

Technical Document

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Features

- Operating voltage:
f_{SYS}=4MHz: 2.2V~5.5V
f_{SYS}=8MHz: 3.3V~5.5V
- Low voltage reset function
- 56 bidirectional I/O lines (max.)
- Two interrupt input
- 16-bit×2 programmable timer/event counter and overflow interrupts with PFD outputs
- 8-bit×1 programmable timer/event counter
- On-chip RC oscillator, external crystal and RC oscillator
- 32768Hz crystal oscillator for timing purposes only
- Watchdog Timer
- 16K×16 program memory ROM
- 576×8 data memory RAM
- Universal Asynchronous Receiver/Transmitter (UART)
- HALT function and wake-up feature reduce power consumption
- 16-level subroutine nesting
- Up to 0.5μs instruction cycle with 8MHz system clock at V_{DD}=5V
- Bit manipulation instruction
- 16-bit table read instruction
- 63 powerful instructions
- All instructions in one or two machine cycles
- 48-pin SSOP, 64-pin LQFP package

General Description

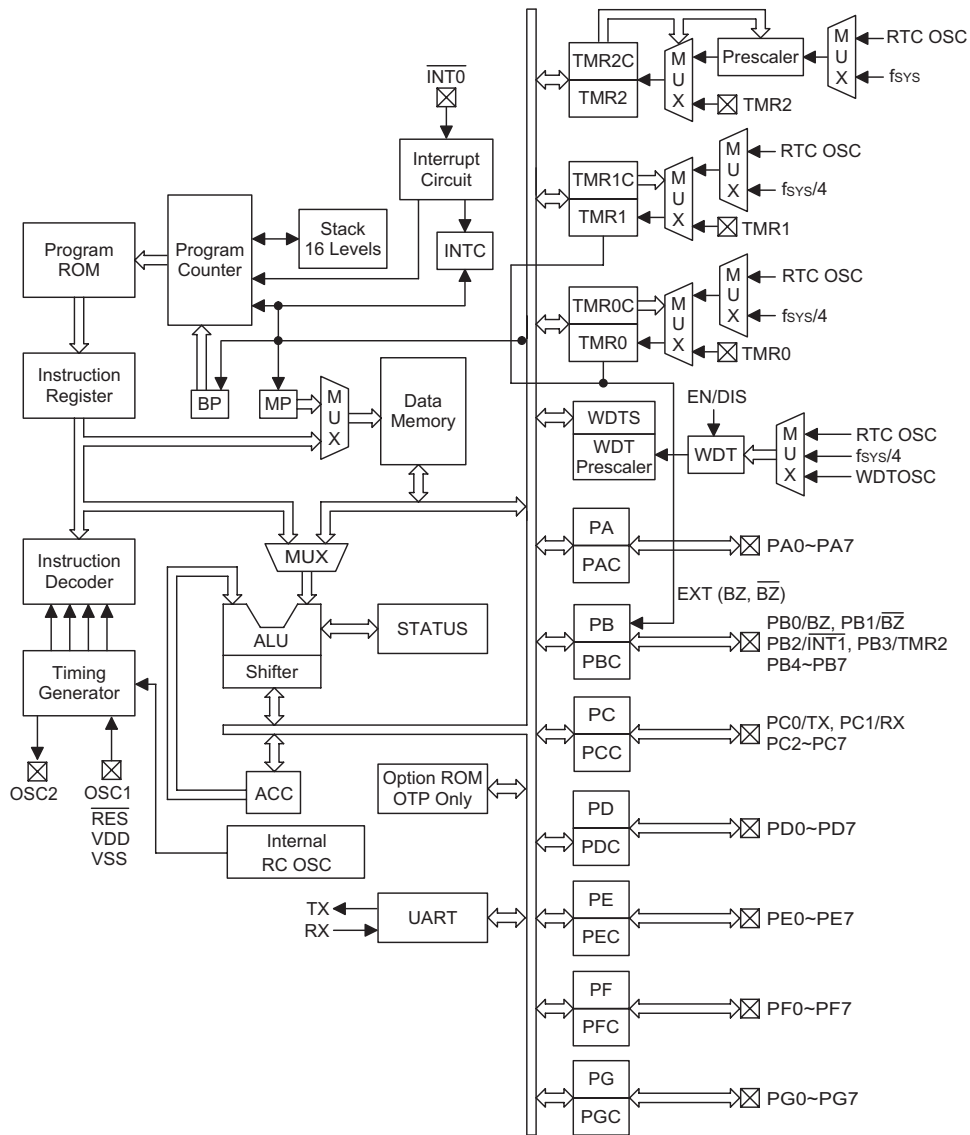
The HT48RU80/HT48CU80 are 8-bit high performance, RISC architecture microcontroller devices specifically designed for multiple I/O control product applications. The mask version HT48CU80 is fully pin and functionally compatible with the OTP version HT48RU80 device.

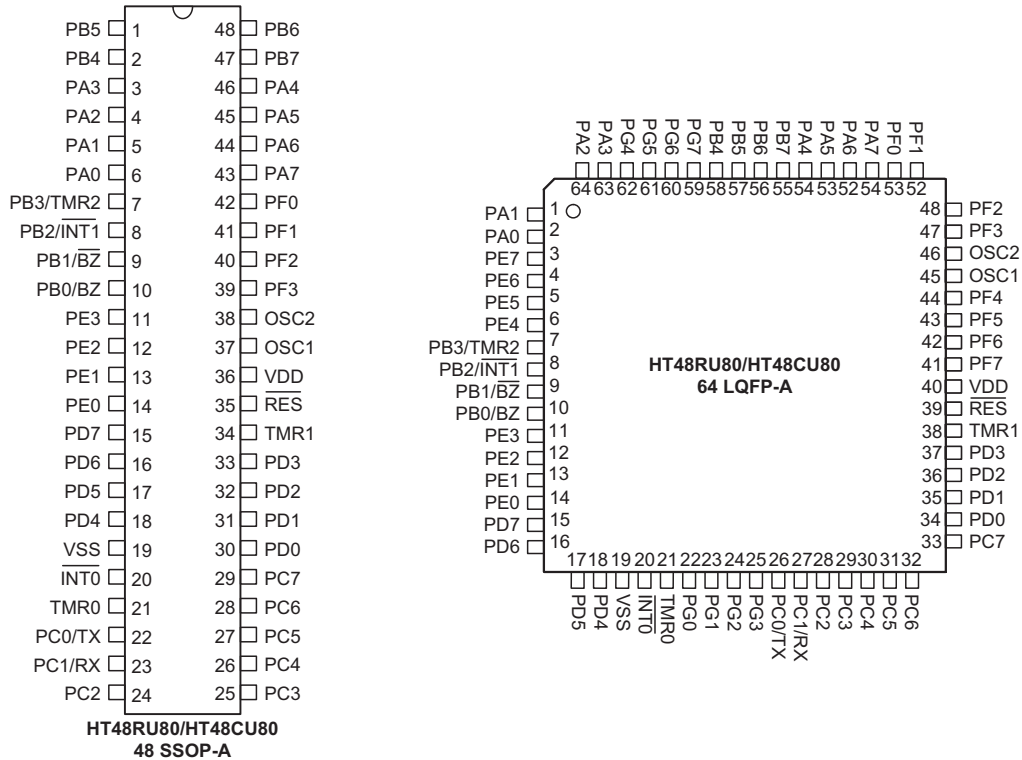
The advantages of low power consumption, I/O flexibility, timer functions, oscillator options, HALT and

wake-up functions, watchdog timer, buzzer driver, as well as low cost, enhance the versatility of these devices to suit a wide range of application possibilities such as industrial control, consumer products, subsystem controllers, etc.

The HT48CU80 is under development and will be available soon.

Block Diagram



Pin Assignment

Pin Description

Pin Name	I/O	Options	Description
PA0~PA7	I/O	Pull-high Wake-up Schmitt Trigger	Bidirectional 8-bit input/output port. Each bit can be configured as a wake-up input by configuration option. Software instructions determine if the pin is a CMOS output or input. Configuration options determine if all pins on this port have pull-high resistors and if the inputs are Schmitt trigger or non Schmitt trigger.
PB0/BZ PB1/BZ PB2/INT1 PB3/TMR2 PB4~PB7 PC0/TX PC1/RX PC2~PC7 PD0~PD7 PE0~PE7 PF0~PF7 PG0~PG7	I/O	Pull-high I/O or BZ/BZ	Bidirectional 8-bit input/output ports. Software instructions determine if the pin is a CMOS output or Schmitt trigger input. A configuration option for each port determines if all pins on the relevant port have pull-high resistors. Pins PB0, PB1, PB2 and PB3 are pin-shared with BZ, BZ, INT1 and TMR2, respectively. Pins PC0 and PC1 are pin-shared with the UART pins TX and RX.
INT0	I	—	External interrupt Schmitt trigger input. Edge triggered on high to low transition.
TMR0	I	—	Schmitt trigger input for Timer/Event Counter 0
TMR1	I	—	Schmitt trigger input for Timer/Event Counter 1

Pin Name	I/O	Options	Description
OSC1 OSC2	I O	Crystal or RC or Int. RC+RTC	OSC1, OSC2 are connected to an external RC network or external Crystal (determined by configuration option) for the internal system clock. For external RC system clock operation, OSC2 is an output pin for 1/4 system clock. These two pins also can be optioned as an RTC oscillator (32768Hz). In this case, the system clock comes from an internal RC oscillator whose nominal frequency at 5V has 4 options, 3.2MHz, 1.6MHz, 800kHz, 400kHz.
RES	I	—	Schmitt trigger reset input. Active low.
VDD	—	—	Positive power supply
VSS	—	—	Negative power supply, ground.

Note: Each pin on PA can be programmed through a configuration option to have a wake-up function.

Individual pins cannot be selected to have pull-high resistors. If the pull-high configuration is chosen for a particular port, then all input pins on this port will be connected to pull-high resistors.

Pins PE4~PE7 and pins PF4~PF7 only exist on the 64-pin package.

Port G only exists on the 64-pin package.

Absolute Maximum Ratings

Supply Voltage	$V_{SS}-0.3V$ to $V_{SS}+6.0V$	Storage Temperature	$-50^{\circ}C$ to $125^{\circ}C$
Input Voltage	$V_{SS}-0.3V$ to $V_{DD}+0.3V$	Operating Temperature	$-40^{\circ}C$ to $85^{\circ}C$
I_{OL} Total	150mA	I_{OH} Total	$-100mA$
Total Power Dissipation	500mW		

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

$T_a=25^{\circ}C$

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	$f_{SYS}=4MHz$	2.2	—	5.5	V
		—	$f_{SYS}=8MHz$	3.3	—	5.5	V
I_{DD1}	Operating Current (Crystal OSC)	3V	No load, $f_{SYS}=4MHz$, UART disable	—	0.6	1.5	mA
		5V	—	—	2	4	mA
I_{DD2}	Operating Current (RC OSC)	3V	No load, $f_{SYS}=4MHz$, UART disable	—	0.8	1.5	mA
		5V	—	—	2.5	4	mA
I_{DD3}	Operating Current (Crystal OSC, RC OSC)	3V	No load, $f_{SYS}=4MHz$, UART On	—	1.5	3	mA
		5V	—	—	3	6	mA
I_{DD4}	Operating Current (Crystal OSC, RC OSC)	5V	No load, $f_{SYS}=8MHz$, UART Off	—	3	5	mA
I_{DD5}	Operating Current (Crystal OSC, RC OSC)	5V	No load, $f_{SYS}=8MHz$, UART On	—	5	10	mA
I_{STB1}	Standby Current (WDTOSC On, RTC Off)	3V	No load, system HALT	—	—	5	μA
		5V	—	—	—	10	μA
I_{STB2}	Standby Current (WDTOSC Off, RTC Off)	3V	No load, system HALT	—	—	1	μA
		5V	—	—	—	2	μA

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V _{DD}	Conditions				
I _{STB3}	Standby Current (WDTOSC Off, RTC On)	3V	No load, system HALT	—	—	5	μA
		5V		—	—	10	μA
V _{IL1}	Input Low Voltage for I/O Ports	—	—	0	—	0.3V _{DD}	V
V _{IH1}	Input High Voltage for I/O Ports	—	—	0.7V _{DD}	—	V _{DD}	V
V _{IL2}	Input Low Voltage ($\overline{\text{RES}}$)	—	—	0	—	0.4V _{DD}	V
V _{IH2}	Input High Voltage ($\overline{\text{RES}}$)	—	—	0.9V _{DD}	—	V _{DD}	V
V _{LVR}	Low Voltage Reset	—	LVRenabled	2.7	3.0	3.3	V
I _{OL}	I/O Port Sink Current	3V	V _{OL} =0.1V _{DD}	4	8	—	mA
		5V	V _{OL} =0.1V _{DD}	10	20	—	mA
I _{OH}	I/O Port Source Current	3V	V _{OH} =0.9V _{DD}	-2	-4	—	mA
		5V	V _{OH} =0.9V _{DD}	-5	-10	—	mA
R _{PH}	Pull-high Resistance	3V	—	20	60	100	kΩ
		5V		10	30	50	kΩ

