Technical Document

- Tools Information
- FAQs
- Application Note

Features

- Operating voltage: 2.4V~5.2V
- Up to 1μs (0.5μs) instruction cycle with 4MHz (8MHz) system clock
- System clock: 4MHz~8MHz (2.4V)
- Crystal or RC oscillator for system clock
- 12 I/O pins
- 2K×15 program ROM
- 80×8 RAM
- Two 8-bit programmable timer counter with 8-stage prescaler and one time base counter
- Watchdog Timer
- 4-level subroutine nesting
- HALT function and wake-up feature reduce power consumption
- PWM circuit direct drive speaker or output by transistor
- 20-pin SSOP (150mil/209mil) package
  28-pin SOP (300mil) package

Applications

- Intelligent educational leisure products
- Alert and warning systems
- Sound effect generators

General Description

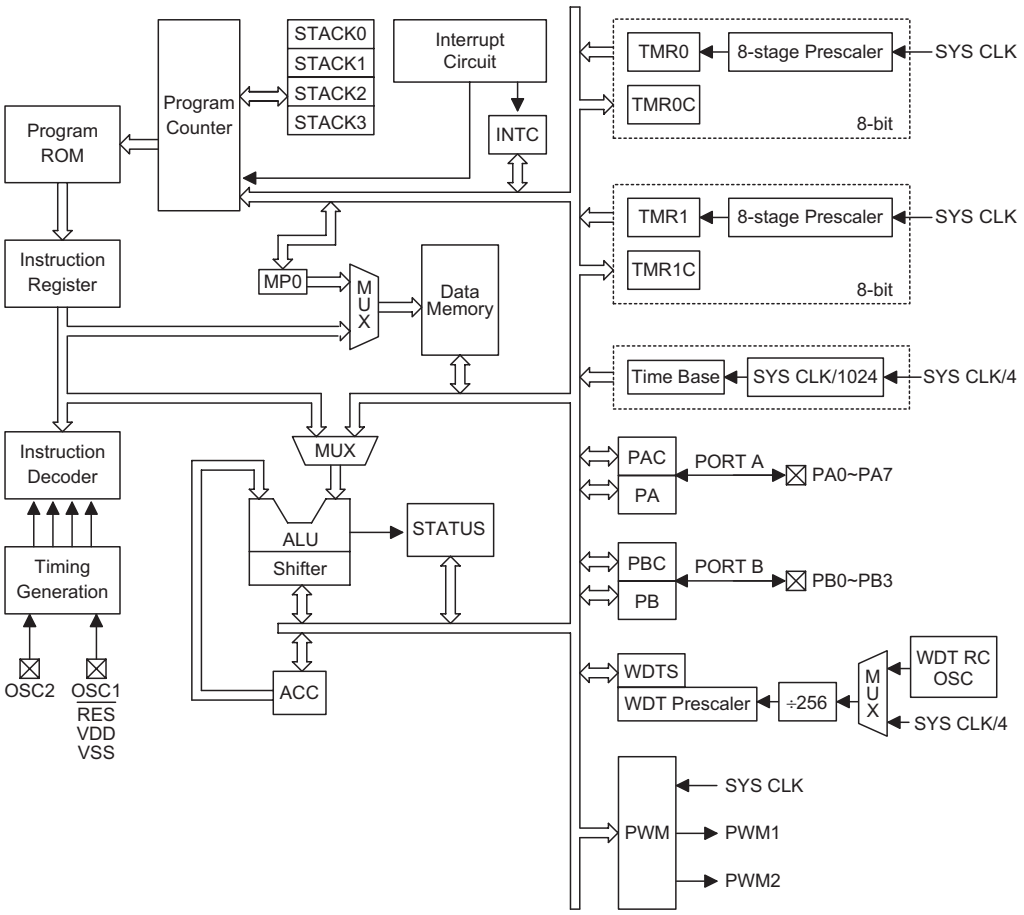
The HT83XXX is 8-bit high performance microcontroller with voice synthesizer and tone generator. The HT83XXX is designed for applications on multiple I/Os with sound effects, such as voice and melody. It can provide various sampling rates and beats, tone levels, tempos for speech synthesizer and melody generator.

The HT83XXX is excellent for versatile voice and sound effect product applications. The efficient MCU instructions allow users to program the powerful custom applications. The system frequency of HT83XXX can be up to 8MHz under 2.4V and include a HALT function to reduce power consumption.

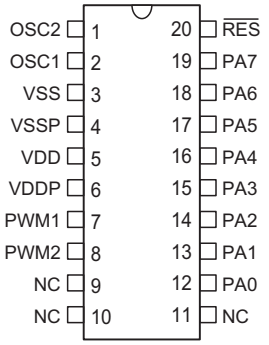
Selection Table

Body	HT83004	HT83007	HT83010	HT83020	HT83038	HT83050	HT83074
Voice ROM Size	64K-bit	128K-bit	192K-bit	384K-bit	768K-bit	1024K-bit	1536K-bit
Voice Length	3 sec	6 sec	9 sec	18 sec	36 sec	48 sec	72 sec

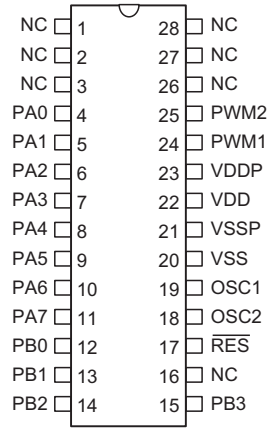
Block Diagram



Pin Assignment



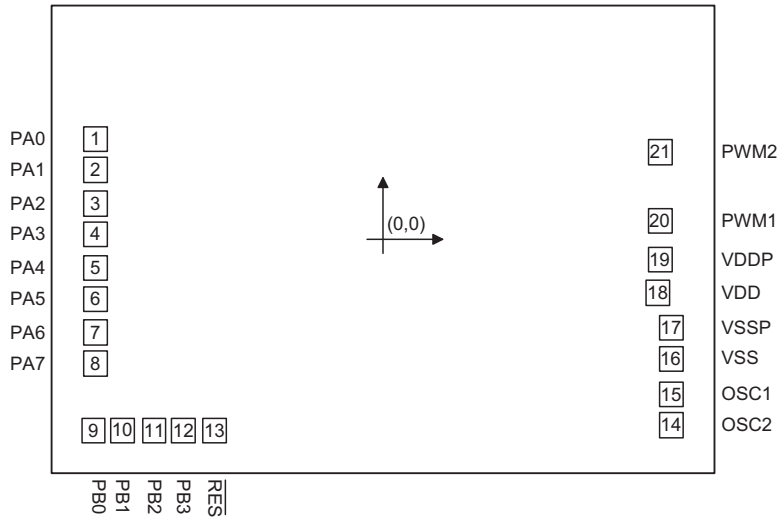
HT83004/HT83007/HT83010/HT83020
HT83038/HT83050/HT83074
– 20 SSOP-A



HT83004/HT83007/HT83010/HT83020
HT83038/HT83050/HT83074
– 28 SOP-A

Pad Assignment

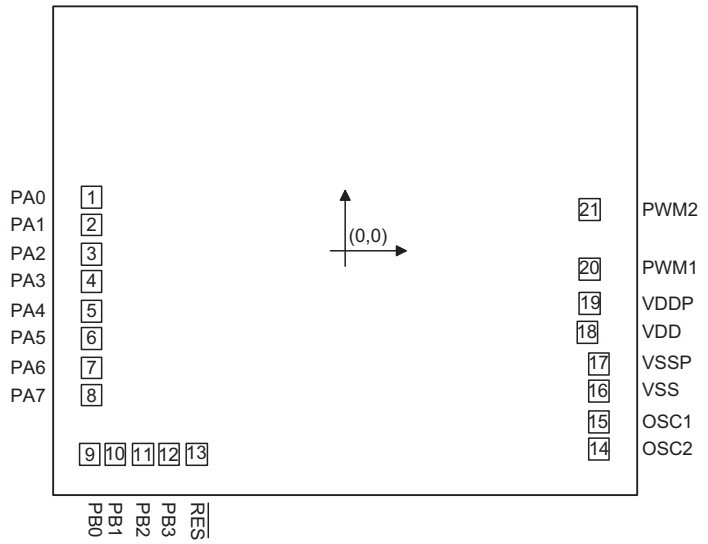
HT83004/HT83007/HT83010



Chip size: 2280×1475 (μm)^2

* The IC substrate should be connected to VSS in the PCB layout artwork.

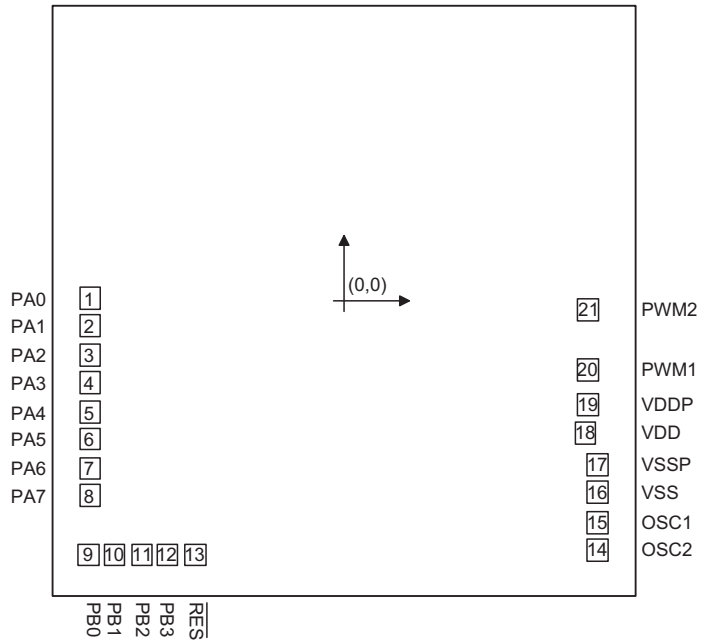
HT83020/HT83038



Chip size: 2180×1720 (μm)^2

* The IC substrate should be connected to VSS in the PCB layout artwork.

HT83050/HT83074



Chip size: 2180×2075 (μm)^2

* The IC substrate should be connected to VSS in the PCB layout artwork.

