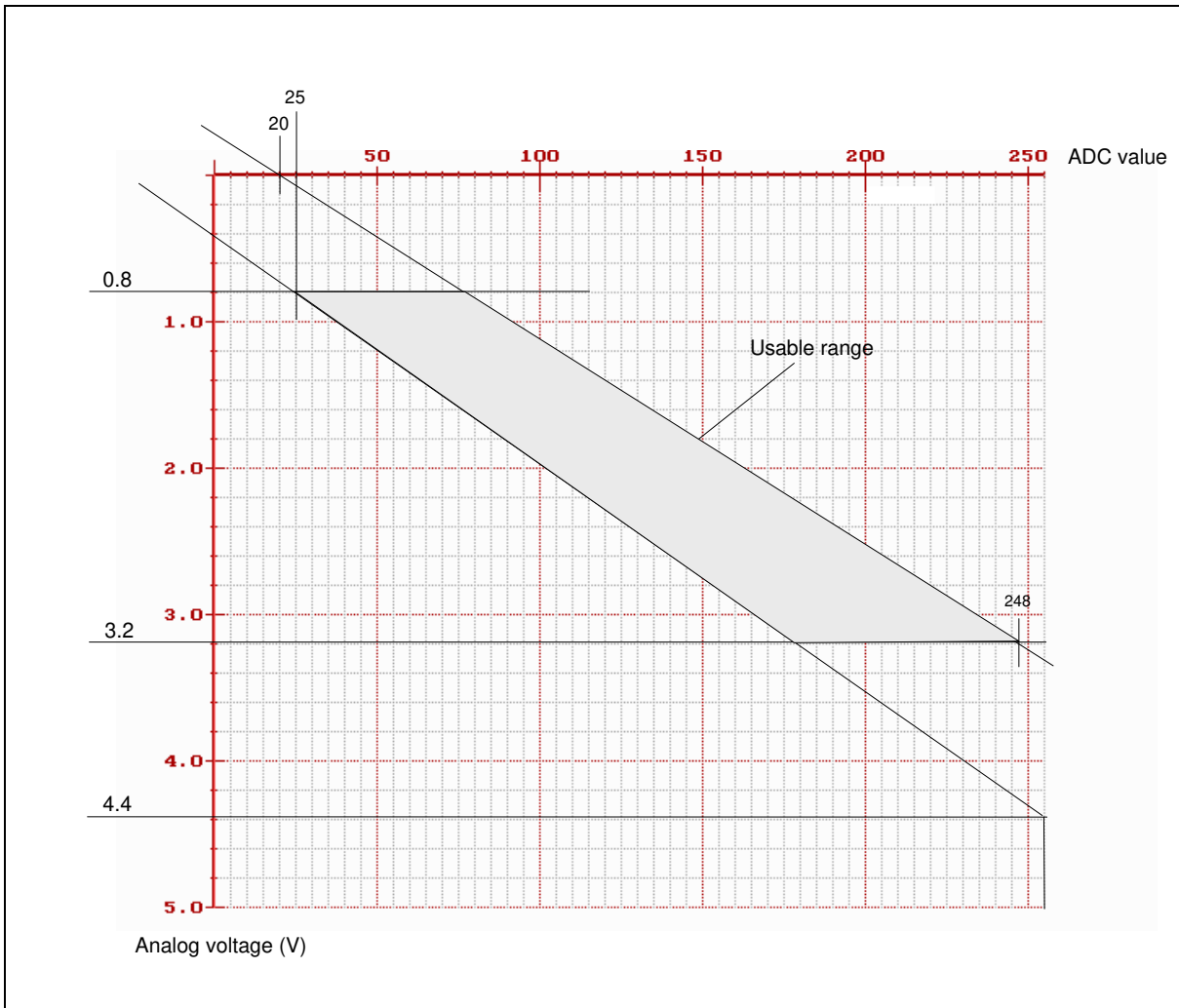


Test strategy before shipping:

- (1) $V_i = 0V \Rightarrow \text{ADC} < 20$
- (2) $V_i = 0.8V \Rightarrow \text{ADC} > 25$
- (3) $V_i = 3.2V \Rightarrow \text{ADC} < 248$
- (4) $V_i = 4.4V \Rightarrow \text{ADC} = 255$
- (5) $0.8V < V_i < 3.2V$, 25 points (step 0.1V) will be tested. All test points should be recognized correctly.