A.C. Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V _{DD}	Conditions				
f _{SYS1}	System Clock (Crystal OSC)	—	2.2V~5.5V	400	—	4000	kHz
		—	3.3V~5.5V	400	—	8000	kHz
f _{SYS2}	System Clock (RC OSC)	—	2.2V~5.5V	400	—	4000	kHz
		—	3.3V~5.5V	400	—	8000	kHz
f _{SYS3}	System Clock (Internal RC OSC)	5V	3.2MHz	1800	—	5400	kHz
			1.6MHz	900	—	2700	kHz
			800kHz	450	—	1350	kHz
			400kHz	225	—	675	kHz
f _{TIMER}	Timer I/P Frequency (TMR)	—	2.2V~5.5V	0	—	4000	kHz
		—	3.3V~5.5V	0	—	8000	kHz
t _{WDTOSC}	Watchdog Oscillator Period	3V	—	45	90	180	μs
		5V	—	32	65	130	μs
t _{WDT1}	Watchdog Time-out Period (WDT OSC)	3V	Without WDT prescaler	11	23	46	ms
		5V		8	17	33	ms
t _{WDT2}	Watchdog Time-out Period (System Clock)	—	Without WDT prescaler	—	1024	—	t _{sys}
t _{WDT3}	Watchdog Time-out Period (RTC OSC)	—	Without WDT prescaler	—	7.812	—	ms
t _{RES}	External Reset Low Pulse Width	—	—	1	—	—	μs
t _{SST}	System Start-up Timer Period	—	Wake-up from HALT	—	1024	—	t _{sys}
t _{INT}	Interrupt Pulse Width	—	—	1	—	—	μs

Functional Description

Execution Flow

The system clock for the microcontroller is derived from either a crystal or an RC oscillator. The system clock 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 an instruction cycle while decoding and execution takes the next instruction cycle. However, the pipelining scheme causes each instruction to be effectively executed in a cycle. If an instruction changes the program counter, two cycles are required to complete the instruction.

Program Counter – PC

The program counter (PC) controls the sequence in which the instructions stored in the program ROM are executed and its contents specify a full range of program memory.

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 register, subroutine call or return from subroutine, initial reset, internal interrupt, external interrupt or return from interrupts, the PC manages the program transfer by loading the address corresponding to each instruction.

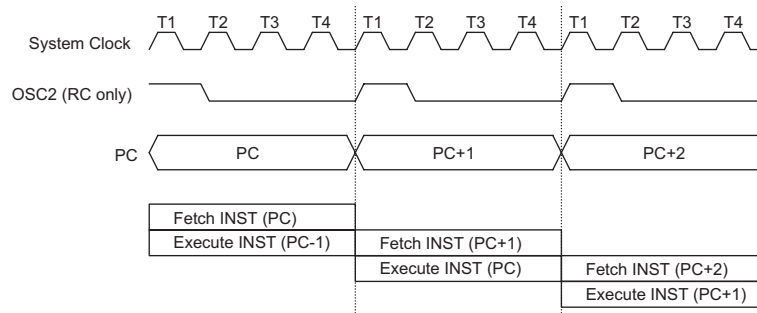
The conditional skip is activated by instructions. Once the condition is met, the next instruction, fetched during the current instruction execution, is discarded and a dummy cycle replaces it to get the proper instruction. Otherwise proceed with the next instruction.

The lower byte of the program counter (PCL) is a readable and writeable register (06H). Moving data into the PCL performs a short jump. The destination will be within the current program ROM page.

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

Program Memory – ROM

The program memory is used to store the program instructions which are to be executed. It also contains data, table, and interrupt entries, and is organized into



Execution Flow

Mode	Program Counter													
	*13	*12	*11	*10	*9	*8	*7	*6	*5	*4	*3	*2	*1	*0
Initial Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External Interrupt 0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Timer/Event Counter 0 Overflow	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Timer/Event Counter 1 Overflow	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Timer/Event Counter 2 Overflow	0	0	0	0	0	0	0	0	0	1	1	0	0	0
External Interrupt 1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
UART Interrupt	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Skip	Program Counter+2													
Loading PCL	*13	*12	*11	*10	*9	*8	@7	@6	@5	@4	@3	@2	@1	@0
Jump, Call Branch	BP.5	#12	#11	#10	#9	#8	#7	#6	#5	#4	#3	#2	#1	#0
Return (RET, RETI)	S13	S12	S11	S10	S9	S8	S7	S6	S5	S4	S3	S2	S1	S0

Program Counter

Note: *13~*0: Program counter bits
#13~#0: Instruction code bits

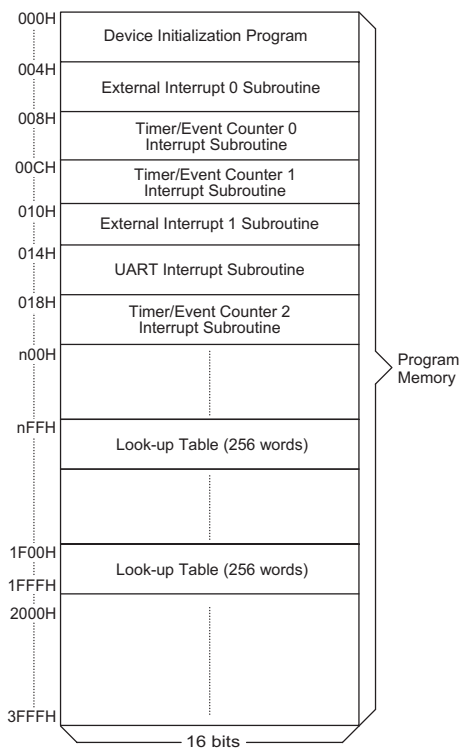
S13~S0: Stack register bits
@7~@0: PCL bits

8192×16 bits×2 banks, addressed by the Program Counter and table pointer.

The BP register bit5 is used to select the ROM bank. When the BP's bit5=0, the ROM bank 0 ranges from 0000H to 1FFFH. When the BP's bit5=1, the ROM bank1 ranges from 2000H to 3FFFH.

The "CALL" and "JMP" instruction provide only 13 bits of address to allow branching within any 8K program memory bank. When doing a "CALL" or "JMP" instruction, the upper 1 bit of the address is provided by BP5. When doing a "CALL" or "JMP" instruction, user must ensure that the bank select bit is programmed so that the desired program memory bank is addressed. If a return from "CALL" instruction (or interrupt) is executed, the entire 14-bit Program Counter is popped off the stack.

Certain locations in the program memory are reserved for special usage:



Note: n ranges from 0 to 3F

Program Memory

- Location 000H
This area is reserved for program initialization. After a chip reset, the program always begins execution at location 000H.
- Location 004H
This area is reserved for the external interrupt 0 service program. If the $\overline{INT0}$ interrupt pin is activated, the interrupt enabled and the stack is not full, the program begins execution at location 004H.
- Location 008H
This area is reserved for the Timer/Event Counter 0 interrupt service program. If a timer interrupt results from a Timer/Event Counter 0 overflow, and if the interrupt is enabled and the stack is not full, the program begins execution at location 008H.
- Location 00CH
This location is reserved for the Timer/Event Counter 1 interrupt service program. If a timer interrupt results from a Timer/Event Counter 1 overflow, and the interrupt is enabled and the stack is not full, the program begins execution at location 00CH.
- Location 010H
This area is reserved for the external interrupt 1 service program. If the $\overline{INT1}$ interrupt pin is activated, the interrupt enabled and the stack is not full, the program begins execution at location 010H.
- Location 014H
This area is reserved for the UART interrupt service program. If a UART interrupt results from a UART TX or RX, and the interrupt is enabled and the stack is not full, the program begins execution at location 014H.
- Location 018H
This location is reserved for the Timer/Event Counter 2 interrupt service program. If a timer interrupt results from a Timer/Event Counter 2 overflow, and the interrupt is enabled and the stack is not full, the program begins execution at location 018H.
- Table location
Any location in the ROM can be used as a look-up table. The instructions "TABRDC [m]" (page specified by TBHP) and "TABRDL [m]" (the last page) transfer the contents of the lower-order byte to the specified data memory, and the contents of the higher-order byte to TBLH (Table Higher-order byte register) (08H).

Instruction	Table Location								
	*13~*8	*7	*6	*5	*4	*3	*2	*1	*0
TABRDC [m]	TBHP	@7	@6	@5	@4	@3	@2	@1	@0
TABRDL [m]	111111	@7	@6	@5	@4	@3	@2	@1	@0

Table Location

Note: *13~*0: Table location bits
@7~@0: Table pointer bits

TBHP: Table pointer higher-order bits

Only the destination of the lower-order byte in the table is well-defined; the other bits of the table word are all transferred to the lower portion of TBLH. The TBLH is read only, the higher-order byte table pointer TBHP (1FH) and the lower-order byte table pointer TBLP (07H) are read/write registers, indicating the table location. Before accessing the table, the location the location has to be placed in TBHP and TBLP. All the table related instructions require 2 cycles to complete the operation. These areas may function as a normal ROM depending upon the user's requirements.

Stack Register – STACK

This is a special part of the memory which is used to save the contents of the program counter only. The stack is organized into 16 levels and is neither part of the data nor part of the program space, and is neither readable nor writeable. The activated level is indexed by the stack pointer (SP) and is neither readable nor writeable. At a subroutine call or interrupt acknowledge signal, the contents of the program counter are pushed onto the stack. At the end of a subroutine or an interrupt routine, signaled by a return instruction (RET or RETI), the program counter is restored to its previous value from the stack. After a chip reset, the SP will point to the top of the stack.

If the stack is full and a non-masked interrupt takes place, the interrupt request flag will be recorded but the acknowledge signal will be inhibited. When the stack pointer is decremented (by RET or RETI), the interrupt will be serviced. This feature prevents stack overflow allowing the programmer 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 will be lost (only the most recent 16 return addresses are stored).

Data Memory – RAM

The data memory (RAM) is designed with 617×8 bits, and is divided into two functional groups, namely, special function registers and general purpose data memory (192×8bits×3banks), most of which are readable/writeable, although some are read only.

[BP REG] Bit1~Bit0	RAM Bank
00	0
01	1
10	2

The special function registers consist of an Indirect addressing register 0 (IAR0;00H), a Memory pointer register 0 (MP0;01H), an Indirect addressing register 1 (IAR1;02H), a Memory pointer register 1 (MP1;03H), a

Bank pointer (BP;04H), an Accumulator (ACC;05H), a Program counter lower-order byte register (PCL;06H), a lower-order byte table pointer (TBLP;07H), a Table higher-order byte register (TBLH;08H), a Watchdog Timer option setting register (WDTS;09H), a Status register (STATUS;0AH), an Interrupt control register 0 (INTC0;0BH), a Timer/Event Counter 0 higher order byte register (TMR0H;0CH), a Timer/Event Counter 0 lower order byte register (TMR0L;0DH), a Timer/Event Counter 0 control register (TMR0C;0EH), a Timer/Event Counter 1 higher order byte register (TMR1H;0FH), a Timer/Event Counter 1 lower order byte register (TMR1L;10H), a Timer/Event Counter 1 control register (TMR1C;11H), I/O registers (PA;12H, PB;14H, PC;16H, PD;18H, PE;1AH, PF;1CH, PG;25H) and I/O control registers (PAC;13H, PBC;15H, PCC;17H, PDC;19H, PEC;1BH, PFC;1DH, PGC;26H), a Timer/Event Counter 2 (TMR2;21H), a Timer/Event Counter 2 control register (TMR2C;22H), a higher-order byte table pointer (TBHP;1FH), an Interrupt control register 1 (INTC1;1EH), a UART Status register (USR;28H), a UART Control register 1 (UCR1;29H), a UART Control register 2 (UCR2;2AH), a UART TX/RX Buffer register (TXR/RXR;2BH), and a UART Baud Rate generator prescaler register (BRG;2CH). On the other hand, the general purpose data memory, addressed from 40H to FFH (bank0~2), is used for data and control information under instruction commands.