Pad Coordinates

HT83004/HT83007/HT83010

Pad No.	X	Y	Pad No.	X	Y
1	–940.400	307.150	12	–654.200	–587.900
2	–940.400	212.150	13	–551.200	–587.900
3	–940.400	109.150	14	940.400	–571.200
4	–940.400	14.150	15	940.400	–476.200
5	–940.400	–88.850	16	940.600	–368.500
6	–940.400	–183.850	17	940.600	–273.000
7	–940.400	–286.850	18	896.250	–165.350
8	–940.400	–381.850	19	904.900	–63.250
9	–947.200	–587.900	20	904.900	56.300
10	–852.200	–587.900	21	904.900	266.800
11	–749.200	–587.900			

HT83020/HT83038

Pad No.	X	Y	Pad No.	X	Y
1	–940.400	184.650	12	–654.200	–710.400
2	–940.400	89.650	13	–551.200	–710.400
3	–940.400	–13.350	14	940.400	–693.700
4	–940.400	–108.350	15	940.400	–598.700
5	–940.400	–211.350	16	940.600	–491.000
6	–940.400	–306.350	17	940.600	–395.500
7	–940.400	–409.350	18	896.250	–285.750
8	–940.400	–504.350	19	904.900	–185.750
9	–947.200	–710.400	20	904.900	–66.200
10	–852.200	–710.400	21	904.900	144.300
11	–749.200	–710.400			

HT83050/HT83074

Pad No.	X	Y	Pad No.	X	Y
1	–940.400	7.150	12	–654.200	–887.900
2	–940.400	–87.850	13	–551.200	–887.900
3	–940.400	–190.850	14	940.400	–871.200
4	–940.400	–285.850	15	940.400	–776.200
5	–940.400	–388.850	16	940.600	–668.500
6	–940.400	–483.850	17	940.600	–573.000
7	–940.400	–586.850	18	896.250	–463.250
8	–940.400	–681.850	19	904.900	–363.250
9	–947.200	–887.900	20	904.900	–243.700
10	–852.200	–887.900	21	904.900	–33.200
11	–749.200	–887.900			

Pad Description

Pad Name	I/O	Mask Option	Description
PA0~PA7	I/O	Wake-up, Pull-high or None	Bidirectional 8-bit I/O port. Each bit can be configured as a wake-up input by mask option. Software instructions determine the CMOS output or Schmitt trigger input with or without pull-high resistor (mask option).
PB0~PB3	I/O	Pull-high or None	Bidirectional 4-bit I/O port. Software instructions determine the CMOS output or Schmitt trigger input (pull-high resistor depending on mask option).
VSS	—	—	Negative power supply, ground
VSSP	—	—	PWM negative power supply, ground
VDD	—	—	Positive power supply
VDDP	—	—	PWM positive power supply, ground
$\overline{RES}$	I	—	Schmitt trigger reset input, active low
OSC1, OSC2	—	RC or Crystal	OSC1 and OSC2 are connected to an RC network or crystal (by mask option) for the internal system clock. In the case of RC operation, OSC2 is the output terminal for 1/4 system clock. The system clock may came form the crystal, the two pins cannot be floating.
PWM1, PWM2	O	—	PWM output for driving a external transistor or speaker

Absolute Maximum Ratings

Supply Voltage .....V_{SS}+2.4V to V_{SS}+5.5V

Input Voltage .....V_{SS}–0.3V to V_{DD}+0.3V

Storage Temperature .....–50°C to 125°C

Operating Temperature .....–40°C to 85°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

D.C. Characteristics

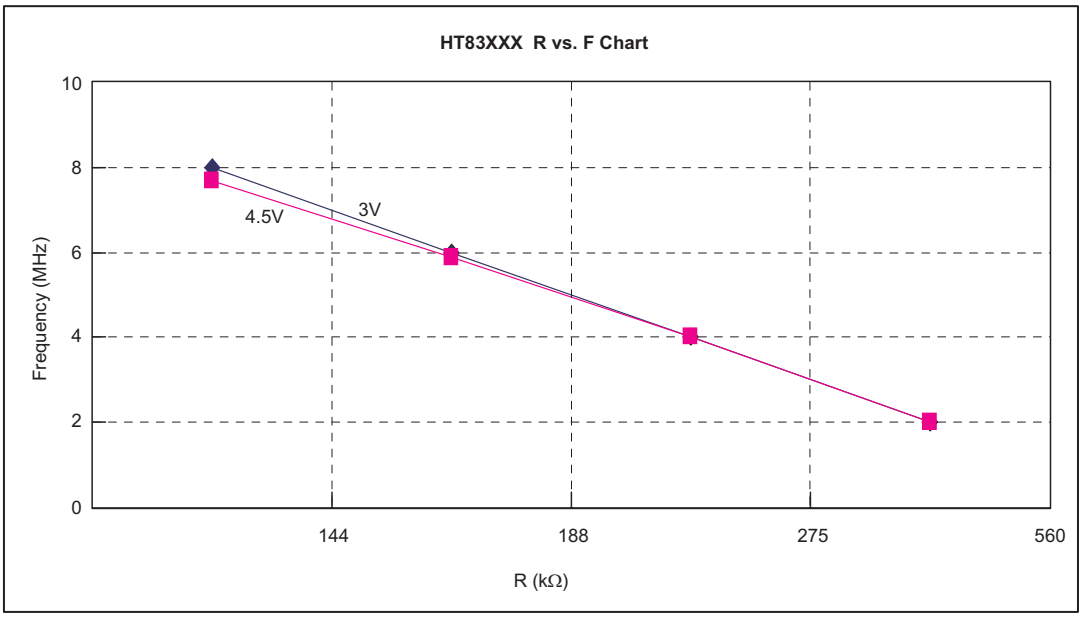
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	f_{SYS}=4MHz/8MHz	2.4	—	5.2	V
I_{STB1}	Standby Current (Watchdog Off)	3V	No load, system HALT	—	—	1	μA
		5V		—	—	2	μA
I_{STB2}	Standby Current (Watchdog On)	3V	No load, system HALT	—	—	7	μA
		5V		—	—	10	μA
I_{DD}	Operating Current	3V	No load, f_{SYS}=4MHz	—	—	3	mA
		5V		—	—	7	mA
I_{OL1}	I/O Port Sink Current	3V	V_{OL}=0.1V_{DD}	7	—	—	mA
		5V		15	—	—	mA
I_{OH1}	I/O Port Source Current	3V	V_{OH}=0.9V_{DD}	–3.5	—	—	mA
		5V		–8	—	—	mA
I_{OL2}	PWM1/PWM2 Sink Current	3V	V_{OL}=0.1V_{DD}	50	—	—	mA
		5V		80	—	—	mA
I_{OH2}	PWM1/PWM2 Source Current	3V	V_{OH}=0.9V_{DD}	–14.5	—	—	mA
		5V		–26	—	—	mA
V_{IL1}	Input Low Voltage for I/O Ports	3V	—	—	1	—	V
		5V		—	2	—	V
V_{IH1}	Input High Voltage for I/O Ports	3V	—	—	2	—	V
		5V		—	3.2	—	V
V_{IL2}	Reset Low Voltage ($\overline{RES}$)	3V	—	—	1.5	—	V
		5V		—	2.5	—	V
V_{IH2}	Reset High Voltage ($\overline{RES}$)	3V	—	—	2.1	—	V
		5V		—	3.5	—	V
f_{SYS}	System Frequency	3V	$R_{TYPICAL}$=275kΩ	—	4.0	—	MHz
			$R_{TYPICAL}$=144kΩ	—	8.0	—	MHz
R_{PH}	Pull-high Resistance	3V	—	20	60	100	kΩ
		5V		10	30	50	kΩ

A.C. Characteristics

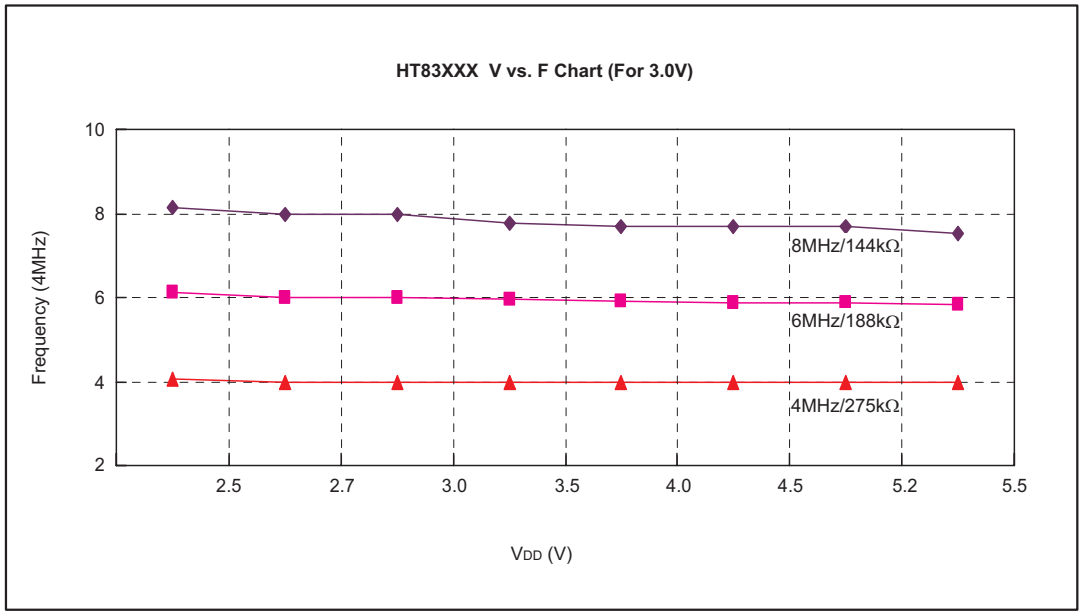
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
f_{SYS1}	System Clock (RC OSC)	—	2.4V~5.2V	4	—	8	MHz
f_{SYS2}	System Clock (Crystal OSC)	—	2.4V~5.2V	4	—	8	MHz
f_{TIMER}	Timer Input Frequency	—	2.4V~5.2V	0	—	8	MHz
t_{WDTOSC}	Watchdog Oscillator Period	3V	—	50	100	200	μs
		5V		37	74	148	μs
t_{WDT1}	Watchdog Time-out Period (WDT OSC)	3V	Without WDT prescaler	12	23	46	ms
		5V		8	17	33	ms
t_{WDT2}	Watchdog Time-out Period (System Clock)	—	Without WDT prescaler	—	1024	—	t_{SYS}
t_{RES}	External Reset Low Pulse Width	—	—	1	—	—	μs
t_{SST}	System Start-up Timer Period	—	Power-up or Wake-up from HALT	—	1024	—	t_{SYS}
t_{INT}	Interrupt Pulse Width	—	—	1	—	—	μs
t_{DRT}	Data ROM Access Timer	—	—	5	—	—	ms
t_{DRR}	Data ROM enable Read	—	Read after data ROM enable	30	—	—	ms

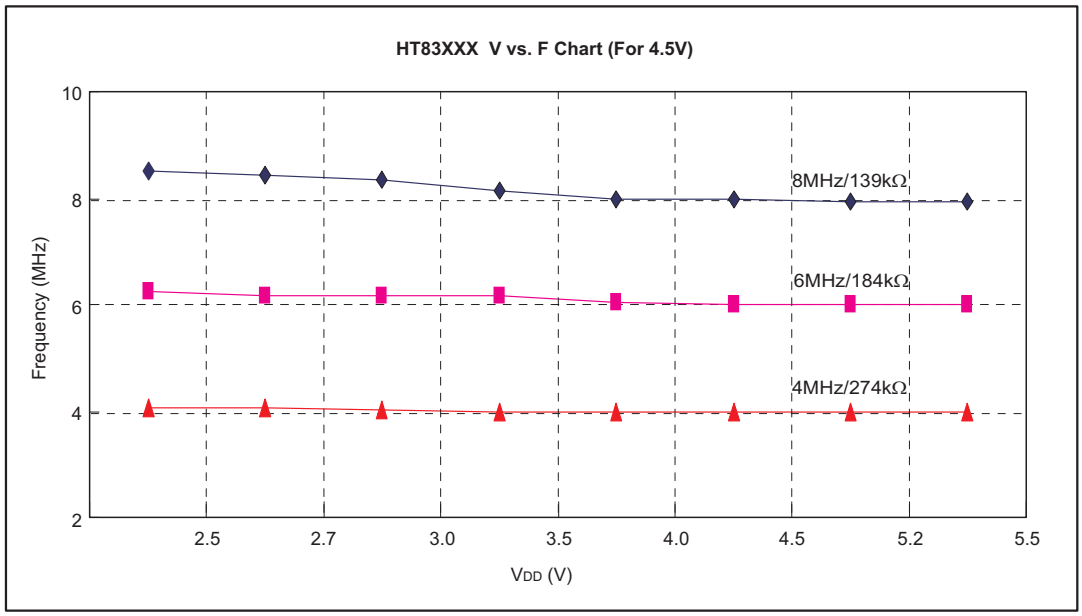
Characteristics Curves

R vs. F Characteristics Curve



V vs. F Characteristics Curve





Functional Description

Execution Flow

The system clock for the HT83XXX is derived from either a crystal or RC oscillator. It is internally divided into four non-overlapping clocks. One instruction cycle consists of four system clock cycles.