Comment:

- a. (1) guarantees 0V input can be recognized (ADC value < 20).
- b. (4) guarantees 5V input can be recognized (ADC value = 255).
- c. (2), (3) and (5) guarantee linear (with 4 bits at least) within the usable range (0.8V to 3.2V).

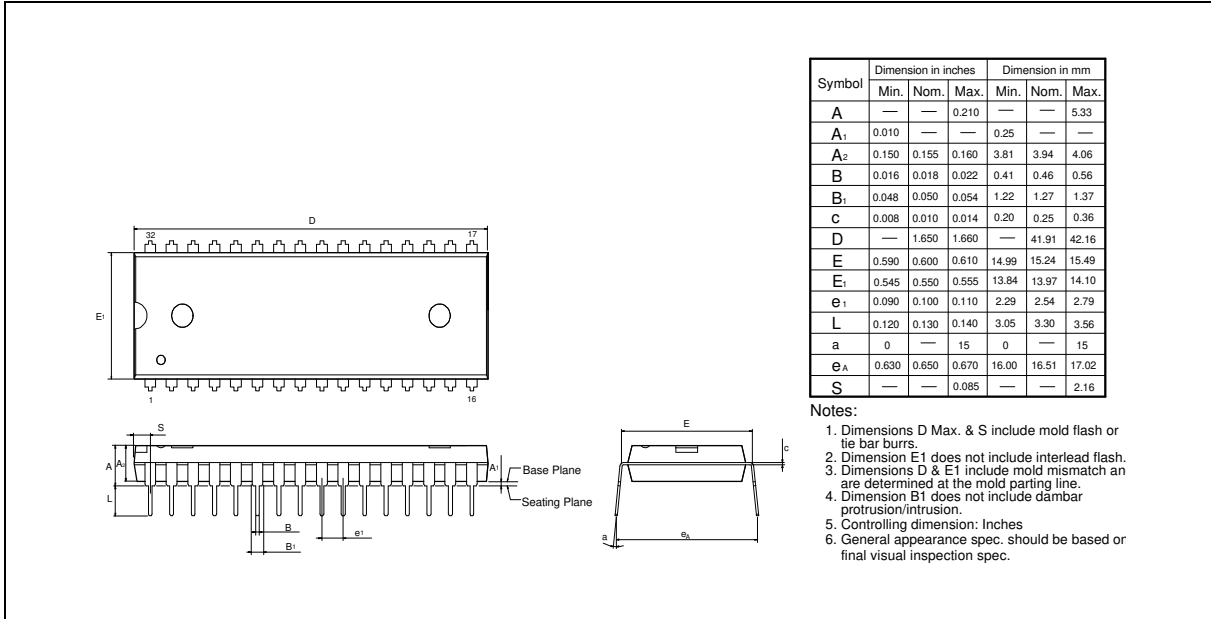


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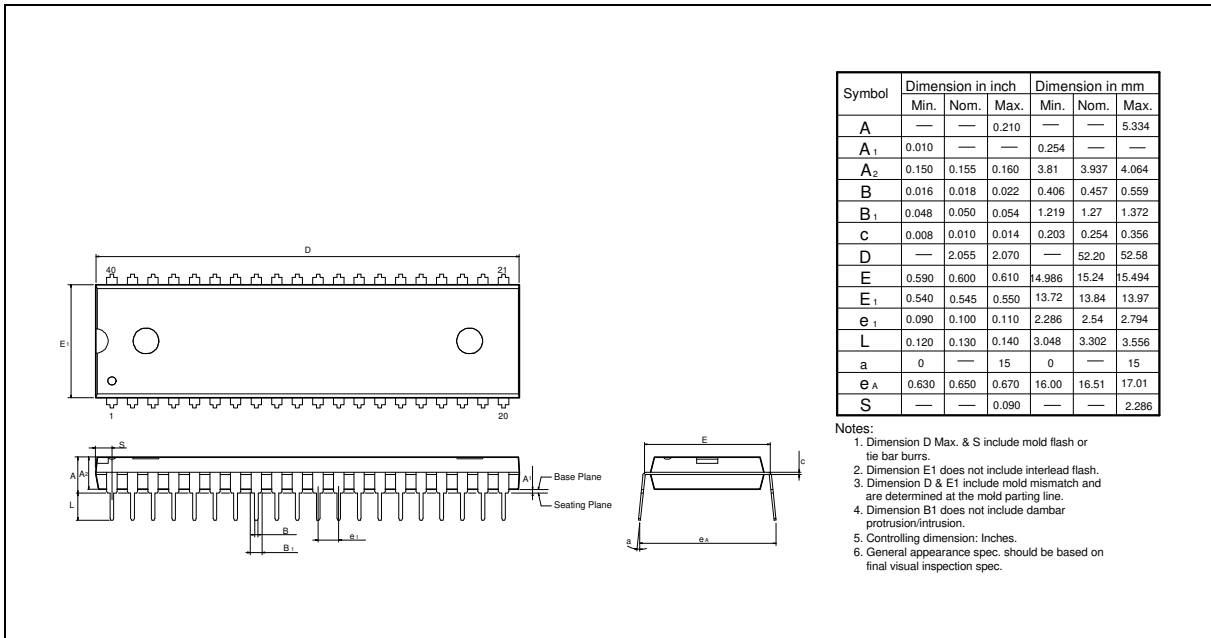