All of the data memory areas can handle arithmetic, logic, increment, decrement and rotate operations directly. Except for some dedicated bits, each bit in the data memory can be set and reset by "SET [m].i" and "CLR [m].i". They are also indirectly accessible through memory pointer registers (MP0 or MP1).

Indirect Addressing Register


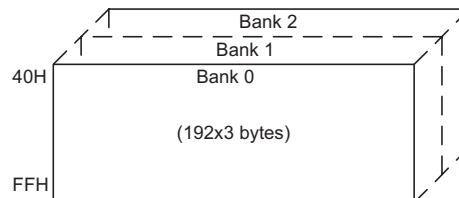
Location 00H and 02H are indirect addressing registers that are not physically implemented. Any read/write operation of [00H] ([02H]) will access data memory pointed to by MP0 (MP1). Reading location 00H (02H) itself indirectly will return the result 00H. Writing indirectly results in no operation. The memory pointer registers (MP0 and MP1) are 8-bit registers.

Accumulator – ACC

The accumulator is closely related to ALU operations. It is also mapped to location 05H of the data memory and can carry out immediate data operations. The data movement between two data memory locations must pass through the accumulator.

00H	Indirect Addressing Register 0
01H	MP0
02H	Indirect Addressing Register 1
03H	MP1
04H	BP
05H	ACC
06H	PCL
07H	TBLP
08H	TBLH
09H	WDT5
0AH	STATUS
0BH	INTC0
0CH	TMR0H
0DH	TMR0L
0EH	TMR0C
0FH	TMR1H
10H	TMR1L
11H	TMR1C
12H	PA
13H	PAC
14H	PB
15H	PBC
16H	PC
17H	PCC
18H	PD
19H	PDC
1AH	PE
1BH	PEC
1CH	PF
1DH	PFC
1EH	INTC1
1FH	TBHP
20H	
21H	TMR2
22H	TMR2C
23H	
24H	
25H	PG
26H	PGC
27H	
28H	USR
29H	UCR1
2AH	UCR2
2BH	TXR/RXR
2CH	BRG

Special Function Registers

 : Unused, Read as "00"


General Purpose Data Memory

RAM Mapping

Arithmetic and Logic Unit – ALU

This circuit performs 8-bit arithmetic and logic operations. The ALU 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)

The ALU not only saves the results of a data operation but also changes the status register.

Status Register – STATUS

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

With the exception of the TO and PDF flags, bits in the status register can be altered by instructions like most other registers. Any data written into the status register will not change the TO or PDF flag. In addition, operations related to the status register may

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 logic 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 a system power-up or executing the "CLR WDT" instruction. PDF is set by executing the "HALT" instruction.
5	TO	TO is cleared by a 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

give different results from those intended. The TO flag can be affected only by a system power-up, a WDT time-out or executing the "CLR WDT" or "HALT" instruction. The PDF flag can be affected only by executing the "HALT" or "CLR WDT" instruction or during a system power-up.

The Z, OV, AC and C flags generally reflect the status of the latest operations.

In addition, on entering the interrupt sequence or executing a subroutine call, the status register will not be pushed onto the stack automatically. If the contents of the status are important and if the subroutine can corrupt the status register, precautions must be taken to save it properly.

Interrupt

The device provides two external interrupts, three internal timer/event counter interrupts, and a UART TX/ RX interrupt. The Interrupt Control Register 0 (INTC0; 0BH) and Interrupt Control Register 1 (INTC1; 1EH) both contain the interrupt control bits that are used to set the enable/disable status and interrupt request flags.

Once an interrupt subroutine is serviced, all the other interrupts will be blocked (by clearing the EMI bit). This scheme may prevent any further interrupt nesting. Other interrupt requests may occur during this interval but only the interrupt request flag is recorded. If a certain interrupt requires servicing within the service routine, the EMI bit and the corresponding bit of the INTC0 or INTC1 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 SP is decremented. If immediate service is desired, the stack must be prevented from becoming full.

All these kinds of interrupts have a wake-up capability. As an interrupt is serviced, a control transfer occurs by pushing the program counter onto the stack, followed by a branch to a subroutine at specified location in the pro-

gram memory. Only the program counter is pushed onto the stack. If the contents of the register or status register (STATUS) are altered by the interrupt service program which corrupts the desired control sequence, the contents should be saved in advance.

External interrupts are triggered by a high to low transition of the INT0 or INT1 and the related interrupt request flag (EIF0; bit 4 of the INTC0; EIF1; bit 4 of the INTC1) will be set. When the interrupt is enabled, the stack is not full and the external interrupt is active, a subroutine call to location 04H or 10H will occur. The interrupt request flag (EIF0 or EIF1) and EMI bits will be cleared to disable other interrupts.

The internal Timer/Event Counter 0 interrupt is initialized by setting the Timer/Event Counter 0 interrupt request flag (T0F; bit 5 of the INTC0), caused by a timer 0 overflow. When the interrupt is enabled, 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/Event Counter 1 interrupt is initialized by setting the Timer/Event Counter 1 interrupt request flag (T1F; bit 6 of the INTC0), caused by a T 1 overflow. When the interrupt is enabled, the stack is not full and the T1F 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.

The UART interrupt is initialized by setting the interrupt request flag (URF; bit 5 of the INTC1), that is caused by a regular UART receive signal, caused by a UART transmit signal. After the interrupt is enabled, the stack is not full, and the URF bit is set, a subroutine call to location 14H occurs. The related interrupt request flag (URF) is reset and the EMI bit is cleared to disable further other interrupts.

Bit No.	Label	Function
0	EMI	Controls the master (global) interrupt (1= enable; 0= disable)
1	EEI0	Controls the external interrupt 0 (1= enable; 0= disable)
2	ET0I	Controls the Timer/Event Counter 0 interrupt (1= enable; 0= disable)
3	ET1I	Controls the Timer/Event Counter 1 interrupt (1= enable; 0= disable)
4	EIF0	External interrupt 0 request flag (1= active; 0= inactive)
5	T0F	Internal Timer/Event Counter 0 request flag (1= active; 0= inactive)
6	T1F	Internal Timer/Event Counter 1 request flag (1= active; 0= inactive)
7	—	Unused bit, read as "0"

INTC0 (0BH) Register

Bit No.	Label	Function
0	EEI1	Controls the external interrupt 1 (1= enable; 0= disable)
1	EURI	Controls the UART TX or RX interrupt (1= enable; 0= disable)
2	ET2I	Controls the Timer/Event Counter 2 overflow interrupt (1= enable; 0= disable)
3, 7	—	Unused bit, read as "0"
4	EIF1	External interrupt 1 request flag (1= active; 0= inactive)
5	URF	UART TX or RX interrupt request flag (1= active; 0= inactive)
6	T2F	Timer/Event Counter 2 overflow request flag (1= active; 0= inactive)

INTC1 (1EH) Register

The internal Timer/Event Counter 2 interrupt is initialized by setting the Timer/Event Counter 2 interrupt request flag (T2F; bit 6 of the INTC1), caused by a T 2 overflow. When the interrupt is enabled, the stack is not full and the T2F is set, a subroutine call to location 18H will occur. The related interrupt request flag (T2F) will be reset and the EMI bit cleared to disable further interrupts.

During the execution of an interrupt subroutine, other interrupt acknowledge signals are held until the "RETI" instruction is executed or the EMI bit and the related interrupt control bit are set to 1 (if the stack is not full). To return from the interrupt subroutine, "RET" or "RETI" 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.

No.	Interrupt Source	Priority	Vector
a	External Interrupt 0	1	04H
b	Timer/Event Counter 0 Overflow	2	08H
c	Timer/Event Counter 1 Overflow	3	0CH
d	External Interrupt 1	4	010H
e	UART Interrupt	5	014H
f	Timer/Event Counter 2 Overflow Interrupt	6	018H

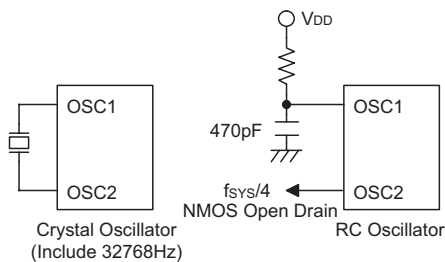
The Timer/Event Counter 0/1 interrupt request flag (T0F/T1F), external interrupt 0 request flag (EIF0), enable Timer/Event Counter 0/1 interrupt bit (ET0I/ET1I), enable external interrupt 0 bit (EEI0) and enable master interrupt bit (EMI) constitute an interrupt control register (INTC0) which is located at 0BH in the data memory. EMI, EEI0, ET0I and ET1I are used to control the enabling or disabling of interrupts. These bits prevent the requested interrupt from being serviced. Once the interrupt request flags (T0F, T1F, EIF0) are set, they will remain in the INTC0 register until the interrupts are serviced or cleared by a software instruction.

The External Interrupt 1 request flag (EIF1), UART interrupt request flag (URF), Timer/Event Counter 2 interrupt request flag (T2F), External Interrupt 1 bit (EEI1), and enable UART interrupt bit (EURI), enable Timer/Event Counter 2 interrupt bit (ET2I), constitute the Interrupt Control register 1 (INTC1) which is located at 1EH in the data memory. EEI1, EURI and ET2I are used to control the enabling or disabling of interrupts. These bits prevent the requested interrupt from being serviced. Once the interrupt request flags (EIF1, URF, T2F) are set, they will remain in the INTC1 register until the interrupts are serviced or cleared by a software instruction.

It is recommended that a program does not use the "CALL subroutine" within the 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 enabling the interrupt is not well controlled, the original control sequence will be damaged once the "CALL" operates in the interrupt subroutine.

Oscillator Configuration

There are three oscillator circuits in the microcontroller.



System Oscillator

All of them are designed for system clocks, namely, the external RC oscillator, the external Crystal oscillator and the internal RC oscillator, which are determined by options. No matter what oscillator type is selected, the signal provides the system clock. The HALT mode stops the system oscillator and ignores an external signal to conserve power.

If an RC oscillator is used, an external resistor between OSC1 and VDD is required and the resistance must range from 24kΩ to 1MΩ. The system clock, divided by 4, is available on OSC2, which can be used to synchronize external logic. The RC oscillator provides the most

cost effective solution. However, the frequency of oscillation may vary with VDD, temperatures and the chip itself due to process variations. It is, therefore, not suitable for timing sensitive operations where an accurate oscillator frequency is desired.

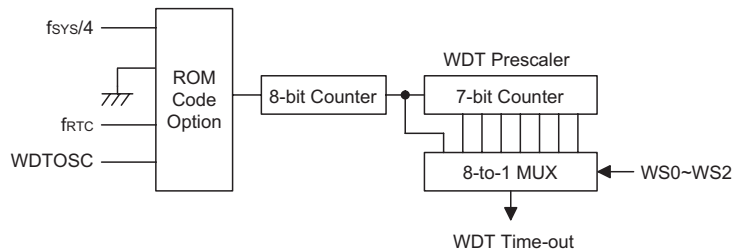
If the Crystal oscillator is used, a crystal across OSC1 and OSC2 is needed to provide the feedback and phase shift required for the oscillator. No other external components are required. In stead of a crystal, a resonator can also be connected between OSC1 and OSC2 to get a frequency reference, but two external capacitors in OSC1 and OSC2 are required. If the internal RC oscillator is used, the OSC1 and OSC2 can be selected as 32768Hz crystal oscillator (RTC OSC). Also, the frequencies of the internal RC oscillator can be 3.2MHz, 1.6MHz, 800kHz and 400kHz, depending on the options.

The WDT oscillator is a free running on-chip RC oscillator, and no external components are required. Even if the system enters the power down mode, the system clock is stopped, but the WDT oscillator still works within a period of approximately 65μs at 5V. The WDT oscillator can be disabled by options to conserve power.

Watchdog Timer – WDT

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

Once the internal WDT oscillator (RC oscillator with a period of 65μs at 5V normally) is selected, it is first divided by 256 (8-stage) to get the nominal time-out period of 17ms at 5V. This time-out period may vary with temperatures, VDD and process variations. By invoking the WDT prescaler, longer time-out periods can be realized. Writing data to WS2, WS1, WS0 (bits 2, 1, 0 of the WDTS) can give different time-out periods. If WS2, WS1, and WS0 are all equal to 1, the division ratio is up to 1:128, and the maximum time-out period is 2.1 seconds at 5V. If the WDT oscillator is disabled, the WDT



Watchdog Timer

clock may still come from the instruction clock and operates in the same manner except that in the HALT state the WDT may stop counting and lose its protecting purpose. In this situation the logic can only be restarted by external logic. The high nibbles and bit 3 of the WDTS are reserved for users defined flags, which can be used to indicate some specified status.