Instruction fetching and execution are pipelined in such a way that a fetch takes one instruction cycle while decoding and execution takes the next instruction cycle. However, the pipelining scheme causes each instruction to effectively execute within one cycle. If an instruction changes the Program Counter, two cycles are required to complete the instruction.

Program Counter – PC

The 11-bit program counter (PC) controls the sequence in which the instructions stored in program ROM are executed.

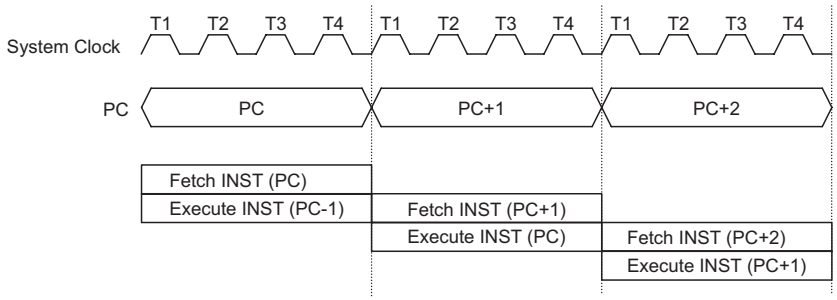
After accessing a program memory word to fetch an instruction code, the contents of the program counter are incremented by one. The program counter then points to the memory word containing the next instruction code.

When executing a jump instruction, conditional skip execution, loading PCL register, subroutine call, initial reset, internal interrupt or return from subroutine, the PC manipulates the program transfer by loading the address corresponding to each instruction.

The conditional skip is activated by instruction. Once the condition is met, the next instruction, fetched during the current instruction execution, is discarded and a dummy cycle takes its place while the correct instruction is obtained.

The lower byte of the program counter (PCL) is a read/write register (06H). Moving data into the PCL performs a short jump. The destination must be within 256 locations.

When a control transfer takes place, an additional dummy cycle is required.



Execution Flow

Mode	Program Counter										
	***10**	***9**	***8**	***7**	***6**	***5**	***4**	***3**	***2**	***1**	***0**
Initial Reset	0	0	0	0	0	0	0	0	0	0	0
Time Base Overflow	0	0	0	0	0	0	0	0	1	0	0
Timer Counter 0 Overflow	0	0	0	0	0	0	0	1	0	0	0
Timer Counter 1 Overflow	0	0	0	0	0	0	0	1	1	0	0
Skip	Program Counter+2										
Loading PCL	*10	*9	*8	@7	@6	@5	@4	@3	@2	@1	@0
Jump, Call Branch	#10	#9	#8	#7	#6	#5	#4	#3	#2	#1	#0
Return from Subroutine	S10	S9	S8	S7	S6	S5	S4	S3	S2	S1	S0

Program Counter

Note: *10~*0: Program counter bits
#10~#0: Instruction code bits
S10~S0: Stack register bits
@7~@0: PCL bits

Program Memory – ROM

The program memory stores the program instructions that are to be executed. It also includes data, table and interrupt entries, addressed by the program counter along with the table pointer. The program memory size for HT83XXX is 2048×15 bits. Certain locations in the program memory are reserved for special usage:

- Location 000H

  This area is reserved for program initialization. The program always begins execution at location 000H each time the system is reset.

- Location 004H

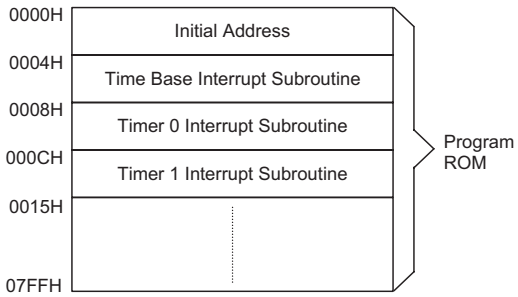
  This area is reserved for the time base interrupt service program. If the ETBI (intc.1) is activated, and the interrupt is enabled and the stack is not full, the program will jump to location 004H and begins execution.

- Location 008H

  This area is reserved for the 8-bit Timer Counter 0 interrupt service program. If a timer interrupt results from a Timer Counter 0 overflow, and if the interrupt is enabled and the stack is not full, the program will jump to location 008H and begins execution.

- Location 00CH

  This area is reserved for the 8-bit Timer Counter 1 interrupt service program. If a timer interrupt results from a Timer Counter 1 overflow, and if the interrupt is enabled and the stack is not full, the program will jump to location 00CH and begins execution.



Program Memory

Table Location

Any location in the ROM space can be used as look up tables. The instructions "TABRDC [m]" (used for any bank) and "TABRDL [m]" (only used for last page of program ROM) transfer the contents of the lower-order byte to the specified data memory [m], and the higher-order byte to TBLH (08H). Only the destination of the lower-order byte in the table is well-defined. The higher-order bytes of the table word are transferred to the TBLH. The table higher-order byte register (TBLH) is read only.

The table pointer (TBLP) is a read/write register, which indicates the table location.

Stack Register – Stack

The stack register is a special part of the memory used to save the contents of the Program Counter. This stack is organized into four levels. It is neither part of the data nor part of the program space, and cannot be read or written to. Its activated level is indexed by a stack pointer (SP) and cannot be read or written to. At a subroutine call or interrupt acknowledgment, the contents of the program counter are pushed onto the stack.

The program counter is restored to its previous value from the stack at the end of subroutine or interrupt routine, which is signaled by return instruction (RET or RETI). After a chip resets, SP will point to the top of the stack.

The interrupt request flag will be recorded but the acknowledgment will be inhibited when the stack is full and a non-masked interrupt takes place. After the stack pointer is decremented (by RET or RETI), the interrupt request will be serviced. This feature prevents stack overflow and allows programmers to use the structure more easily. In a similar case, if the stack is full and a "CALL" is subsequently executed, stack overflow occurs and the first entry is lost.

Instruction	Table Location										
	*10	*9	*8	*7	*6	*5	*4	*3	*2	*1	*0
TABRDC [m]	P10	P9	P8	@7	@6	@5	@4	@3	@2	@1	@0
TABRDL [m]	1	1	1	@7	@6	@5	@4	@3	@2	@1	@0

Table Location

Note: *10~*0: Current program ROM table

P10~P8: Bits of current program counter

@7~@0: Write @7~@0 to TBLP pointer register

Data Memory – RAM

The data memory is designed with 80×8 bits. The data memory is further divided into two functional groups, namely, special function registers (00H~2AH) and general purpose user data memory (30H~7FH). Although most of them can be read or be written to, some are read only.

The general purpose data memory, addressed from 30H~7FH, is used for data and control information under instruction commands.

The areas in the RAM can directly handle the arithmetic, logic, increment, decrement and rotate operations. Except some dedicated bits, each bit in the RAM can be set and reset by "SET [m].i" and "CLR [m].i". They are also indirectly accessible through the Memory Pointer register 0 (MP0:01H).

Indirect Addressing Register

Location 00H is indirect addressing registers that are not physically implemented. Any read/write operation of [00H] accesses the RAM pointed to by MP0 (01H) respectively. Reading location 00H indirectly returns the result 00H. While, writing it indirectly leads to no operation.

Accumulator – ACC (05H)

The accumulator (ACC) is related to the ALU operations. It is also mapped to location 05H of the RAM and is capable of operating with immediate data. The data movement between two data memory locations must pass through the ACC.

Arithmetic and Logic Unit – ALU

This circuit performs 8-bit arithmetic and logic operations and provides the following functions:

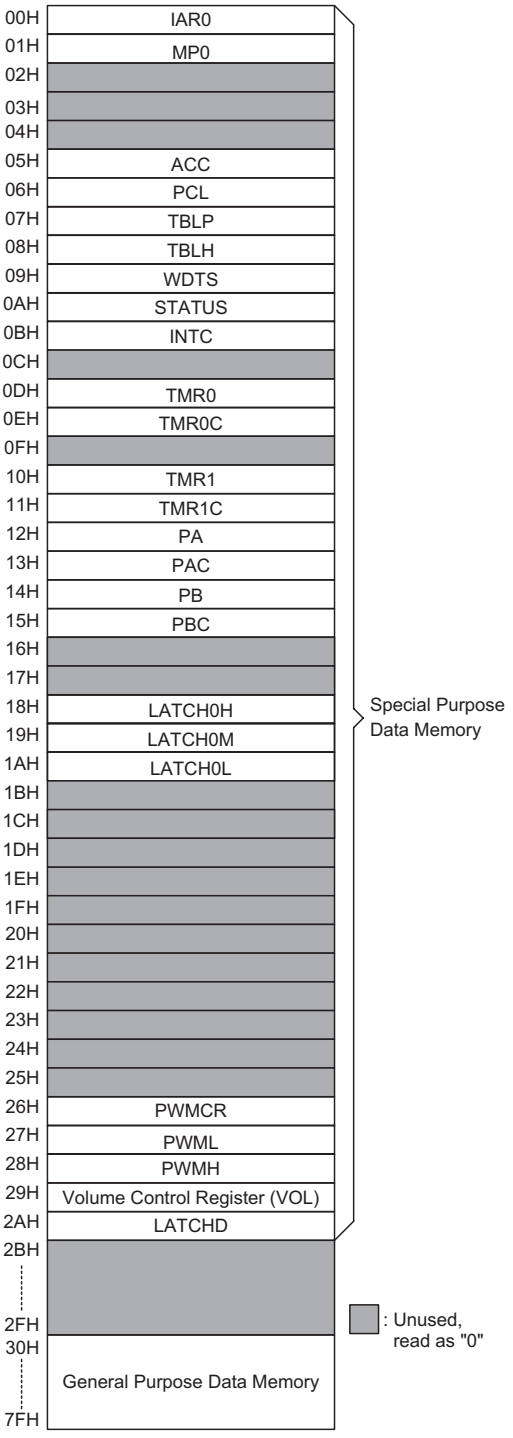
- Arithmetic operations (ADD, ADC, SUB, SBC, DAA)
- Logic operations (AND, OR, XOR, CPL)
- Rotation (RL, RR, RLC, RRC)
- Increment and Decrement (INC, DEC)
- Branch decision (SZ, SNZ, SIZ, SDZ etc)

Status Register – STATUS (0AH)

This 8-bit STATUS register (0AH) consists of a zero flag (Z), carry flag (C), auxiliary carry flag (AC), overflow flag (OV), power down flag (PDF), watchdog time-out flag (TO). It also records the status information and controls the operation sequence.

Except the TO and PDF flags, bits in the status register can be altered by instructions similar to other registers. Data written into the status register does not alter the TO or PDF flags. Operations related to the status register, however, may yield different results from those intended. The TO and PDF flags can only be changed by a Watchdog Timer overflow, chip power-up, or clearing the Watchdog Timer and executing the "HALT" instruction. The Z, OV, AC, and C flags reflect the status of the latest operations.

On entering the interrupt sequence or executing the subroutine call, the status register will not be automatically pushed onto the stack. If the contents of the status is important, and if the subroutine is likely to corrupt the status register, the programmer should take precautions and save it properly.