PACKAGE DIMENSIONS

32-pin P-DIP



40-pin DIP

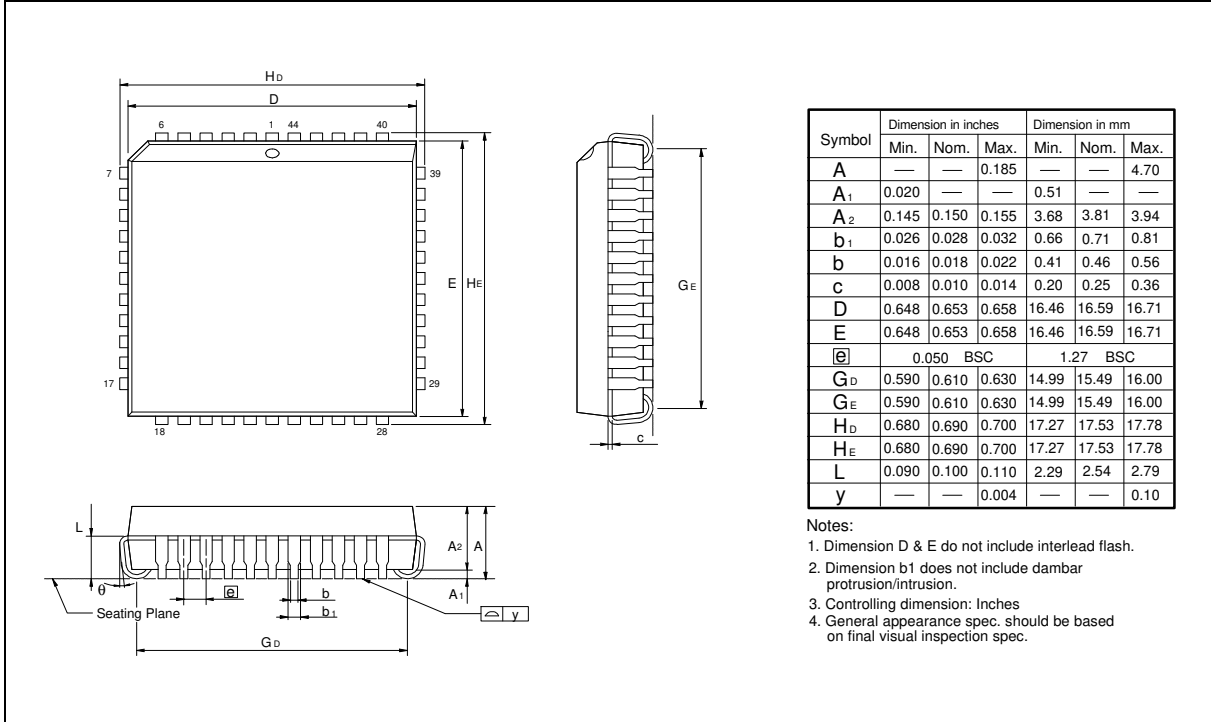


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Package Dimensions, continued

44-pin PLCC



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Note: All data and specifications are subject to change without notice.