If the device operates in a noisy environment, using the on-chip RC oscillator (WDT OSC) or 32kHz crystal oscillator (RTC OSC) is strongly recommended, since the HALT will stop the system clock.

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 Register

The WDT overflow under normal operation will initialize a "chip reset" and set the status bit "TO". But in the HALT mode, the overflow will initialize a "warm reset" and only the Program Counter and SP are reset to zero. To clear the WDT contents (including the WDT prescaler), three methods are adopted; external reset (a low level to \overline{RES}), software instruction and a "HALT" instruction. The software instruction include "CLR WDT" and the other set – "CLR WDT1" and "CLR WDT2". Of these two types of instruction, only one can be active depending on the option – "CLR WDT times selection option". If the "CLR WDT" is selected (i.e. CLRWDT times equal one), any execution of the "CLR WDT" instruction will clear the WDT. In the case that "CLR WDT1" and "CLR WDT2" are chosen (i.e. CLRWDT times equal two), these two instructions must be executed to clear the WDT, otherwise, the WDT may reset the chip as a result of time-out.

Power Down Operation – HALT

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

- The system oscillator will be turned off but the WDT oscillator remains running (if the WDT oscillator is selected).
- The contents of the on chip RAM and registers remain unchanged.
- The WDT and WDT prescaler will be cleared and re-counted again (if the WDT clock is from the WDT oscillator).

- All of the 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". After the TO and PDF flags are examined, the cause for a chip reset can be determined. The PDF flag is cleared by a system power-up or executing the "CLR WDT" instruction and is set when executing the "HALT" instruction. The TO flag is set if the WDT time-out occurs, and causes a wake-up that only resets the Program Counter and SP; the others remain in 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 options. Awakening from an I/O port stimulus, the program will resume execution of the next instruction. If it awakens from an interrupt, two sequence may occur. If the related interrupt is disabled or the interrupt is enabled but 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. 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. Once a wake-up event occurs, it takes $1024 t_{SYS}$ (system clock period) to resume normal operation. In other words, a dummy period will be inserted after a wake-up. If the wake-up results from an interrupt acknowledge signal, the actual interrupt subroutine execution will be delayed by one or more cycles. If the wake-up results in the next instruction execution, this will be executed immediately after the dummy period is finished.

To minimize power consumption, all the I/O pins should be carefully managed before entering the HALT status. The RTC oscillator still runs in the HALT mode (if the RTC oscillator is enabled).

Reset

There are three ways in which a reset can occur:

- \overline{RES} reset during normal operation
- \overline{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 other reset conditions. Most registers are reset to the "initial condition" when the reset conditions are met. By examining the PDF and TO flags, 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"

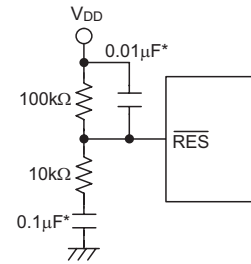
To guarantee that the system oscillator is started and stabilized, the SST (System Start-up Timer) provides an extra delay of 1024 system clock pulses when the system resets (power-up, WDT time-out or $\overline{\text{RES}}$ reset) or the system awakes from the HALT state.

When a system reset occurs, the SST delay is added during the reset period. Any wake-up from HALT will enable the SST delay.

An extra option load time delay is added during system reset (power-up, WDT time-out at normal mode or $\overline{\text{RES}}$ reset).

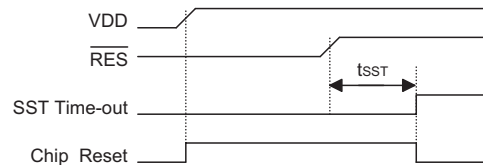
The functional unit chip reset status are shown below.

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

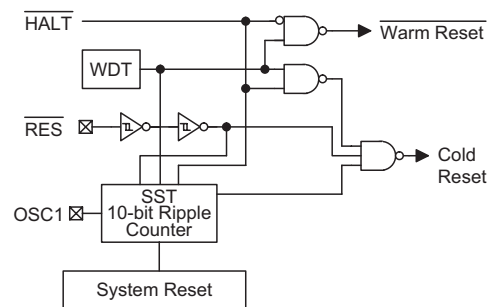


Reset Circuit

Note: "*" Make the length of the wiring, which is connected to the $\overline{\text{RES}}$ pin as short as possible, to avoid noise interference.



Reset Timing Chart



Reset Configuration

The states of the registers are summarized in the following table.

Register	Reset (Power On)	WDT Time-out (Normal Operation)	RES Reset (Normal Operation)	RES Reset (HALT)	WDT Time-out (HALT)*
TMR0H	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
TMR0L	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
TMR0C	00-0 1---	00-0 1---	00-0 1---	00-0 1---	uu-u u---
TMR1H	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
TMR1L	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
TMR1C	00-0 1---	00-0 1---	00-0 1---	00-0 1---	uu-u u---
TMR2	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
TMR2C	00-0 1000	00-0 1000	00-0 1000	00-0 1000	uu-u uuuu
Program Counter	000H	000H	000H	000H	000H
MP0	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
MP1	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
BP	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
ACC	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLP	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLH	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBHP	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu	uuuu uuuu
STATUS	--00 xxxx	--1u uuuu	--uu uuuu	--01 uuuu	--11 uuuu
INTC0	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
INTC1	-000 -000	-000 -000	-000 -000	-000 -000	-uuu -uuu
WDTS	0000 0111	0000 0111	0000 0111	0000 0111	uuuu uuuu
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	1111 1111	1111 1111	uuuu uuuu
PBC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PCC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PD	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PDC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PE	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PEC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PF	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PFC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PG	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PGC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
USR	0000 1011	0000 1011	0000 1011	0000 1011	uuuu uuuu
UCR1	0000 00x0	0000 00x0	0000 00x0	0000 00x0	uuuu uuuu
UCR2	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
TXR/RXR	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
BRG	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu

Note: "*" stands for "warm reset"
 "u" stands for "unchanged"
 "x" stands for "unknown"

Timer/Event Counter

Three timer/event counters (TMR0, TMR1, TMR2) are implemented in this microcontroller.

The Timer/Event Counter 0 contains a 16-bit programmable count-up counter and the clock may come from an external source or from the system clock divided by 4 or RTC.

The Timer/Event Counter 1 contains a 16-bit programmable count-up counter and the clock may come from an external source or from the system clock divided by 4 or RTC.

The Timer/Event Counter 2 contains an 8-bit programmable count-up counter and the clock may come from an external source or from the system clock or RTC.

Using the internal clock sources, there are two reference time-bases for the Timer/Event Counter 0. The internal clock source can be selected as coming from $f_{SYS}/4$ (can always be optioned) or RTC (enabled only by a system oscillator in the Int. RC+RTC mode) by options.

Using the internal clock sources, there are two reference time-bases for the Timer/Event Counter 1. The internal clock source can be selected as coming from $f_{SYS}/4$ (can always be optioned) or RTC (enabled only by a system oscillator in the Int. RC+RTC mode) by options.

Using external clock input allows the user to count external events, measure time internals or pulse widths, or generate an accurate time base. While using the internal clock allows the user to generate an accurate time base.

There are three registers related to the Timer/Event Counter 0, namely, TMR0H ([0CH]), TMR0L ([0DH]), and TMR0C ([0EH]). Writing to the TMR0L will only put the written data to an internal lower-order byte buffer (8 bits) and writing to the TMR0H will transfer the specified data and the contents of the lower-order byte buffer to TMR0H and TMR0L preload registers, respectively. The Timer/Event Counter 0 preload register is changed by each writing operations to the TMR0H. Reading from the TMR0H will latch the contents of the TMR0H and TMR0L counters to the destination and the lower-order byte buffer, respectively. Reading the TMR0L will read the contents of the lower-order byte buffer. The TMR0C is the Timer/Event Counter 0 control register, which defines the operating mode, counting enable or disable and active edge.

There are three registers related to the Timer/Event Counter 1; TMR1H (0FH), TMR1L (10H), TMR1C (11H). Writing to the TMR1L will only put the written data to an internal lower-order byte buffer (8 bits) and writing to the TMR1H will transfer the specified data and the contents of the lower-order byte buffer to TMR1H and TMR1L preload registers, respectively. The Timer/Event Counter 1 preload register is changed by each writing opera-

tions to the TMR1H. Reading from the TMR1H will latch the contents of TMR1H and TMR1L counters to the destination and the lower-order byte buffer, respectively. Reading the TMR1L will read the contents of the lower-order byte buffer. The TMR1C is the Timer/Event Counter 1 control register, which defines the operating mode, counting enable or disable and active edge.

There are two registers related to timer/event counter, namely, TMR2 (21H) and TMR2C (22H). In the timer/event counter counting mode (T2ON=1), writing TMR2 will only put the written data to the preload register (8 bits). The timer/event counter preload register is changed by each writing operations to the TMR2. Reading from the TMR2 will also latch the TMR2 to the destination. The TMR2C is the timer/event counter control register, which defines the operating mode, counting enable or disable and active edge.

The T0M0, T0M1 (TMR0C), T1M0, T1M1 (TMR1C), T2M0, T2M1 (TMR2C) bits define the operating mode. The event count mode is used to count external events, which means the clock source comes from an external pin (TMR0/TMR1/TMR2). The timer mode functions as a normal timer with the clock source coming from the instruction clock or RTC clock (Timer0/Timer1/Timer2). The pulse width measurement mode can be used to count the high or low level duration of the external signal (TMR0/TMR1/TMR2). The counting is based on the instruction clock or RTC clock (Timer0/Timer1/Timer2).

In the event count or timer mode, once the Timer/Event Counter 0/1 starts counting, it will count from the current contents in the Timer/Event Counter 0/1 to FFFFH. Once overflow occurs, the counter is reloaded from the Timer/Event Counter 0/1 preload register and at the same time generates the interrupt request flag (T0F/T1F; bit 5/6 of the INTC0).

In the event count or timer mode, once the Timer/Event Counter 2 starts counting, it will count from the current contents in the timer/event counter to FFH. Once overflow occurs, the counter is reloaded from the Timer/Event Counter 2 preload register and at the same time generates the corresponding interrupt request flag (T2F; bit 6 of the INTC1).

In the pulse width measurement mode with the T0ON/T1ON/T2ON and T0E/T1E/T2E bits equal to one, once the TMR0/TMR1/TMR2 has received a transient from low to high (or high to low if the T0E/T1E/T2E bits are "0") it will start counting until the TMR0/TMR1/TMR2 returns to the original level and resets the T0ON/T1ON/T2ON. The measured result will remain in the Timer/Event Counter 0/1/2 even if the activated transient occurs again. In other words, only one cycle measurement can be done. Until setting the T0ON/T1ON/T2ON, the cycle measurement will function again as long as it receives further transient pulse. Note that, in this operating mode, the Timer/Event Counter 0/1/2 starts counting not according to the logic level but ac-

Bit No.	Label	Function
0~2, 5	—	Unused bit, read as "0"
3	T0E	Defines the TMR0 active edge of the Timer/Event Counter 0 (0=active on low to high; 1=active on high to low)
4	T0ON	Enables or disables the Timer 0 counting (0=disable; 1=enable)
6 7	T0M0 T0M1	Defines the operating mode 01=Event count mode (external clock) 10=Timer mode (internal clock) 11=Pulse width measurement mode 00=Unused

TMR0C (0EH) Register

Bit No.	Label	Function
0~2, 5	—	Unused bit, read as "0"
3	T1E	Defines the TMR1 active edge of the Timer/Event Counter 1 (0=active on low to high; 1=active on high to low)
4	T1ON	Enables or disables the Timer 1 counting (0=disable; 1=enable)
6 7	T1M0 T1M1	Defines the operating mode 01=Event count mode (external clock) 10=Timer mode (internal clock) 11=Pulse width measurement mode 00=Unused