RAM Mapping

Address	RAM Mapping	Read/Write	Description
00H	IAR0	R/W	Indirect Addressing Register 0
01H	MP0	R/W	Memory Pointer 0
05H	ACC	R/W	Accumulator
06H	PCL	R/W	Program counter lower-order byte address
07H	TBLP	R/W	Table pointer lower-order byte register
08H	TBLH	R	Table higher-order byte content register
09H	WDTS	R/W	Watchdog Timer option setting register
0AH	STATUS	R/W	Status register
0BH	INTC	R/W	Interrupt control register 0
0DH	TMR0	R/W	Timer Counter 0 register
0EH	TMR0C	R/W	Timer Counter 0 control register
10H	TMR1	R/W	Timer Counter 1 register
11H	TMR1C	R/W	Timer Counter 1 control register
12H	PA	R/W	Port A I/O data register
13H	PAC	R/W	Port A I/O control register
14H	PB	R/W	Port B I/O data register
15H	PBC	R/W	Port B I/O control register
18H	LATCH0H	R/W	Voice ROM address latch 0 [A17, A16]
19H	LATCH0M	R/W	Voice ROM address latch 0 [A15~A8]
1AH	LATCH0L	R/W	Voice ROM address latch 0 [A7~A0]
26H	PWMCR	R/W	PWM control register
27H	PWML	R/W, higher-nibble available only	PWM output data P3~P0 to PWML7~PWML4
28H	PWMH	R/W	PWM output data P11~P4 to PWMH7~PWMH0
29H	VOL	R/W, higher-nibble available only	Volume control register and volume controlled by VOL8~VOL4
2AH	LATCHD	R	Voice ROM data register
2BH~2FH	Unused		
30H~7FH	User data RAM	R/W	User data RAM

Note: R: Read only
W: Write only
R/W: Read/Write

Interrupts

The HT83XXX provides two 8-bit programmable timer interrupts, and a time base interrupt. The Interrupt Control registers (INTC:0BH) contain the interrupt control bits to set to enable/disable and the interrupt request flags.

Once an interrupt subroutine is serviced, all other interrupts will be blocked (by clearing the EMI bit). This scheme may prevent any further interrupt nesting. Other interrupt requests may happen during this interval but only the interrupt request flag is recorded. If a certain interrupt needs servicing within the service routine, the EMI bit and the corresponding INTC bit may be set to allow interrupt nesting. If the stack is full, the interrupt request will not be acknowledged, even if the related interrupt is enabled, until the Stack Pointer is decremented. If immediate service is desired, the stack must be prevented from becoming full.

As an interrupt is serviced, a control transfer occurs by pushing the program counter onto the stack and then branching to subroutines at the specified location(s) in the program memory. Only the program counter is pushed onto the stack. The programmer must save the contents of the register or status register (STATUS) in advance if they are altered by an interrupt service program which corrupts the desired control sequence.

Bit No.	Label	Function
0	C	C is set if an operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation; otherwise C is cleared. C is also affected by a rotate through carry instruction.
1	AC	AC is set if an operation results in a carry out of the low nibbles in addition or no borrow from the high nibble into the low nibble in subtraction; otherwise AC is cleared.
2	Z	Z is set if the result of an arithmetic or logical operation is zero; otherwise Z is cleared.
3	OV	OV is set if an operation results in a carry into the highest-order bit but not a carry out of the highest-order bit, or vice versa; otherwise OV is cleared.
4	PDF	PDF is cleared by system power-up or executing the ″CLR WDT″ instruction. PDF is set by executing the ″HALT″ instruction.
5	TO	TO is cleared by system power-up or executing the ″CLR WDT″ or ″HALT″ instruction. TO is set by a WDT time-out.
6~7	—	Unused bit, read as ″0″

Status (0AH) Register

The Internal Timer Counter 0 Interrupt is initialized by setting the Timer Counter 0 interrupt request flag (T0F:bit 5 of INTC), caused by a Timer Counter 0 overflow. When the interrupt is enabled, and the stack is not full and the T0F bit is set, a subroutine call to location 08H will occur. The related interrupt request flag (T0F) will be reset and the EMI bit cleared to disable further interrupts.

The Internal Timer Counter 1 Interrupt is initialized by setting the Timer Counter 1 interrupt request flag (T1F:bit 6 of INTC), caused by a Timer Counter 1 overflow. When the interrupt is enabled, and the stack is not full and the T1F bit is set, a subroutine call to location 0CH will occur. The related interrupt request flag (T1F) will be reset and the EMI bit cleared to disable further interrupts.

Time Base Interrupt is triggered by set INTC.1 (ETBI) which sets the related interrupt request flag (TBF:bit 4 of INTC). When the interrupt is enabled, and the stack is not full and the external interrupt is active, a subroutine call to location 04H will occur. The interrupt request flag (TBF) and EMI bits will be cleared to disable other interrupts.

During the execution of an interrupt subroutine, other interrupt acknowledgment are held until the ″RETI″ instruction is executed or the EMI bit and the related interrupt control bit are set to ″1″ (of course, if the stack is not full). To return from the interrupt subroutine, the ″RET″ or ″RETI″ instruction may be invoked. RETI will set the EMI bit to enable an interrupt service, but RET will not.

Interrupts occurring in the interval between the rising edges of two consecutive T2 pulses, will be serviced on the latter of the two T2 pulses, if the corresponding interrupts are enabled. In the case of simultaneous requests, the following table shows the priority that is applied. These can be masked by resetting the EMI bit.

The Timer Counter 0/1 interrupt request flag (T0F/T1F) which enables Timer Counter 0/1 control bit (ET0I/ ET1I), the time base interrupt request flag (TBF) which enables time base control bit (ETBI) from the interrupt control register (INTC:0BH) EMI, ETBI, ET0I, ET1I are used to control the enabling/disabling of interrupts. These bits prevent the requested interrupt begin serviced. Once the interrupt request flags (T0F, T1F, TBF) are set, they will remain in the INTC register until the interrupts are serviced or cleared by a software instruction.

It is recommended that application programs do not use CALL subroutines within an interrupt subroutine. Interrupts often occur in an unpredictable manner or need to be serviced immediately in some applications. If only one stack is left and the interrupt enable is not well controlled, once a CALL subroutine if used in the interrupt subroutine will corrupt the original control sequence.

Bit No.	Label	Function
0	EMI	Controls the master (global) interrupt (1= enabled; 0= disabled)
1	ETBI	Controls the time base interrupt (1= enabled; 0= disabled)
2	ET0I	Controls the timer 0 interrupt (1= enabled; 0= disabled)
3	ET1I	Controls the timer 1 interrupt (1= enabled; 0= disabled)
4	TBF	Time base interrupt request flag (1= active; 0= inactive)
5	T0F	Timer 0 request flag (1= active; 0= inactive)
6	T1F	Timer 1 request flag (1= active; 0= inactive)
7	—	Unused bit, read as ″0″

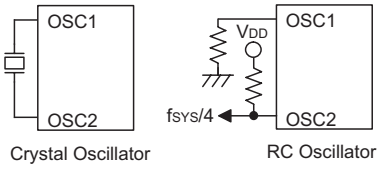
INTC (0BH) Register

Interrupt Source	Priority	Vector
Time Base Interrupt	1	04H
Timer Counter 0 Overflow	2	08H
Timer Counter 1 Overflow	3	0CH

Oscillator Configuration

The HT83XXX provides two oscillator circuits for system clock, i.e., RC oscillator and Crystal oscillator. No matter what type of oscillator.. The signal is used for the system clock. The HALT mode stops the system oscillator to conserve power. If the RC oscillator is used, an external resistor between OSC1 and VSS is required, and the range of the resistance should be from 144kΩ to 275kΩ. The system clock, divided by 4. The RC oscillator provides the most cost effective solution. However, the frequency of the oscillation may vary with VDD, temperature, and the chip itself due to process variations. It is therefore not suitable for timing sensitive operations where accurate oscillator frequency is desired.

On the other hand, if the crystal oscillator is selected, a crystal across OSC1 and OSC2 is needed to provide the feedback and phase shift required for the oscillator, and no other external components are required. A resonator may be connected between OSC1 and OSC2 to replace the crystal and to get a frequency reference, but two external capacitors in OSC1 and OSC2 are required.



System Oscillator

Watchdog Timer – WDT

The WDT clock source is implemented by a dedicated RC oscillator (WDT oscillator) or instruction clock (system clock divided by 4), decided by mask options. This timer is designed to prevent a software malfunction or sequence jumping to an unknown location with unpredictable results. The Watchdog Timer can be disabled by mask option. If the Watchdog Timer is disabled, all the executions related to the WDT result in no operation.

Once the internal WDT oscillator (RC oscillator with period 78μs normally) is selected, it is first divided by 256 (8-stages) to get the nominal time-out period of approximately 20ms. This time-out period may vary with temperature, VDD and process variations. By invoking the WDT prescaler, longer time-out period can be realized. Writing data to WS2, WS1, WS0 (bit 2,1,0 of WDTS(09H)) can give different time-out period.

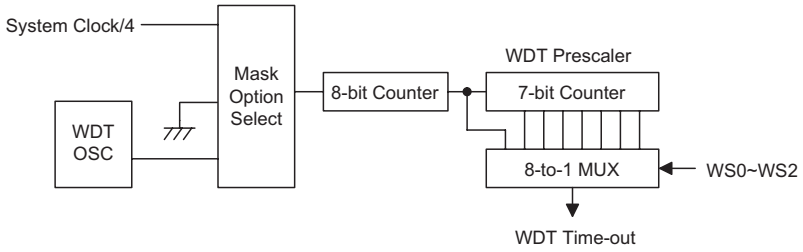
If WS2, WS1, WS0 all equal to 1, the division ratio is up to 1:128, and the maximum time-out period is 2.6 seconds.

If the device operates in a noisy environment, using the on-chip RC oscillator (WDT OSC) is strongly recommended, since the HALT will stop the system clock.

The WDT overflow under normal operation will initialize a "chip reset" and set the status bit "TO". Whereas in the HALT mode, the overflow will initialize a "warm reset" only the Program Counter and SP are reset to zero. To clear the contents of the WDT (including the WDT prescaler), three methods are adopted; external reset (external reset (a low level to $\overline{RES}$), software instructions, or a "HALT" instruction. The software instruction is "CLR WDT" and execution of the "CLR WDT" instruction will clear the WDT.

WS7	WS6	WS5	WS4	WS3	WS2	WS1	WS0	Division Ratio
—	—	—	—	—	0	0	0	1:1
—	—	—	—	—	0	0	1	1:2
—	—	—	—	—	0	1	0	1:4
—	—	—	—	—	0	1	1	1:8
—	—	—	—	—	1	0	0	1:16
—	—	—	—	—	1	0	1	1:32
—	—	—	—	—	1	1	0	1:64
—	—	—	—	—	1	1	1	1:128

WDTS (09H) Register



Watchdog Timer

Power Down – HALT

The HALT mode is initialized by a ″HALT″ instruction and results in the following:

- The system oscillator will be turned off but the WDT oscillator keeps running (if the WDT oscillator is selected).
- The contents of the on chip RAM and registers remain unchanged.
- WDT and WDT prescaler will be cleared and recount again.
- All I/O ports maintain their original status.
- The PDF flag is set and the TO flag is cleared.

The system can leave the HALT mode by means of an external reset, an interrupt, an external falling edge signal on port A or a WDT overflow. An external reset causes a device initialization and the WDT overflow performs a ″warm reset″. By examining the TO and PDF flags, the reason for the chip reset can be determined. The PDF flag is cleared when the system powers-up or executes the ″CLR WDT″ instruction, and is set when the ″HALT″ instruction is executed. The TO flag is set if a WDT time-out occurs, and causes a wake-up that only resets the Program Counter and Stack Pointer. The other maintain their original status.

The port A wake-up and interrupt methods can be considered as a continuation of normal execution. Each bit in port A can be independently selected to wake up the device by mask option. Awakening from an I/O port stimulus, the program will resume execution of the next instruction. If awakening from an interrupt, two sequence may occur. If the related interrupt is disabled or the interrupt is enabled by the stack is full, the program will resume execution at the next instruction. If the interrupt is enabled and the stack is not full, the regular interrupt response takes place.

Once a wake-up event occurs, it takes 1024 system clock period to resume normal operation. In other words, a dummy cycle period will be inserted after a wake-up. If the wake-up results from an interrupt acknowledge, the actual interrupt subroutine will be delayed by one more cycle. If the wake-up results in next instruction execution, this will be executed immediately after a dummy period is finished. If an interrupt request flag is set to ″1″ before entering the HALT mode, the wake-up function of the related interrupt will be disabled. To minimize power consumption, all I/O pins should be carefully managed before entering the HALT status.