TMR1C (11H) Register

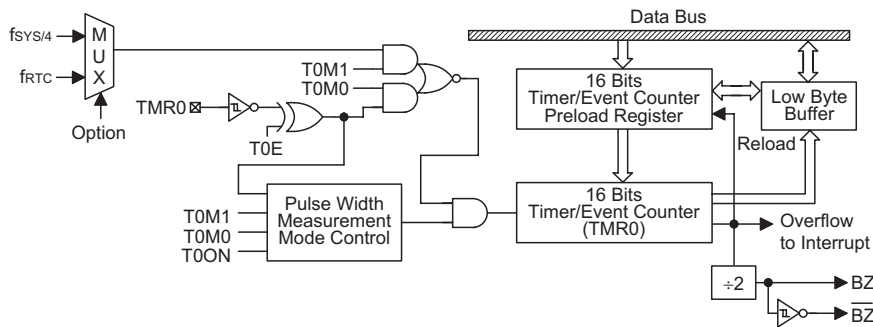
Bit No.	Label	Function
0~2	T2PSC0~ T2PSC2	Defines the prescaler stages 000: $f_{INT}=f_S/2$ 001: $f_{INT}=f_S/4$ 010: $f_{INT}=f_S/8$ 011: $f_{INT}=f_S/16$ 100: $f_{INT}=f_S/32$ 101: $f_{INT}=f_S/64$ 110: $f_{INT}=f_S/128$ 111: $f_{INT}=f_S/256$
3	T2E	Defines the active edge of the TMR2 pin input signal (0=active on low to high; 1=active on high to low)
4	T2ON	Enables or disables the timer counting (0=disable; 1=enable)
5	—	Unused bit, read as "0"
6 7	T2M0 T2M1	Defines the operating mode 01=Event count mode (external clock) 10=Timer mode (internal clock) 11=Pulse width measurement mode 00=Unused

TMR2C (22H) Register

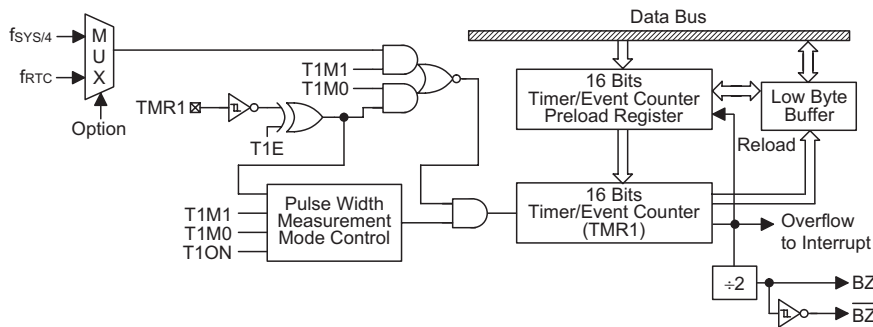
ording to the transient edges. In the case of counter overflows, the Counter 0/1/2 is reloaded from the Timer/Event Counter 0/1/2 preload register and issues the interrupt request just like the other two modes. To enable the counting operation, the timer ON bit (T0ON: bit 4 of the TMR0C; T1ON: bit 4 of the TMR1C; T2ON: bit 4 of the TMR2C) should be set to 1.

In the pulse width measurement mode, the T0ON/T1ON/T2ON will be cleared automatically after the measurement cycle is completed. But in the other two modes the T0ON/T1ON/T2ON can only be reset by instructions. The overflow of the Timer/Event Counter 0/1/2 is one of the wake-up sources. No matter what the operation mode is, writing a 0 to ET0I/ET1I/ET2I can dis-

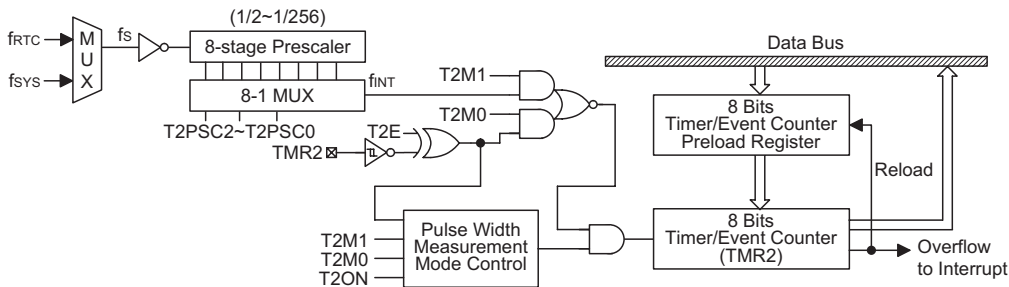
able the corresponding interrupt services. In the case of Timer/Event Counter 0/1/2 OFF condition, writing data to the Timer/Event Counter 0/1/2 preload register will also reload that data to the Timer/Event Counter 0/1/2. But if the Timer/Event Counter 0/1/2 is turned on, data written to it will only be kept in the Timer/Event Counter 0/1/2 preload register. The Timer/Event Counter 0/1/2 will still operate until overflow occurs (a Timer/Event Counter 0/1/2 reloading will occur at the same time). When the Timer/Event Counter 0/1/2 (reading TMR0/TMR1/TMR2) is read, the clock will be blocked to avoid errors. As clock blocking may results in a counting error, this must be taken into consideration by the programmer.



Timer/Event Counter 0



Timer/Event Counter 1



Timer/Event Counter 2

Input/Output Ports

There are 56 bidirectional input/output lines in the microcontroller, labeled from PA to PG, which are mapped to the data memory of [12H], [14H], [16H], [18H], [1AH], [1CH] and [25H] 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, 16H, 18H, 1AH, 1CH or 25H). 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, PCC, PDC, PEC, PFC, PGC) 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.

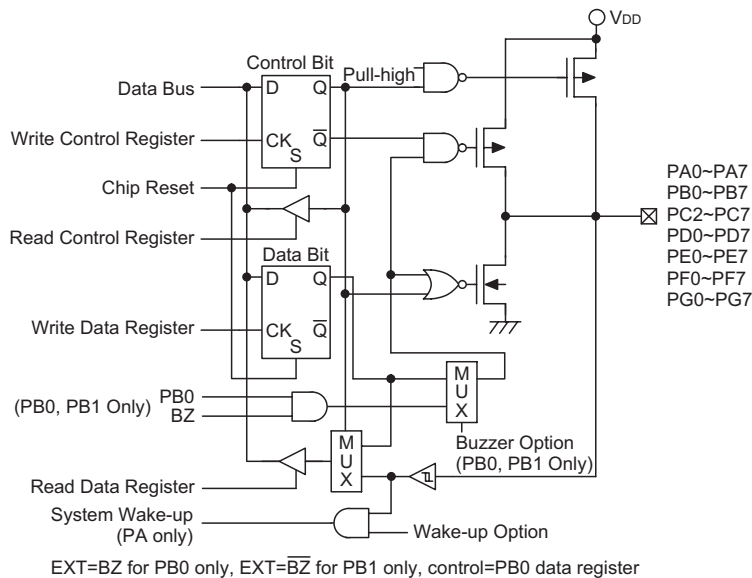
For output function, CMOS is the only configuration. These control registers are mapped to locations 13H, 15H, 17H, 19H, 1BH, 1DH and 26H.

After a chip reset, these input/output lines remain at high levels or floating state (depending on the 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, 16H, 18H, 1AH, 1CH or 25H) instructions.

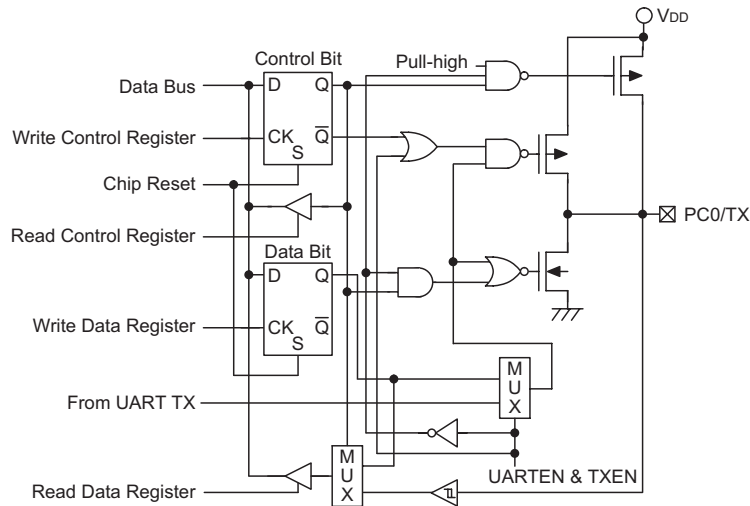
Some instructions first input data and then follow the output operations. For example, "SET [m].i", "CLR [m].i", "CPL [m]", "CPLA [m]" read the entire port states into the CPU, execute the defined operations (bit-operation), and then write the results back to the latches or the accumulator.

Each line of Port A has the capability of waking-up the device.

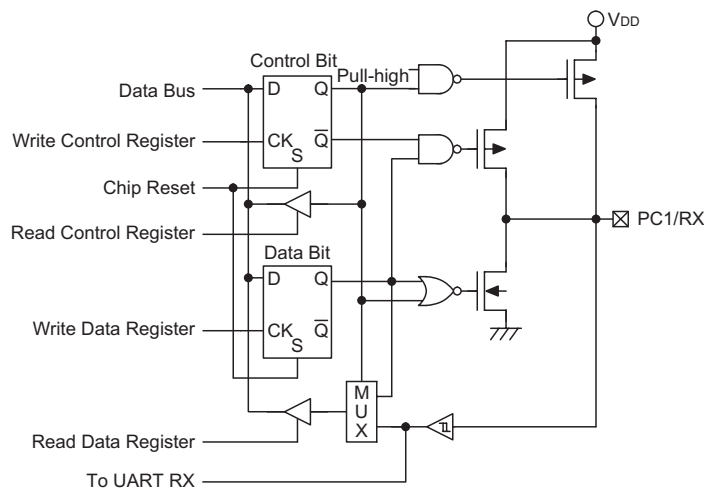
There is a pull-high option available for all I/O lines (port option). Once the pull-high option of an I/O line is selected, the I/O line has a pull-high resistor. Otherwise, the pull-high resistor is absent. It should be noted that a non-pull-high I/O line operating in input mode will cause a floating state.



PA, PB, PC2~PC7, PD, PE, PF, PG Input/Output Ports



PC0/TX Input/Output Ports



PC1/RX Input/Output Ports

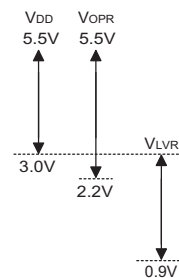
Low Voltage Reset – LVR

The microcontroller provides a low voltage reset circuit in order to monitor the supply voltage of the device. If the supply voltage of the device is within the range $0.9V \sim V_{LVR}$, such as changing a battery, the LVR will automatically reset the device internally.

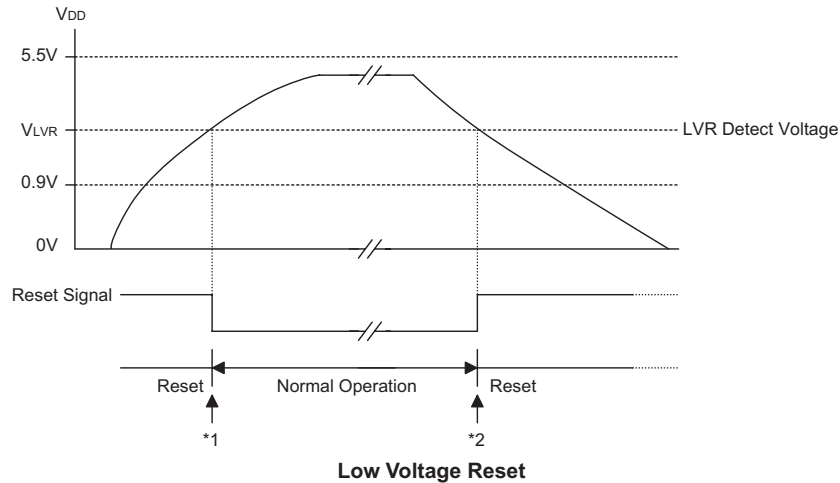
The LVR includes the following specifications:

- The low voltage ($0.9V \sim V_{LVR}$) has to remain in its original state for longer than 1ms. If the low voltage state does not exceed 1ms, the LVR will ignore it and will not perform a reset function.
- The LVR uses an "OR" function with the external \overline{RES} signal to perform a chip reset.

The relationship between V_{DD} and V_{LVR} is shown below.



Note: V_{OPR} is the voltage range for proper chip operation at 4MHz system clock.



Note: *1: To make sure that the system oscillator has stabilized, the SST provides an extra delay of 1024 system clock pulses before entering the normal operation.

*2: Since the low voltage has to maintain its original state for longer than 1ms, therefore a 1ms delay enters the reset mode.