Reset

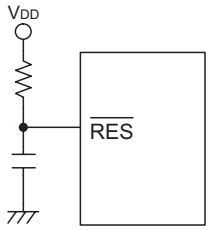
There are 3 ways in which a reset can occur:

- $\overline{\text{RES}}$ reset during normal operation
- $\overline{\text{RES}}$ reset during HALT
- WDT time-out reset during normal operation

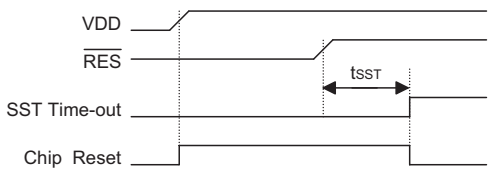
The WDT time-out during HALT is different from other chip reset conditions, since it can perform a ″warm reset″ that resets only the Program Counter and SP, leaving the other circuits in their original state. Some registers remain unchanged during any other reset conditions. Most registers are reset to their ″initial condition″ when the reset conditions are met. By examining the PDF flag and TO flag, the program can distinguish between different ″chip resets″.

TO	PDF	RESET Conditions
0	0	$\overline{\text{RES}}$ reset during power-up
u	u	$\overline{\text{RES}}$ reset during normal operation
0	1	$\overline{\text{RES}}$ wake-up HALT
1	u	WDT time-out during normal operation
1	1	WDT wake-up HALT

Note: ″u″ stands for ″unchanged″



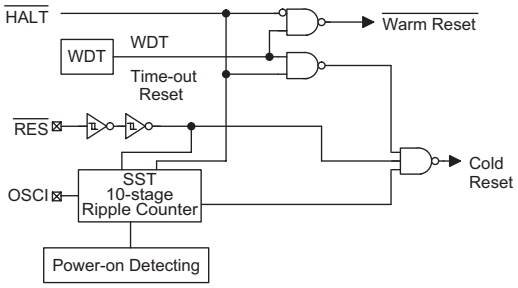
Reset Circuit



Reset Timing Chart

To guarantee that the system oscillator has started and stabilized, the SST (System Start-up Timer) provides an extra-delay of 1024 system clock pulses after a system power up or when awakening from a HALT state.

When a system power up occurs, the SST delay is added during the reset period. But when the reset comes from the $\overline{RES}$ pin, the SST delay is disabled. Any wake-up from HALT will enable the SST delay.



Reset Configuration

The functional unit chip reset status are shown below.

Program Counter	000H
Interrupt	Disable
Prescaler	Clear
WDT	Clear. After master reset, WDT begins counting
Timer Counter	Off
Input/Output Ports	Input mode
Stack Pointer	Points to the top of the stack

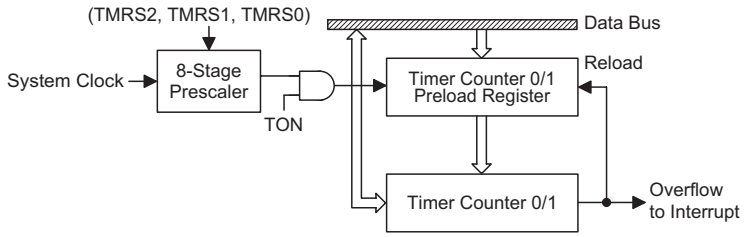
Timer Counter 0/1

The TMR0/TMR1 is internal clock source only, i.e. (TM1, TM0) = (0, 1). There is a 3-bit prescaler (TMRS2, TMRS1, TMRS0) which defines different division ratio of TMR0/TMR1′s clock source.

Bit No.	Label	Function
0~2	TMRS2, TMRS1, TMRS0	Defines the operating clock source (TMRS2, TMRS1, TMRS0) 000: clock source/2 001: clock source/4 010: clock source/8 011: clock source/16 100: clock source/32 101: clock source/64 110: clock source/128 111: clock source/256
3	TE	Defines the TMR0/TMR1 active edge of Timer Counter
4	TON	Enable/disable timer counting (0=disabled; 1=enabled)
5	—	Unused bit, read as ″0″
6 7	TM0, TM1	Defines the operating mode (TM1, TM0)

TMR0C (0EH)/TMR1C (11H) Register

Note: TMR0C/TMR1C bit 3 always write ″0″
TMR0C/TMR1C bit 5 always write ″0″
TMR0C/TMR1C bit 6 always write ″1″
TMR0C/TMR1C bit 7 always write ″0″



Timer Counter 0/1

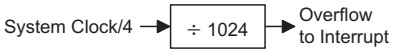
The TMR0C is the Timer Counter 0 control register, which defines the Timer Counter 0 options. The Timer Counter 1 has the same options as the Timer Counter 0 and is defined by TMR1C.

To enable the counting operation, the Timer ON bit (TON; bit 4 of TMR0C/TMR1C) should be set to "1". The overflow of the timer counter is one of the wake-up sources. No matter what the operation mode is, writing a 0 to ET0I/ET1I can disable the corresponding interrupt service.

The TMR0/1 is internal clock source only. There is a 3-bit prescaler (TMRS2, TMRS1, TMRS0) which defines different division ratio of TMR0/1's clock source.

Time Base

The time base enables the counting operation by INTC.1 (ETBI) bit. The overflow to interrupt as set INTC.4. The time base is internal clock source only. Time base of 1ms to overflow as system clock is 4MHz. Time base of 0.5ms to overflow as system clock is 8MHz.



Time Base

The registers states are summarized in the following table.

Register	Reset (Power-on)	WDT Time-out (Normal Operation)	$\overline{RES}$ Reset (Normal Operation)	$\overline{RES}$ Reset (HALT)	WDT Time-out (HALT)
MP0	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
ACC	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
Program Counter	0000H	0000H	0000H	0000H	0000H
TBLP	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLH	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
WDTS	0000 0111	0000 0111	0000 0111	0000 0111	uuuu uuuu
STATUS	--00 xxxx	--1u uuuu	--uu uuuu	--01 uuuu	--11 uuuu
INTC	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
TMR0	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx
TMR0C	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx
TMR1	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx
TMR1C	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx
PA	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PB	---- 1111	---- 1111	---- 1111	---- 1111	---- uuuu
PBC	---- 1111	---- 1111	---- 1111	---- 1111	---- uuuu
LATCH0H	---- --xx	---- --uu	---- --uu	---- --uu	---- --uu
LATCH0M	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
LATCH0L	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
PWMCR	0--- 00-0	u--- uu-u	u--- uu-u	u--- uu-u	u--- uu-u
PWML	xxxx ----	uuuu ----	uuuu ----	uuuu ----	uuuu ----
PWMH	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu	uuuu uuuu
VOL	xxxx ----	uuuu ----	uuuu ----	uuuu ----	uuuu ----
LATCHD	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu

Note: "u" means "unchanged"
"x" means "unknown"
"–" means "undefined"

Input/Output Ports

There are 12 bidirectional input/output lines in the microcontroller, labeled from PA to PB, which are mapped to the data memory of [12H], [14H] respectively. All of these I/O ports can be used for input and output operations. For input operation, these ports are non-latching, that is, the inputs must be ready at the T2 rising edge of instruction "MOV A, [m]" (m=12H, 14H). For output operation, all the data is latched and remains unchanged until the output latch is rewritten.

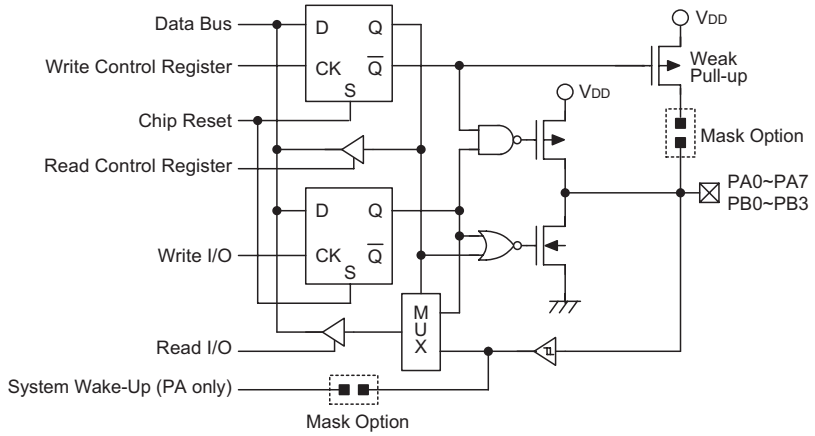
Each I/O line has its own control register (PAC, PBC) to control the input/output configuration. With this control register, CMOS output or Schmitt trigger input with or without pull-high resistor structures can be reconfigured dynamically under software control. To function as an input, the corresponding latch of the control register must write "1". The input source also depends on the control register. If the control register bit is "1", the input will read the pad state. If the control register bit is "0", the contents of the latches will move to the internal bus. The latter is possible in the "read-modify-write" instruction.

For output function, CMOS is the only configuration. These control registers are mapped to locations 13Hm 15H.

After a chip reset, these input/output lines remain at high levels or floating state (dependent on pull-high options). Each bit of these input/output latches can be set or cleared by "SET [m].i" and "CLR [m].i" (m=12H, 14H) instructions.

Some instructions first input data and then follow the output operations. For example, "SET [m].i", "CLR [m].i", "CPL [m]", "CPLA [m]" read the entire port states into the CPU, execute the defined operations (bit-operation), and then write the results back to the latches or the accumulator.

Each line of port A has the capability of waking-up the device. The wake-up capability of port A is determined by mask option. There is a pull-high option available for all I/O lines. Once the pull-high option is selected, all I/O lines have pull-high resistors. Otherwise, the pull-high resistors are absent. It should be noted that a non-pull-high I/O line operating in input mode will cause a floating state.



Input/Output Ports

Pulse Width Modulation Output – PWML/PWMH (27H/28H)

The HT83XXX provide one 12-bit PWM interface for driving an external 8Ω speaker. The programmer must write the voice data to register PWML/PWMH (27H/28H)

Pulse Width Modulation Control Register – PWMCR (26H)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3 (R/W)	Bit 2 (R/W)	Bit 1	Bit 0 (R/W)
MSB_SIGN	—	—	—	Single_PWM	VROMC	—	PWMC

PWMC: Start bit of PWM output

- PWM start counter: 0 to 1
- PWM stop counter: 1 to 0

After waiting one cycle end , stop the PWM counter and keep in low signal

VROMC: Enable voice ROM power circuit
(1=enable; 0=disable)

Single_PWM: Driving PWM signal by PWM1 output.
(1=PWM1 output; 0=PWM1/PWM2 output)

The HT83XXX provide an 12-bit (bit 7 is a sign bit, if Single_PWM = 0) PWM interface. The PWM provides two pad outputs: PWM1, PWM2 which can directly drive a piezo or an 8Ω speaker without adding any external element (green mode), or using only port PWM1 (Set Single_PWM = 1) to drive piezo or an 8Ω speaker with external element.

When Setting Single_PWM= 1, choose voice data7~ data1 as the output data (no sign bit on it).

If the sign bit is 0, then the signal is output to PWM1and the PWM2 will get a GND level voltage after setting start bit to 1. If the sign bit is 1, then the signal is output to PWM2 and the PWM1 will get a GND level voltage after setting start bit to 1.

PWM output Initial low level , and stop in low level

If PWMC from low to high then start PWM output latch new data , if no update then keep the old value.

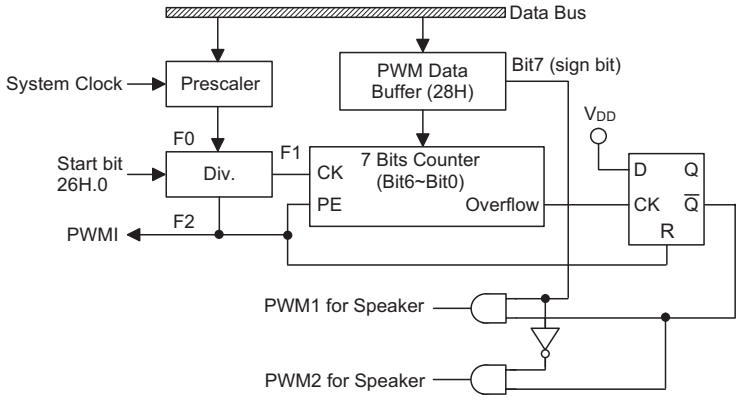
If PWMC from high to low, in duty end, stop PWM output and stop the counter.

Voice ROM Data Address Latch Counter

The voice ROM data address latch counter is the handshaking between the microcontroller and voice ROM, where the voice codes are stored. One 8-bit of voice ROM data will be addressed by setting 18-bit address latch counter LATCH0H/LATCH0M/LATCH0L. After the 8-bit voice ROM data is addressed, a few instruction cycles (4μs at least) will be generated to latch the voice ROM data, then the microcontroller can read the voice data from LATCHD (2AH).

Example: Read an 8-bit voice ROM data which is located at address 000007H by address latch 0

```
set     [26H].2       ; Enable voice ROM circuit
mov     A, 07H        ;
mov     LATCH0L, A    ; Set LATCH0L to 07H
mov     A, 00H        ;
mov     LATCH0M, A    ; Set LATCH0M to 00H
mov     A, 00H        ;
mov     LATCH0H, A    ; Set LATCH0H to 00H
call    Delay Time    ; Delay a short period of time
mov     A, LATCHD     ; Get voice data at 000007H
```



PWM

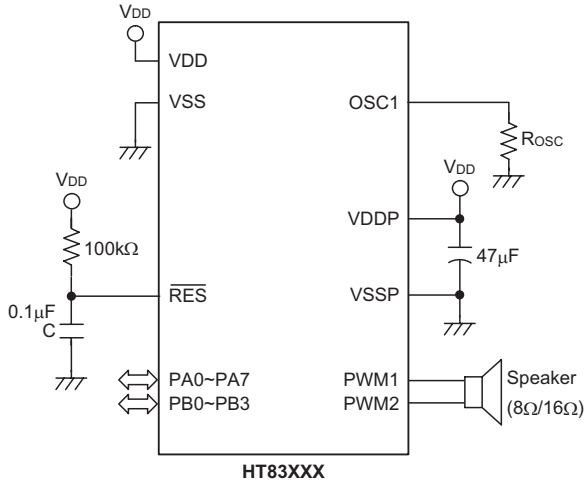
Mask Option

Mask Option	Description
PA Wake-up	Enable or disable PA wake-up function
Watchdog Timer (WDT)	Enable or disable WDT function WDT clock source is from WDTOSC or T1
PA Pull-high	Enable or disable PA pull-high
PB Pull-high	Enable or disable PB pull-high
OSC Option	Crystal or Resistor type

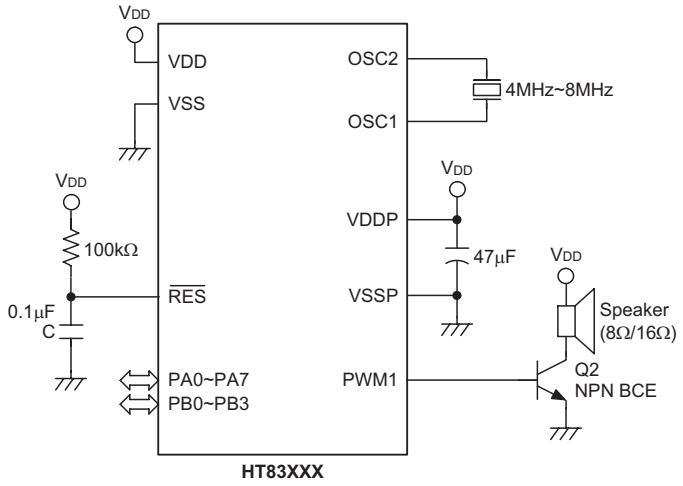
f_{OSC} – $R_{TYPICAL}$ Table (V_{DD}=3V)

f_{OSC}	$R_{TYPICAL}$
4MHz±10%	275kΩ
6MHz±10%	188kΩ
8MHz±10%	144kΩ

Application Circuits



Single PWM Mode



Instruction Set

Introduction

Central to the successful operation of any microcontroller is its instruction set, which is a set of program instruction codes that directs the microcontroller to perform certain operations. In the case of Holtek microcontrollers, a comprehensive and flexible set of over 60 instructions is provided to enable programmers to implement their application with the minimum of programming overheads.

For easier understanding of the various instruction codes, they have been subdivided into several functional groupings.

Instruction Timing

Most instructions are implemented within one instruction cycle. The exceptions to this are branch, call, or table read instructions where two instruction cycles are required. One instruction cycle is equal to 4 system clock cycles, therefore in the case of an 8MHz system oscillator, most instructions would be implemented within 0.5μs and branch or call instructions would be implemented within 1μs. Although instructions which require one more cycle to implement are generally limited to the JMP, CALL, RET, RETI and table read instructions, it is important to realize that any other instructions which involve manipulation of the Program Counter Low register or PCL will also take one more cycle to implement. As instructions which change the contents of the PCL will imply a direct jump to that new address, one more cycle will be required. Examples of such instructions would be ″CLR PCL″ or ″MOV PCL, A″. For the case of skip instructions, it must be noted that if the result of the comparison involves a skip operation then this will also take one more cycle, if no skip is involved then only one cycle is required.

Moving and Transferring Data

The transfer of data within the microcontroller program is one of the most frequently used operations. Making use of three kinds of MOV instructions, data can be transferred from registers to the Accumulator and vice-versa as well as being able to move specific immediate data directly into the Accumulator. One of the most important data transfer applications is to receive data from the input ports and transfer data to the output ports.

Arithmetic Operations

The ability to perform certain arithmetic operations and data manipulation is a necessary feature of most microcontroller applications. Within the Holtek microcontroller instruction set are a range of add and subtract instruction mnemonics to enable the necessary arithmetic to be carried out. Care must be taken to ensure correct handling of carry and borrow data when results exceed 255 for addition and less than 0 for subtraction. The increment and decrement instructions INC, INCA, DEC and DECA provide a simple means of increasing or decreasing by a value of one of the values in the destination specified.

Logical and Rotate Operations

The standard logical operations such as AND, OR, XOR and CPL all have their own instruction within the Holtek microcontroller instruction set. As with the case of most instructions involving data manipulation, data must pass through the Accumulator which may involve additional programming steps. In all logical data operations, the zero flag may be set if the result of the operation is zero. Another form of logical data manipulation comes from the rotate instructions such as RR, RL, RRC and RLC which provide a simple means of rotating one bit right or left. Different rotate instructions exist depending on program requirements. Rotate instructions are useful for serial port programming applications where data can be rotated from an internal register into the Carry bit from where it can be examined and the necessary serial bit set high or low. Another application where rotate data operations are used is to implement multiplication and division calculations.

Branches and Control Transfer

Program branching takes the form of either jumps to specified locations using the JMP instruction or to a subroutine using the CALL instruction. They differ in the sense that in the case of a subroutine call, the program must return to the instruction immediately when the subroutine has been carried out. This is done by placing a return instruction RET in the subroutine which will cause the program to jump back to the address right after the CALL instruction. In the case of a JMP instruction, the program simply jumps to the desired location. There is no requirement to jump back to the original jumping off point as in the case of the CALL instruction. One special and extremely useful set of branch instructions are the conditional branches. Here a decision is first made regarding the condition of a certain data memory or individual bits. Depending upon the conditions, the program will continue with the next instruction or skip over it and jump to the following instruction. These instructions are the key to decision making and branching within the program perhaps determined by the condition of certain input switches or by the condition of internal data bits.

Bit Operations

The ability to provide single bit operations on Data Memory is an extremely flexible feature of all Holtek microcontrollers. This feature is especially useful for output port bit programming where individual bits or port pins can be directly set high or low using either the "SET [m].i" or "CLR [m].i" instructions respectively. The feature removes the need for programmers to first read the 8-bit output port, manipulate the input data to ensure that other bits are not changed and then output the port with the correct new data. This read-modify-write process is taken care of automatically when these bit operation instructions are used.

Table Read Operations

Data storage is normally implemented by using registers. However, when working with large amounts of fixed data, the volume involved often makes it inconvenient to store the fixed data in the Data Memory. To overcome this problem, Holtek microcontrollers allow an area of Program Memory to be setup as a table where data can be directly stored. A set of easy to use instructions provides the means by which this fixed data can be referenced and retrieved from the Program Memory.

Other Operations

In addition to the above functional instructions, a range of other instructions also exist such as the "HALT" instruction for Power-down operations and instructions to control the operation of the Watchdog Timer for reliable program operations under extreme electric or electromagnetic environments. For their relevant operations, refer to the functional related sections.

Instruction Set Summary

The following table depicts a summary of the instruction set categorised according to function and can be consulted as a basic instruction reference using the following listed conventions.

Table conventions:

x: Bits immediate data

m: Data Memory address

A: Accumulator

i: 0~7 number of bits

addr: Program memory address

Mnemonic	Description	Cycles	Flag Affected
Arithmetic			
ADD A,[m]	Add Data Memory to ACC	1	Z, C, AC, OV
ADDM A,[m]	Add ACC to Data Memory	1Note	Z, C, AC, OV
ADD A,x	Add immediate data to ACC	1	Z, C, AC, OV
ADC A,[m]	Add Data Memory to ACC with Carry	1	Z, C, AC, OV
ADCM A,[m]	Add ACC to Data memory with Carry	1Note	Z, C, AC, OV
SUB A,x	Subtract immediate data from the ACC	1	Z, C, AC, OV
SUB A,[m]	Subtract Data Memory from ACC	1	Z, C, AC, OV
SUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	1Note	Z, C, AC, OV
SBC A,[m]	Subtract Data Memory from ACC with Carry	1	Z, C, AC, OV
SBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	1Note	Z, C, AC, OV
DAA [m]	Decimal adjust ACC for Addition with result in Data Memory	1Note	C
Logic Operation			
AND A,[m]	Logical AND Data Memory to ACC	1	Z
OR A,[m]	Logical OR Data Memory to ACC	1	Z
XOR A,[m]	Logical XOR Data Memory to ACC	1	Z
ANDM A,[m]	Logical AND ACC to Data Memory	1Note	Z
ORM A,[m]	Logical OR ACC to Data Memory	1Note	Z
XORM A,[m]	Logical XOR ACC to Data Memory	1Note	Z
AND A,x	Logical AND immediate Data to ACC	1	Z
OR A,x	Logical OR immediate Data to ACC	1	Z
XOR A,x	Logical XOR immediate Data to ACC	1	Z
CPL [m]	Complement Data Memory	1Note	Z
CPLA [m]	Complement Data Memory with result in ACC	1	Z
Increment & Decrement			
INCA [m]	Increment Data Memory with result in ACC	1	Z
INC [m]	Increment Data Memory	1Note	Z
DECA [m]	Decrement Data Memory with result in ACC	1	Z
DEC [m]	Decrement Data Memory	1Note	Z