UART Bus Serial Interface

The HT48RU80/HT48CU80 devices contain an integrated full-duplex asynchronous serial communications UART interface that enables communication with external devices that contain a serial interface. The UART function has many features and can transmit and receive data serially by transferring a frame of data with eight or nine data bits per transmission as well as being able to detect errors when the data is overwritten or incorrectly framed. The UART function possesses its own internal interrupt which can be used to indicate when a reception occurs or when a transmission terminates.

• UART features

The integrated UART function contains the following features:

- ♦ Full-duplex, asynchronous communication
- ♦ 8 or 9 bits character length
- ♦ Even, odd or no parity options
- ♦ One or two stop bits
- ♦ Baud rate generator with 8-bit prescaler
- ♦ Parity, framing, noise and overrun error detection
- ♦ Support for interrupt on address detect (last character bit=1)
- ♦ Separately enabled transmitter and receiver
- ♦ 2-byte Deep Fifo Receive Data Buffer
- ♦ Transmit and receive interrupts
- ♦ Interrupts can be initialized by the following conditions:
 - Transmitter Empty
 - Transmitter Idle
 - Receiver Full
 - Receiver Overrun
 - Address Mode Detect

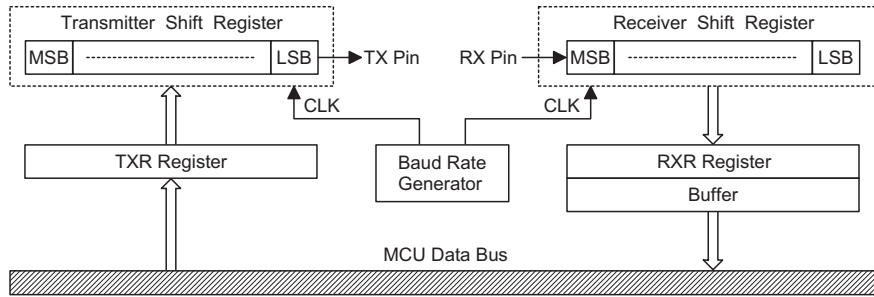
• UART external pin interfacing

To communicate with an external serial interface, the internal UART has two external pins known as TX and RX. The TX pin is the UART transmitter pin, which can be used as a general purpose I/O pin if the pin is not configured as a UART transmitter, which occurs when the TXEN bit in the UCR2 control register is equal to zero. Similarly, the RX pin is the UART receiver pin, which can also be used as a general purpose I/O pin, if the pin is not configured as a receiver, which occurs if the RXEN bit in the UCR2 register is equal to zero. Along with the UARTEEN bit, the TXEN and RXEN bits, if set, will automatically setup these I/O pins to their respective TX output and RX input conditions and disable any pull-high resistor option which may exist on the RX pin.

• UART data transfer scheme

The block diagram shows the overall data transfer structure arrangement for the UART. The actual data to be transmitted from the MCU is first transferred to the TXR register by the application program. The data will then be transferred to the Transmit Shift Register from where it will be shifted out, LSB first, onto the TX pin at a rate controlled by the Baud Rate Generator. Only the TXR register is mapped onto the MCU Data Memory, the Transmit Shift Register is not mapped and is therefore inaccessible to the application program.

Data to be received by the UART is accepted on the external RX pin, from where it is shifted in, LSB first, to the Receiver Shift Register at a rate controlled by the Baud Rate Generator. When the shift register is full, the data will then be transferred from the shift register to the internal RXR register, where it is buffered and can be manipulated by the application program.



UART Data Transfer Scheme

Only the RXR register is mapped onto the MCU Data Memory, the Receiver Shift Register is not mapped and is therefore inaccessible to the application program.

It should be noted that the actual register for data transmission and reception, although referred to in the text, and in application programs, as separate TXR and RXR registers, only exists as a single shared register in the Data Memory. This shared register known as the TXR/RXR register is used for both data transmission and data reception.

- UART status and control registers

There are five control registers associated with the UART function. The USR, UCR1 and UCR2 registers control the overall function of the UART, while the BRG register controls the Baud rate. The actual data to be transmitted and received on the serial interface is managed through the TXR/RXR data registers.

- USR register

The USR register is the status register for the UART, which can be read by the program to determine the present status of the UART. All flags within the USR register are read only.

Further explanation on each of the flags is given below:

- ♦ TXIF

The TXIF flag is the transmit data register empty flag. When this read only flag is "0" it indicates that the character is not transferred to the transmit shift registers. When the flag is "1" it indicates that the transmit shift register has received a character from the TXR data register. The TXIF flag is cleared by reading the UART status register (USR) with TXIF set and then writing to the TXR data register. Note that when the TXEN bit is set, the TXIF flag bit will also be set since the transmit buffer is not yet full.

- ♦ TIDLE

The TIDLE flag is known as the transmission complete flag. When this read only flag is "0" it indicates that a transmission is in progress. This flag will be set to "1" when the TXIF flag is "1" and when there is no transmit data, or break character being transmitted. When TIDLE is "1" the TX pin becomes idle. The TIDLE flag is cleared by reading the USR regis-

ter with TIDLE set and then writing to the TXR register. The flag is not generated when a data character, or a break is queued and ready to be sent.

- ♦ RXIF

The RXIF flag is the receive register status flag. When this read only flag is "0" it indicates that the RXR read data register is empty. When the flag is "1" it indicates that the RXR read data register contains new data. When the contents of the shift register are transferred to the RXR register, an interrupt is generated if RIE=1 in the UCR2 register. If one or more errors are detected in the received word, the appropriate receive-related flags NF, FERR, and/or PERR are set within the same clock cycle. The RXIF flag is cleared when the USR register is read with RXIF set, followed by a read from the RXR register, and if the RXR register has no data available.

- ♦ RIDLE

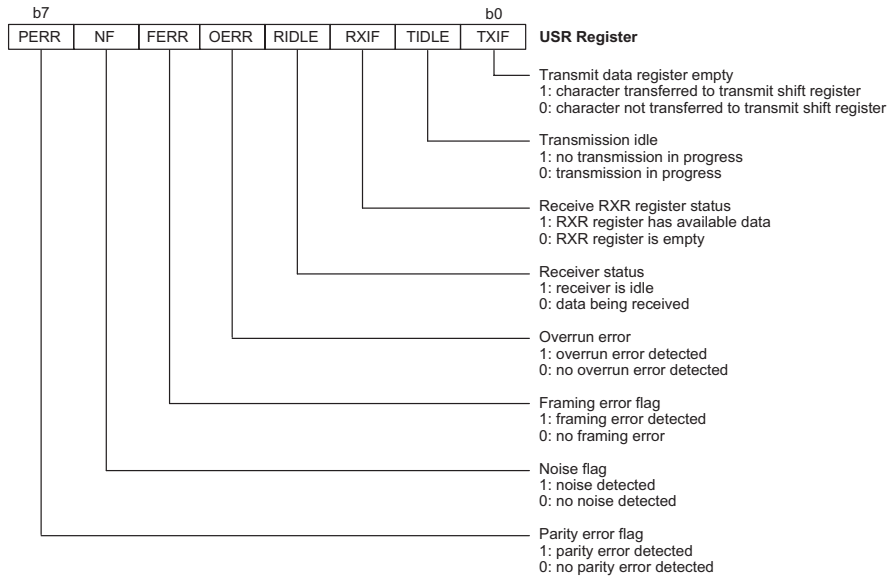
The RIDLE flag is the receiver status flag. When this read only flag is "0" it indicates that the receiver is between the initial detection of the start bit and the completion of the stop bit. When the flag is "1" it indicates that the receiver is idle. Between the completion of the stop bit and the detection of the next start bit, the RIDLE bit is "1" indicating that the UART is idle.

- ♦ OERR

The OERR flag is the overrun error flag, which indicates when the receiver buffer has overflowed. When this read only flag is "0" there is no overrun error. When the flag is "1" an overrun error occurs which will inhibit further transfers to the RXR receive data register. The flag is cleared by a software sequence, which is a read to the status register USR followed by an access to the RXR data register.

- ♦ FERR

The FERR flag is the framing error flag. When this read only flag is "0" it indicates no framing error. When the flag is "1" it indicates that a framing error has been detected for the current character. The flag can also be cleared by a software sequence which will involve a read to the USR status register followed by an access to the RXR data register.



◆ NF

The NF flag is the noise flag. When this read only flag is "0" it indicates a no noise condition. When the flag is "1" it indicates that the UART has detected noise on the receiver input. The NF flag is set during the same cycle as the RXIF flag but will not be set in the case of an overrun. The NF flag can be cleared by a software sequence which will involve a read to the USR status register, followed by an access to the RXR data register.

◆ PERR

The PERR flag is the parity error flag. When this read only flag is "0" it indicates that a parity error has not been detected. When the flag is "1" it indicates that the parity of the received word is incorrect. This error flag is applicable only if Parity mode (odd or even) is selected. The flag can also be cleared by a software sequence which involves a read to the USR status register, followed by an access to the RXR data register.

• UCR1 register

The UCR1 register together with the UCR2 register are the two UART control registers that are used to set the various options for the UART function, such as overall on/off control, parity control, data transfer bit length etc.

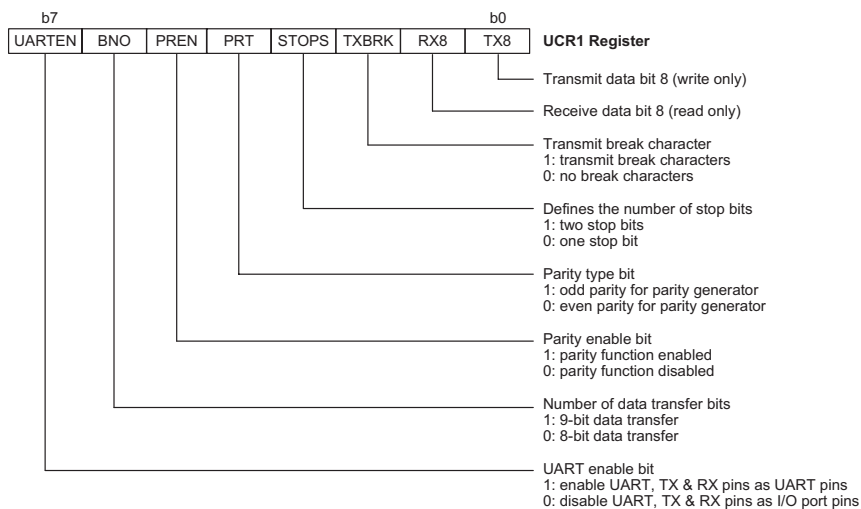
Further explanation on each of the bits is given below:

◆ TX8

This bit is only used if 9-bit data transfers are used, in which case this bit location will store the 9th bit of the transmitted data, known as TX8. The BNO bit is used to determine whether data transfers are in 8-bit or 9-bit format.

◆ RX8

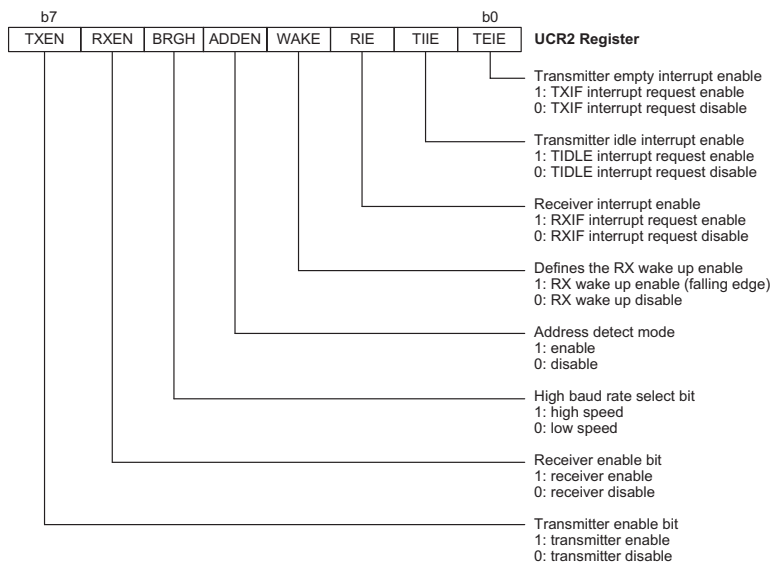
This bit is only used if 9-bit data transfers are used, in which case this bit location will store the 9th bit of the received data, known as RX8. The BNO bit is used to determine whether data transfers are in 8-bit or 9-bit format.