Mnemonic	Description	Cycles	Flag Affected
Rotate			
RRA [m]	Rotate Data Memory right with result in ACC	1	None
RR [m]	Rotate Data Memory right	1Note	None
RRCA [m]	Rotate Data Memory right through Carry with result in ACC	1	C
RRC [m]	Rotate Data Memory right through Carry	1Note	C
RLA [m]	Rotate Data Memory left with result in ACC	1	None
RL [m]	Rotate Data Memory left	1Note	None
RLCA [m]	Rotate Data Memory left through Carry with result in ACC	1	C
RLC [m]	Rotate Data Memory left through Carry	1Note	C
Data Move			
MOV A,[m]	Move Data Memory to ACC	1	None
MOV [m],A	Move ACC to Data Memory	1Note	None
MOV A,x	Move immediate data to ACC	1	None
Bit Operation			
CLR [m].i	Clear bit of Data Memory	1Note	None
SET [m].i	Set bit of Data Memory	1Note	None
Branch			
JMP addr	Jump unconditionally	2	None
SZ [m]	Skip if Data Memory is zero	1Note	None
SZA [m]	Skip if Data Memory is zero with data movement to ACC	1note	None
SZ [m].i	Skip if bit i of Data Memory is zero	1Note	None
SNZ [m].i	Skip if bit i of Data Memory is not zero	1Note	None
SIZ [m]	Skip if increment Data Memory is zero	1Note	None
SDZ [m]	Skip if decrement Data Memory is zero	1Note	None
SIZA [m]	Skip if increment Data Memory is zero with result in ACC	1Note	None
SDZA [m]	Skip if decrement Data Memory is zero with result in ACC	1Note	None
CALL addr	Subroutine call	2	None
RET	Return from subroutine	2	None
RET A,x	Return from subroutine and load immediate data to ACC	2	None
RETI	Return from interrupt	2	None
Table Read			
TABRDC [m]	Read table (current page) to TBLH and Data Memory	2Note	None
TABRDL [m]	Read table (last page) to TBLH and Data Memory	2Note	None
Miscellaneous			
NOP	No operation	1	None
CLR [m]	Clear Data Memory	1Note	None
SET [m]	Set Data Memory	1Note	None
CLR WDT	Clear Watchdog Timer	1	TO, PDF
CLR WDT1	Pre-clear Watchdog Timer	1	TO, PDF
CLR WDT2	Pre-clear Watchdog Timer	1	TO, PDF
SWAP [m]	Swap nibbles of Data Memory	1Note	None
SWAPA [m]	Swap nibbles of Data Memory with result in ACC	1	None
HALT	Enter power down mode	1	TO, PDF

Note: 1. For skip instructions, if the result of the comparison involves a skip then two cycles are required, if no skip takes place only one cycle is required.
2. Any instruction which changes the contents of the PCL will also require 2 cycles for execution.
3. For the ″CLR WDT1″ and ″CLR WDT2″ instructions the TO and PDF flags may be affected by the execution status. The TO and PDF flags are cleared after both ″CLR WDT1″ and ″CLR WDT2″ instructions are consecutively executed. Otherwise the TO and PDF flags remain unchanged.

Instruction Definition

ADC A,[m]	Add Data Memory to ACC with Carry
Description	The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.
Operation	ACC ← ACC + [m] + C
Affected flag(s)	OV, Z, AC, C
ADCM A,[m]	Add ACC to Data Memory with Carry
Description	The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.
Operation	[m] ← ACC + [m] + C
Affected flag(s)	OV, Z, AC, C
ADD A,[m]	Add Data Memory to ACC
Description	The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.
Operation	ACC ← ACC + [m]
Affected flag(s)	OV, Z, AC, C
ADD A,x	Add immediate data to ACC
Description	The contents of the Accumulator and the specified immediate data are added. The result is stored in the Accumulator.
Operation	ACC ← ACC + x
Affected flag(s)	OV, Z, AC, C
ADDM A,[m]	Add ACC to Data Memory
Description	The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.
Operation	[m] ← ACC + [m]
Affected flag(s)	OV, Z, AC, C
AND A,[m]	Logical AND Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″AND″ [m]
Affected flag(s)	Z
AND A,x	Logical AND immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bitwise logical AND operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″AND″ x
Affected flag(s)	Z
ANDM A,[m]	Logical AND ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.
Operation	[m] ← ACC ″AND″ [m]
Affected flag(s)	Z

CALL addr	Subroutine call
Description	Unconditionally calls a subroutine at the specified address. The Program Counter then increments by 1 to obtain the address of the next instruction which is then pushed onto the stack. The specified address is then loaded and the program continues execution from this new address. As this instruction requires an additional operation, it is a two cycle instruction.
Operation	Stack ← Program Counter + 1 Program Counter ← addr
Affected flag(s)	None
CLR [m]	Clear Data Memory
Description	Each bit of the specified Data Memory is cleared to 0.
Operation	[m] ← 00H
Affected flag(s)	None
CLR [m].i	Clear bit of Data Memory
Description	Bit i of the specified Data Memory is cleared to 0.
Operation	[m].i ← 0
Affected flag(s)	None
CLR WDT	Clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared.
Operation	WDT cleared TO ← 0 PDF ← 0
Affected flag(s)	TO, PDF
CLR WDT1	Pre-clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared. Note that this instruction works in conjunction with CLR WDT2 and must be executed alternately with CLR WDT2 to have effect. Repetitively executing this instruction without alternately executing CLR WDT2 will have no effect.
Operation	WDT cleared TO ← 0 PDF ← 0
Affected flag(s)	TO, PDF
CLR WDT2	Pre-clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared. Note that this instruction works in conjunction with CLR WDT1 and must be executed alternately with CLR WDT1 to have effect. Repetitively executing this instruction without alternately executing CLR WDT1 will have no effect.
Operation	WDT cleared TO ← 0 PDF ← 0
Affected flag(s)	TO, PDF

CPL [m] Complement Data Memory

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa.

Operation $[m] \leftarrow \overline{[m]}$

Affected flag(s) Z

CPLA [m] Complement Data Memory with result in ACC

Description Each bit of the specified Data Memory is logically complemented (1′s complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow \overline{[m]}$

Affected flag(s) Z

DAA [m] Decimal-Adjust ACC for addition with result in Data Memory

Description Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.

Operation $[m] \leftarrow ACC + 00H$ or
$[m] \leftarrow ACC + 06H$ or
$[m] \leftarrow ACC + 60H$ or
$[m] \leftarrow ACC + 66H$

Affected flag(s) C

DEC [m] Decrement Data Memory

Description Data in the specified Data Memory is decremented by 1.

Operation $[m] \leftarrow [m] - 1$

Affected flag(s) Z

DECA [m] Decrement Data Memory with result in ACC

Description Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation $ACC \leftarrow [m] - 1$

Affected flag(s) Z

HALT Enter power down mode

Description This instruction stops the program execution and turns off the system clock. The contents of the Data Memory and registers are retained. The WDT and prescaler are cleared. The power down flag PDF is set and the WDT time-out flag TO is cleared.

Operation $TO \leftarrow 0$
$PDF \leftarrow 1$

Affected flag(s) TO, PDF

INC [m]	Increment Data Memory
Description	Data in the specified Data Memory is incremented by 1.
Operation	[m] ← [m] + 1
Affected flag(s)	Z
INCA [m]	Increment Data Memory with result in ACC
Description	Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.
Operation	ACC ← [m] + 1
Affected flag(s)	Z
JMP addr	Jump unconditionally
Description	The contents of the Program Counter are replaced with the specified address. Program execution then continues from this new address. As this requires the insertion of a dummy instruction while the new address is loaded, it is a two cycle instruction.
Operation	Program Counter ← addr
Affected flag(s)	None
MOV A,[m]	Move Data Memory to ACC
Description	The contents of the specified Data Memory are copied to the Accumulator.
Operation	ACC ← [m]
Affected flag(s)	None
MOV A,x	Move immediate data to ACC
Description	The immediate data specified is loaded into the Accumulator.
Operation	ACC ← x
Affected flag(s)	None
MOV [m],A	Move ACC to Data Memory
Description	The contents of the Accumulator are copied to the specified Data Memory.
Operation	[m] ← ACC
Affected flag(s)	None
NOP	No operation
Description	No operation is performed. Execution continues with the next instruction.
Operation	No operation
Affected flag(s)	None
OR A,[m]	Logical OR Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″OR″ [m]
Affected flag(s)	Z

OR A,x	Logical OR immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bitwise logical OR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″OR″ x
Affected flag(s)	Z
ORM A,[m]	Logical OR ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.
Operation	[m] ← ACC ″OR″ [m]
Affected flag(s)	Z
RET	Return from subroutine
Description	The Program Counter is restored from the stack. Program execution continues at the restored address.
Operation	Program Counter ← Stack
Affected flag(s)	None
RET A,x	Return from subroutine and load immediate data to ACC
Description	The Program Counter is restored from the stack and the Accumulator loaded with the specified immediate data. Program execution continues at the restored address.
Operation	Program Counter ← Stack ACC ← x
Affected flag(s)	None
RETI	Return from interrupt
Description	The Program Counter is restored from the stack and the interrupts are re-enabled by setting the EMI bit. EMI is the master interrupt global enable bit. If an interrupt was pending when the RETI instruction is executed, the pending Interrupt routine will be processed before returning to the main program.
Operation	Program Counter ← Stack EMI ← 1
Affected flag(s)	None
RL [m]	Rotate Data Memory left
Description	The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.
Operation	[m].(i+1) ← [m].i; (i = 0~6) [m].0 ← [m].7
Affected flag(s)	None
RLA [m]	Rotate Data Memory left with result in ACC
Description	The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	ACC.(i+1) ← [m].i; (i = 0~6) ACC.0 ← [m].7
Affected flag(s)	None

RLC [m] Rotate Data Memory left through Carry

Description The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.

Operation
[m].(i+1) ← [m].i; (i = 0~6)
[m].0 ← C
C ← [m].7

Affected flag(s) C

RLCA [m] Rotate Data Memory left through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation
ACC.(i+1) ← [m].i; (i = 0~6)
ACC.0 ← C
C ← [m].7

Affected flag(s) C

RR [m] Rotate Data Memory right

Description The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.

Operation
[m].i ← [m].(i+1); (i = 0~6)
[m].7 ← [m].0

Affected flag(s) None

RRA [m] Rotate Data Memory right with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit with bit 0 rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation
ACC.i ← [m].(i+1); (i = 0~6)
ACC.7 ← [m].0

Affected flag(s) None

RRC [m] Rotate Data Memory right through Carry

Description The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.

Operation
[m].i ← [m].(i+1); (i = 0~6)
[m].7 ← C
C ← [m].0

Affected flag(s) C

RRCA [m] Rotate Data Memory right through Carry with result in ACC

Description Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.

Operation
ACC.i ← [m].(i+1); (i = 0~6)
ACC.7 ← C
C ← [m].0

Affected flag(s) C

SBC A,[m] Subtract Data Memory from ACC with Carry

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC – [m] – $\overline{C}$

Affected flag(s) OV, Z, AC, C

SBCM A,[m] Subtract Data Memory from ACC with Carry and result in Data Memory

Description The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC – [m] – $\overline{C}$

Affected flag(s) OV, Z, AC, C

SDZ [m] Skip if decrement Data Memory is 0

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] – 1
Skip if [m] = 0

Affected flag(s) None

SDZA [m] Skip if decrement Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation ACC ← [m] – 1
Skip if ACC = 0

Affected flag(s) None

SET [m] Set Data Memory

Description Each bit of the specified Data Memory is set to 1.

Operation [m] ← FFH

Affected flag(s) None

SET [m].i Set bit of Data Memory

Description Bit i of the specified Data Memory is set to 1.

Operation [m].i ← 1

Affected flag(s) None

SIZ [m] Skip if increment Data Memory is 0

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation [m] ← [m] + 1
Skip if [m] = 0

Affected flag(s) None

SIZA [m] Skip if increment Data Memory is zero with result in ACC

Description The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m] + 1
Skip if ACC = 0

Affected flag(s) None

SNZ [m].i Skip if bit i of Data Memory is not 0

Description If bit i of the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.

Operation Skip if [m].i ≠ 0

Affected flag(s) None

SUB A,[m] Subtract Data Memory from ACC

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC – [m]

Affected flag(s) OV, Z, AC, C

SUBM A,[m] Subtract Data Memory from ACC with result in Data Memory

Description The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation [m] ← ACC – [m]

Affected flag(s) OV, Z, AC, C

SUB A,x Subtract immediate data from ACC

Description The immediate data specified by the code is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.