- ◆ **TXBRK**
The TXBRK bit is the Transmit Break Character bit. When this bit is "0" there are no break characters and the TX pin operates normally. When the bit is "1" there are transmit break characters and the transmitter will send logic zeros. When equal to "1" after the buffered data has been transmitted, the transmitter output is held low for a minimum of a 13-bit length and until the TXBRK bit is reset.
- ◆ **STOPS**
This bit determines if one or two stop bits are to be used. When this bit is equal to "1" two stop bits are used, if the bit is equal to "0" then only one stop bit is used.
- ◆ **PRT**
This is the parity type selection bit. When this bit is equal to "1" odd parity will be selected, if the bit is equal to "0" then even parity will be selected.
- ◆ **PREN**
This is parity enable bit. When this bit is equal to "1" the parity function will be enabled, if the bit is equal to "0" then the parity function will be disabled.
- ◆ **BNO**
This bit is used to select the data length format, which can have a choice of either 8-bits or 9-bits. If this bit is equal to "1" then a 9-bit data length will be selected, if the bit is equal to "0" then an 8-bit data length will be selected. If 9-bit data length is selected then bits RX8 and TX8 will be used to store the 9th bit of the received and transmitted data respectively.
- ◆ **UARTEN**
The UARTEN bit is the UART enable bit. When the bit is "0" the UART will be disabled and the RX and TX pins will function as General Purpose I/O pins. When the bit is "1" the UART will be enabled and the TX and RX pins will function as defined by the TXEN and RXEN control bits. When the UART is

disabled it will empty the buffer so any character remaining in the buffer will be discarded. In addition, the baud rate counter value will be reset. When the UART is disabled, all error and status flags will be reset. The TXEN, RXEN, TXBRK, RXIF, OERR, FERR, PERR, and NF bits will be cleared, while the TIDLE, TXIF and RIDLE bits will be set. Other control bits in UCR1, UCR2, and BRG registers will remain unaffected. If the UART is active and the UARTEN bit is cleared, all pending transmissions and receptions will be terminated and the module will be reset as defined above. When the UART is re-enabled it will restart in the same configuration.

- **UCR2 register**
The UCR2 register is the second of the two UART control registers and serves several purposes. One of its main functions is to control the basic enable/disable operation of the UART Transmitter and Receiver as well as enabling the various UART interrupt sources. The register also serves to control the baud rate speed, receiver wake-up enable and the address detect enable. Further explanation on each of the bits is given below:
 - ◆ **TEIE**
This bit enables or disables the transmitter empty interrupt. If this bit is equal to "1" when the transmitter empty TXIF flag is set, due to a transmitter empty condition, the UART interrupt request flag will be set. If this bit is equal to "0" the UART interrupt request flag will not be influenced by the condition of the TXIF flag.
 - ◆ **TIIE**
This bit enables or disables the transmitter idle interrupt. If this bit is equal to "1" when the transmitter idle TIDLE flag is set, the UART interrupt request flag will be set. If this bit is equal to "0" the UART interrupt request flag will not be influenced by the condition of the TIDLE flag.



- ◆ **RIE**
This bit enables or disables the receiver interrupt. If this bit is equal to "1" when the receiver overrun OERR flag or receive data available RXIF flag is set, the UART interrupt request flag will be set. If this bit is equal to "0" the UART interrupt will not be influenced by the condition of the OERR or RXIF flags.
- ◆ **WAKE**
This bit enables or disables the receiver wake-up function. If this bit is equal to "1" and if the MCU is in the Power Down Mode, a low going edge on the RX input pin will wake-up the device. If this bit is equal to "0" and if the MCU is in the Power Down Mode, any edge transitions on the RX pin will not wake-up the device.
- ◆ **ADDEN**
The ADDEN bit is the address detect mode bit. When this bit is "1" the address detect mode is enabled. When this occurs, if the 8th bit, which corresponds to RX7 if BNO=0, or the 9th bit, which corresponds to RX8 if BNO=1, has a value of "1" then the received word will be identified as an address, rather than data. If the corresponding interrupt is enabled, an interrupt request will be generated each time the received word has the address bit set, which is the 8 or 9 bit depending on the value of BNO. If the address bit is "0" an interrupt will not be generated, and the received data will be discarded.
- ◆ **BRGH**
The BRGH bit selects the high or low speed mode of the Baud Rate Generator. This bit, together with the value placed in the BRG register, controls the Baud Rate of the UART. If this bit is equal to "1" the high speed mode is selected. If the bit is equal to "0" the low speed mode is selected.
- ◆ **RXEN**
The RXEN bit is the Receiver Enable Bit. When this bit is equal to "0" the receiver will be disabled with any pending data receptions being aborted. In addition the buffer will be reset. In this situation the RX pin can be used as a general purpose I/O pin. If the RXEN bit is equal to "1" the receiver will be enabled and if the UARTEN bit is equal to "1" the RX pin will be controlled by the UART. Clearing the RXEN bit during a transmission will cause the data reception to be aborted and will reset the receiver. If this occurs, the RX pin can be used as a general purpose I/O pin.
- ◆ **TXEN**
The TXEN bit is the Transmitter Enable Bit. When this bit is equal to "0" the transmitter will be disabled with any pending transmissions being aborted. In addition the buffer will be reset. In this situation the TX pin can be used as a general purpose I/O pin. If the TXEN bit is equal to "1" the transmitter will be enabled and if the UARTEN bit is equal to "1" the

TX pin will be controlled by the UART. Clearing the TXEN bit during a transmission will cause the transmission to be aborted and will reset the transmitter. If this occurs, the TX pin can be used as a general purpose I/O pin.

- **Baud rate generator**
To setup the speed of the serial data communication, the UART function contains its own dedicated baud rate generator. The baud rate is controlled by its own internal free running 8-bit timer, the period of which is determined by two factors. The first of these is the value placed in the BRG register and the second is the value of the BRGH bit within the UCR2 control register. The BRGH bit decides, if the baud rate generator is to be used in a high speed mode or low speed mode, which in turn determines the formula that is used to calculate the baud rate. The value in the BRG register determines the division factor, N, which is used in the following baud rate calculation formula. Note that N is the decimal value placed in the BRG register and has a range of between 0 and 255.

UCR2 BRGH Bit	0	1
Baud Rate	$\frac{f_{\text{SYS}}}{[64 (N + 1)]}$	$\frac{f_{\text{SYS}}}{[16 (N + 1)]}$

By programming the BRGH bit which allows selection of the related formula and programming the required value in the BRG register, the required baud rate can be setup. Note that because the actual baud rate is determined using a discrete value, N, placed in the BRG register, there will be an error associated between the actual and requested value. The following example shows how the BRG register value N and the error value can be calculated.

Calculating the register and error values

For a clock frequency of 8MHz, and with BRGH set to "0" determine the BRG register value N, the actual baud rate and the error value for a desired baud rate of 9600.

From the above table the desired baud rate BR

$$= \frac{f_{\text{SYS}}}{[64 (N + 1)]}$$

Re-arranging this equation gives $N = \frac{f_{\text{SYS}}}{(\text{BR} \times 64)} - 1$

Giving a value for N = $\frac{8000000}{(9600 \times 64)} - 1 = 12.0208$

To obtain the closest value, a decimal value of 12 should be placed into the BRG register. This gives an actual or calculated baud rate value of

$$\text{BR} = \frac{8000000}{[64(12 + 1)]} = 9615$$

Therefore the error is equal to $\frac{9615 - 9600}{9600} = 0.16\%$

The following tables show actual values of baud rate and error values for the two values of BRGH.

Baud Rate K/BPS	Baud Rates for BRGH=0											
	f _{sys} =8MHz			f _{sys} =7.159MHz			f _{sys} =4MHz			f _{sys} =3.579545MHz		
	BRG	Kbaud	Error	BRG	Kbaud	Error	BRG	Kbaud	Error	BRG	Kbaud	Error
0.3	—	—	—	—	—	—	207	0.300	0.00	185	0.300	0.00
1.2	103	1.202	0.16	92	1.203	0.23	51	1.202	0.16	46	1.19	-0.83
2.4	51	2.404	0.16	46	2.38	-0.83	25	2.404	0.16	22	2.432	1.32
4.8	25	4.807	0.16	22	4.863	1.32	12	4.808	0.16	11	4.661	-2.9
9.6	12	9.615	0.16	11	9.322	-2.9	6	8.929	-6.99	5	9.321	-2.9
19.2	6	17.857	-6.99	5	18.64	-2.9	2	20.83	8.51	2	18.643	-2.9
38.4	2	41.667	8.51	2	37.29	-2.9	1	—	—	1	—	—
57.6	1	62.5	8.51	1	55.93	-2.9	0	62.5	8.51	0	55.93	-2.9
115.2	0	125	8.51	0	111.86	-2.9	—	—	—	—	—	—

Baud Rates and Error Values for BRGH = 0

Baud Rate K/BPS	Baud Rates for BRGH=1											
	f _{sys} =8MHz			f _{sys} =7.159MHz			f _{sys} =4MHz			f _{sys} =3.579545MHz		
	BRG	Kbaud	Error	BRG	Kbaud	Error	BRG	Kbaud	Error	BRG	Kbaud	Error
0.3	—	—	—	—	—	—	—	—	—	—	—	—
1.2	—	—	—	—	—	—	207	1.202	0.16	185	1.203	0.23
2.4	207	2.404	0.16	185	2.405	0.23	103	2.404	0.16	92	2.406	0.23
4.8	103	4.808	0.16	92	4.811	0.23	51	4.808	0.16	46	4.76	-0.83
9.6	51	9.615	0.16	46	9.520	-0.832	25	9.615	0.16	22	9.727	1.32
19.2	25	19.231	0.16	22	19.454	1.32	12	19.231	0.16	11	18.643	-2.9
38.4	12	38.462	0.16	11	37.287	-2.9	6	35.714	-6.99	5	37.286	-2.9
57.6	8	55.556	-3.55	7	55.93	-2.9	3	62.5	8.51	3	55.930	-2.9
115.2	3	125	8.51	3	111.86	-2.9	1	125	8.51	1	111.86	-2.9
250	1	250	0	—	—	—	0	250	0	—	—	—

Baud Rates and Error Values for BRGH = 1

- Setting up and controlling the UART

- ♦ Introduction

For data transfer, the UART function utilizes a non-return-to-zero, more commonly known as NRZ, format. This is composed of one start bit, eight or nine data bits, and one or two stop bits. Parity is supported by the UART hardware, and can be setup to be even, odd or no parity. For the most common data format, 8 data bits along with no parity and one stop bit, denoted as 8, N, 1, is used as the default setting, which is the setting at power-on. The number of data bits and stop bits, along with the parity, are setup by programming the corresponding BNO, PRT, PREN, and STOPS bits in the UCR1 register. The baud rate used to transmit and receive data is setup using the internal 8-bit baud rate generator, while the data is transmitted and received

LSB first. Although the UART's transmitter and receiver are functionally independent, they both use the same data format and baud rate. In all cases stop bits will be used for data transmission.

- ♦ Enabling/disabling the UART

The basic on/off function of the internal UART function is controlled using the UARTEN bit in the UCR1 register. As the UART transmit and receive pins, TX and RX respectively, are pin-shared with normal I/O pins, one of the basic functions of the UARTEN control bit is to control the UART function of these two pins. If the UARTEN, TXEN and RXEN bits are set, then these two I/O pins will be setup as a TX output pin and an RX input pin respectively, in effect disabling the normal I/O pin function. If no data is being transmitted on the TX pin then it will default to a logic high value.

Clearing the UARTEN bit will disable the TX and RX pins and allow these two pins to be used as normal I/O pins. When the UART function is disabled the buffer will be reset to an empty condition, at the same time discarding any remaining residual data. Disabling the UART will also reset the error and status flags with bits TXEN, RXEN, TXBRK, RXIF, OERR, FERR, PERR and NF being cleared while bits TIDLE, TXIF and RIDLE will be set. The remaining control bits in the UCR1, UCR2 and BRG registers will remain unaffected. If the UARTEN bit in the UCR1 register is cleared while the UART is active, then all pending transmissions and receptions will be immediately suspended and the UART will be reset to a condition as defined above. If the UART is then subsequently re-enabled, it will restart again in the same configuration.