Operation ACC ← ACC – x

Affected flag(s) OV, Z, AC, C

SWAP [m] Swap nibbles of Data Memory

Description The low-order and high-order nibbles of the specified Data Memory are interchanged.

Operation [m].3~[m].0 ↔ [m].7 ~ [m].4

Affected flag(s) None

SWAPA [m] Swap nibbles of Data Memory with result in ACC

Description The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.

Operation ACC.3 ~ ACC.0 ← [m].7 ~ [m].4
ACC.7 ~ ACC.4 ← [m].3 ~ [m].0

Affected flag(s) None

SZ [m] Skip if Data Memory is 0

Description If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation Skip if [m] = 0

Affected flag(s) None

SZA [m] Skip if Data Memory is 0 with data movement to ACC

Description The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.

Operation ACC ← [m]
Skip if [m] = 0

Affected flag(s) None

SZ [m].i Skip if bit i of Data Memory is 0

Description If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.

Operation Skip if [m].i = 0

Affected flag(s) None

TABRDC [m] Read table (current page) to TBLH and Data Memory

Description The low byte of the program code (current page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

TABRDL [m] Read table (last page) to TBLH and Data Memory

Description The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.

Operation [m] ← program code (low byte)
TBLH ← program code (high byte)

Affected flag(s) None

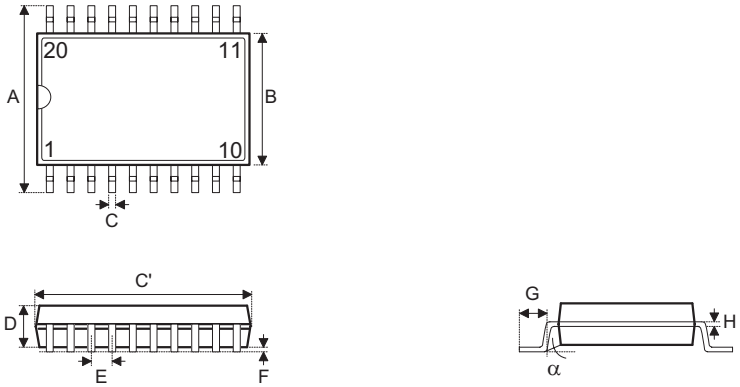
XOR A,[m]	Logical XOR Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″XOR″ [m]
Affected flag(s)	Z

XORM A,[m]	Logical XOR ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.
Operation	[m] ← ACC ″XOR″ [m]
Affected flag(s)	Z

XOR A,x	Logical XOR immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bitwise logical XOR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC ″XOR″ x
Affected flag(s)	Z

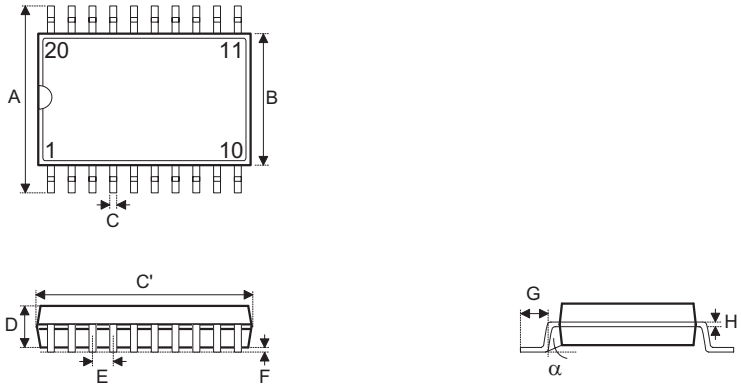
Package Information

20-pin SSOP (150mil) Outline Dimensions



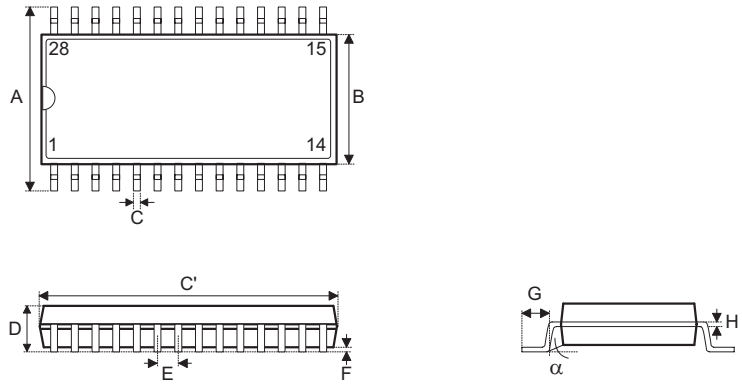
Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	228	—	244
B	150	—	158
C	8	—	12
C′	335	—	347
D	49	—	65
E	—	25	—
F	4	—	10
G	15	—	50
H	7	—	10
α	0°	—	8°

20-pin SSOP (209mil) Outline Dimensions



Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	291	—	323
B	196	—	220
C	9	—	15
C′	271	—	295
D	65	—	73
E	—	25.59	—
F	4	—	10
G	26	—	34
H	4	—	8
α	0°	—	8°

28-pin SOP (300mil) Outline Dimensions

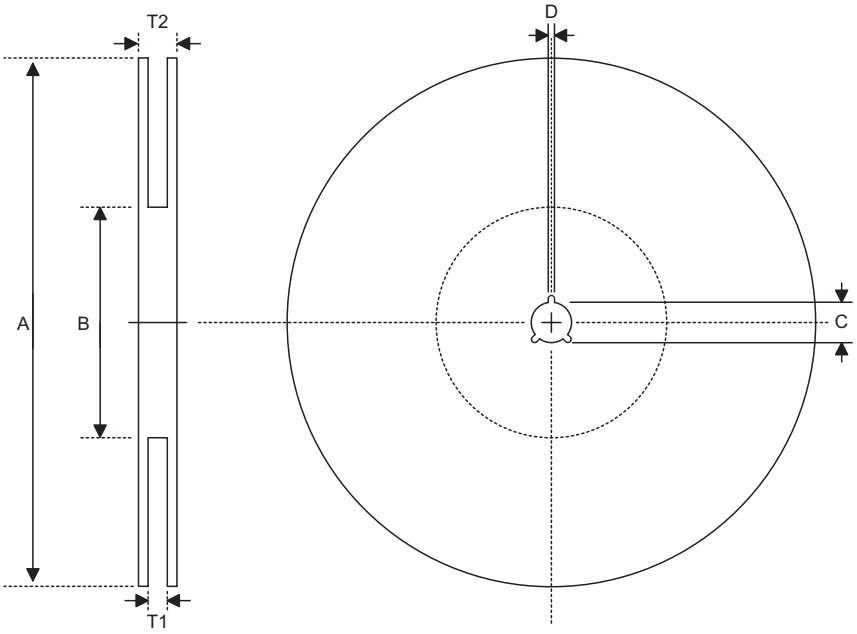


- MS-013

Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	393	—	419
B	256	—	300
C	12	—	20
C′	697	—	713
D	—	—	104
E	—	50	—
F	4	—	12
G	16	—	50
H	8	—	13
α	0°	—	8°

Product Tape and Reel Specifications

Reel Dimensions



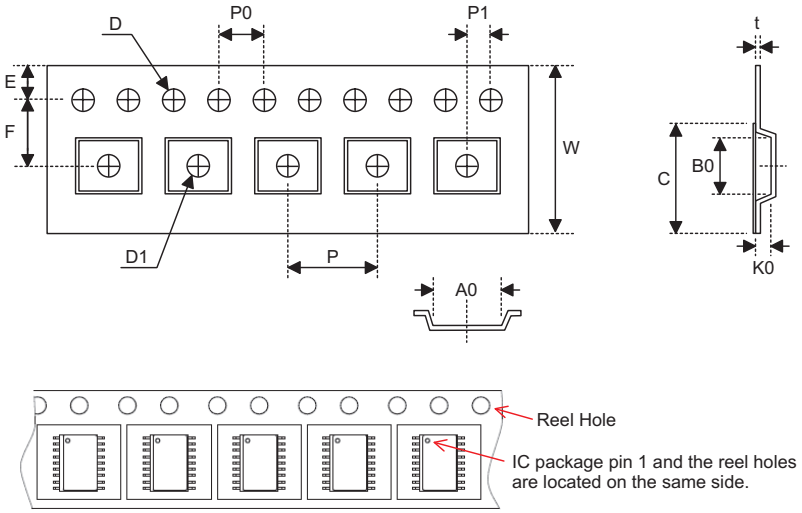
SSOP 20S (150mil), SSOP 20N (209mil)

Symbol	Description	Dimensions in mm
A	Reel Outer Diameter	330.0±1.0
B	Reel Inner Diameter	100.0±1.5
C	Spindle Hole Diameter	$13.0^{+0.5/-0.2}$
D	Key Slit Width	2.0±0.5
T1	Space Between Flange	$16.8^{+0.3/-0.2}$
T2	Reel Thickness	22.2±0.2

SOP 28W (300mil)

Symbol	Description	Dimensions in mm
A	Reel Outer Diameter	330.0±1.0
B	Reel Inner Diameter	100.0±1.5
C	Spindle Hole Diameter	$13.0^{+0.5/-0.2}$
D	Key Slit Width	2.0±0.5
T1	Space Between Flange	$24.8^{+0.3/-0.2}$
T2	Reel Thickness	30.2±0.2

Carrier Tape Dimensions



SSOP 20S (150mil)

Symbol	Description	Dimensions in mm
W	Carrier Tape Width	$16.0^{+0.3/-0.1}$
P	Cavity Pitch	8.0±0.1
E	Perforation Position	1.75±0.10
F	Cavity to Perforation (Width Direction)	7.5±0.1
D	Perforation Diameter	$1.5^{+0.1/-0.0}$
D1	Cavity Hole Diameter	$1.50^{+0.25/-0.00}$
P0	Perforation Pitch	4.0±0.1
P1	Cavity to Perforation (Length Direction)	2.0±0.1
A0	Cavity Length	6.5±0.1
B0	Cavity Width	9.0±0.1
K0	Cavity Depth	2.3±0.1
t	Carrier Tape Thickness	0.30±0.05
C	Cover Tape Width	13.3±0.1

SSOP 20N (209mil)

Symbol	Description	Dimensions in mm
W	Carrier Tape Width	$16.0^{+0.3/-0.1}$
P	Cavity Pitch	12.0±0.1
E	Perforation Position	1.75±0.10
F	Cavity to Perforation (Width Direction)	7.5±0.1
D	Perforation Diameter	$1.5^{+0.1/-0.0}$
D1	Cavity Hole Diameter	$1.50^{+0.25/-0.00}$
P0	Perforation Pitch	4.0±0.1
P1	Cavity to Perforation (Length Direction)	2.0±0.1
A0	Cavity Length	7.1±0.1
B0	Cavity Width	7.2±0.1
K0	Cavity Depth	2.0±0.1
t	Carrier Tape Thickness	0.30±0.05
C	Cover Tape Width	13.3±0.1

SOP 28W (300mil)

Symbol	Description	Dimensions in mm
W	Carrier Tape Width	24.0±0.3
P	Cavity Pitch	12.0±0.1
E	Perforation Position	1.75±0.10
F	Cavity to Perforation (Width Direction)	11.5±0.1
D	Perforation Diameter	$1.5^{+0.1/-0.0}$
D1	Cavity Hole Diameter	$1.50^{+0.25/-0.00}$
P0	Perforation Pitch	4.0±0.1
P1	Cavity to Perforation (Length Direction)	2.0±0.1
A0	Cavity Length	10.85±0.10
B0	Cavity Width	18.34±0.10
K0	Cavity Depth	2.97±0.10
t	Carrier Tape Thickness	0.35±0.01
C	Cover Tape Width	21.3±0.1