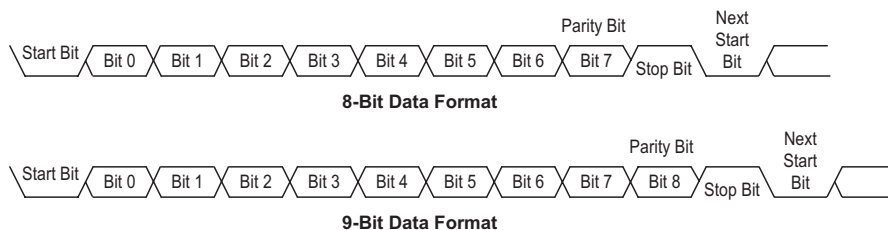
◆ Data, parity and stop bit selection

The format of the data to be transferred, is composed of various factors such as data bit length, parity on/off, parity type, address bits and the number of stop bits. These factors are determined by the setup of various bits within the UCR1 register. The BNO bit controls the number of data bits which can be set to either 8 or 9, the PRT bit controls the choice of odd or even parity, the PREN bit controls the parity on/off function and the STOPS bit decides whether one or two stop bits are to be used. The following table shows various formats for data transmission. The address bit identifies the frame as an address character. The number of stop bits, which can be either one or two, is independent of the data length.

Start Bit	Data Bits	Address Bits	Parity Bits	Stop Bit
Example of 8-bit Data Formats				
1	8	0	0	1
1	7	0	1	1
1	7	1 ¹	0	1
Example of 9-bit Data Formats				
1	9	0	0	1
1	8	0	1	1
1	8	1 ¹	0	1

Transmitter Receiver Data Format

The following diagram shows the transmit and receive waveforms for both 8-bit and 9-bit data formats.



• UART transmitter

Data word lengths of either 8 or 9 bits, can be selected by programming the BNO bit in the UCR1 register. When BNO bit is set, the word length will be set to 9 bits. In this case the 9th bit, which is the MSB, needs to be stored in the TX8 bit in the UCR1 register. At the transmitter core lies the Transmitter Shift Register, more commonly known as the TSR, whose data is obtained from the transmit data register, which is known as the TXR register. The data to be transmitted is loaded into this TXR register by the application program. The TSR register is not written to with new data until the stop bit from the previous transmission has been sent out. As soon as this stop bit has been transmitted, the TSR can then be loaded with new data from the TXR register, if it is available. It should be noted that the TSR register, unlike many other registers, is not directly mapped into the Data Memory area and as such is not available to the application program for direct read/write operations. An actual transmission of data will normally be enabled when the TXEN bit is set, but the data will not be transmitted until the TXR register has been loaded with data and the baud rate generator has defined a shift clock source. However, the transmission can also be initiated by first loading data into the TXR register, after which the TXEN bit can be set. When a transmission of data begins, the TSR is normally empty, in which case a transfer to the TXR register will result in an immediate transfer to the TSR. If during a transmission the TXEN bit is cleared, the transmission will immediately cease and the transmitter will be reset. The TX output pin will then return to having a normal general purpose I/O pin function.

◆ Transmitting data

When the UART is transmitting data, the data is shifted on the TX pin from the shift register, with the least significant bit first. In the transmit mode, the TXR register forms a buffer between the internal bus and the transmitter shift register. It should be noted that if 9-bit data format has been selected, then the MSB will be taken from the TX8 bit in the UCR1 register. The steps to initiate a data transfer can be summarized as follows:

- Make the correct selection of the BNO, PRT, PREN and STOPS bits to define the required word length, parity type and number of stop bits.
- Setup the BRG register to select the desired baud rate.

- Set the TXEN bit to ensure that the TX pin is used as a UART transmitter pin and not as an I/O pin.
- Access the USR register and write the data that is to be transmitted into the TXR register. Note that this step will clear the TXIF bit.
- This sequence of events can now be repeated to send additional data.

It should be noted that when TXIF=0, data will be inhibited from being written to the TXR register. Clearing the TXIF flag is always achieved using the following software sequence:

1. A USR register access
2. A TXR register write execution

The read-only TXIF flag is set by the UART hardware and if set indicates that the TXR register is empty and that other data can now be written into the TXR register without overwriting the previous data. If the TEIE bit is set then the TXIF flag will generate an interrupt.

During a data transmission, a write instruction to the TXR register will place the data into the TXR register, which will be copied to the shift register at the end of the present transmission. When there is no data transmission in progress, a write instruction to the TXR register will place the data directly into the shift register, resulting in the commencement of data transmission, and the TXIF bit being immediately set. When a frame transmission is complete, which happens after stop bits are sent or after the break frame, the TIDLE bit will be set. To clear the TIDLE bit the following software sequence is used:

1. A USR register access
2. A TXR register write execution

Note that both the TXIF and TIDLE bits are cleared by the same software sequence.

♦ Transmit break

If the TXBRK bit is set then break characters will be sent on the next transmission. Break character transmission consists of a start bit, followed by $13 \times N$ '0' bits and stop bits, where $N=1, 2, \text{etc.}$ If a break character is to be transmitted then the TXBRK bit must be first set by the application program, then cleared to generate the stop bits. Transmitting a break character will not generate a transmit interrupt. Note that a break condition length is at least 13 bits long. If the TXBRK bit is continually kept at a logic high level then the transmitter circuitry will transmit continuous break characters. After the application program has cleared the TXBRK bit, the transmitter will finish transmitting the last break character and subsequently send out one or two stop bits. The automatic logic highs at the end of the last break character will ensure that the start bit of the next frame is recognized.

• UART receiver

♦ Introduction

The UART is capable of receiving word lengths of either 8 or 9 bits. If the BNO bit is set, the word length will be set to 9 bits with the MSB being stored in the RX8 bit of the UCR1 register. At the receiver core lies

the Receive Serial Shift Register, commonly known as the RSR. The data which is received on the RX external input pin, is sent to the data recovery block. The data recovery block operating speed is 16 times that of the baud rate, while the main receive serial shifter operates at the baud rate. After the RX pin is sampled for the stop bit, the received data in RSR is transferred to the receive data register, if the register is empty. The data which is received on the external RX input pin is sampled three times by a majority detect circuit to determine the logic level that has been placed onto the RX pin. It should be noted that the RSR register, unlike many other registers, is not directly mapped into the Data Memory area and as such is not available to the application program for direct read/write operations.

♦ Receiving data

When the UART receiver is receiving data, the data is serially shifted in on the external RX input pin, LSB first. In the read mode, the RXR register forms a buffer between the internal bus and the receiver shift register. The RXR register is a two byte deep FIFO data buffer, where two bytes can be held in the FIFO while a third byte can continue to be received. Note that the application program must ensure that the data is read from RXR before the third byte has been completely shifted in, otherwise this third byte will be discarded and an overrun error OERR will be subsequently indicated. The steps to initiate a data transfer can be summarized as follows:

- Make the correct selection of BNO, PRT, PREN and STOPS bits to define the word length, parity type and number of stop bits.
- Setup the BRG register to select the desired baud rate.
- Set the RXEN bit to ensure that the RX pin is used as a UART receiver pin and not as an I/O pin.

At this point the receiver will be enabled which will begin to look for a start bit.

When a character is received the following sequence of events will occur:

- The RXIF bit in the USR register will be set when RXR register has data available, at least one more character can be read.
- When the contents of the shift register have been transferred to the RXR register, then if the RIE bit is set, an interrupt will be generated.
- If during reception, a frame error, noise error, parity error, or an overrun error has been detected, then the error flags can be set.

The RXIF bit can be cleared using the following software sequence:

1. A USR register access
2. An RXR register read execution

♦ Receive break

Any break character received by the UART will be managed as a framing error. The receiver will count and expect a certain number of bit times as specified by the values programmed into the BNO and

STOPS bits. If the break is much longer than 13 bit times, the reception will be considered as complete after the number of bit times specified by BNO and STOPS. The RXIF bit is set, FERR is set, zeros are loaded into the receive data register, interrupts are generated if appropriate and the RIDLE bit is set. If a long break signal has been detected and the receiver has received a start bit, the data bits and the invalid stop bit, which sets the FERR flag, the receiver must wait for a valid stop bit before looking for the next start bit. The receiver will not make the assumption that the break condition on the line is the next start bit. A break is regarded as a character that contains only zeros with the FERR flag set. The break character will be loaded into the buffer and no further data will be received until stop bits are received. It should be noted that the RIDLE read only flag will go high when the stop bits have not yet been received. The reception of a break character on the UART registers will result in the following:

- The framing error flag, FERR, will be set.
- The receive data register, RXR, will be cleared.
- The OERR, NF, PERR, RIDLE or RXIF flags will possibly be set.

♦ Idle status

When the receiver is reading data, which means it will be in between the detection of a start bit and the reading of a stop bit, the receiver status flag in the USR register, otherwise known as the RIDLE flag, will have a zero value. In between the reception of a stop bit and the detection of the next start bit, the RIDLE flag will have a high value, which indicates the receiver is in an idle condition.

♦ Receiver interrupt

The read only receive interrupt flag RXIF in the USR register is set by an edge generated by the receiver. An interrupt is generated if RIE=1, when a word is transferred from the Receive Shift Register, RSR, to the Receive Data Register, RXR. An overrun error can also generate an interrupt if RIE=1.

• Managing receiver errors

Several types of reception errors can occur within the UART module, the following section describes the various types and how they are managed by the UART.

♦ Overrun Error - OERR flag

The RXR register is composed of a two byte deep FIFO data buffer, where two bytes can be held in the FIFO register, while a third byte can continue to be received. Before this third byte has been entirely shifted in, the data should be read from the RXR register. If this is not done, the overrun error flag OERR will be consequently indicated.

In the event of an overrun error occurring, the following will happen:

- The OERR flag in the USR register will be set.
- The RXR contents will not be lost.
- The shift register will be overwritten.
- An interrupt will be generated if the RIE bit is set.

The OERR flag can be cleared by an access to the USR register followed by a read to the RXR register.

♦ Noise Error - NF Flag

Over-sampling is used for data recovery to identify valid incoming data and noise. If noise is detected within a frame the following will occur:

- The read only noise flag, NF, in the USR register will be set on the rising edge of the RXIF bit.
- Data will be transferred from the Shift register to the RXR register.
- No interrupt will be generated. However this bit rises at the same time as the RXIF bit which itself generates an interrupt.

Note that the NF flag is reset by a USR register read operation followed by an RXR register read operation.

♦ Framing Error - FERR Flag

The read only framing error flag, FERR, in the USR register, is set if a zero is detected instead of stop bits. If two stop bits are selected, both stop bits must be high, otherwise the FERR flag will be set. The FERR flag is buffered along with the received data and is cleared on any reset.

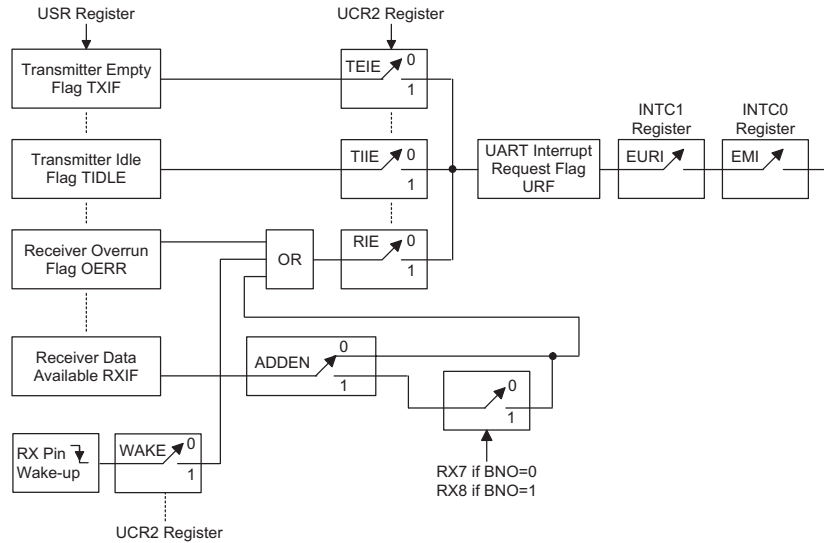
♦ Parity Error - PERR Flag

The read only parity error flag, PERR, in the USR register, is set if the parity of the received word is incorrect. This error flag is only applicable if the parity is enabled, PREN = 1, and if the parity type, odd or even is selected. The read only PERR flag is buffered along with the received data bytes. It is cleared on any reset. It should be noted that the FERR and PERR flags are buffered along with the corresponding word and should be read before reading the data word.

• UART interrupt scheme

The UART internal function possesses its own internal interrupt and independent interrupt vector. Several individual UART conditions can generate an internal UART interrupt. These conditions are, a transmitter data register empty, transmitter idle, receiver data available, receiver overrun, address detect and an RX pin wake-up. When any of these conditions are created, if the UART interrupt is enabled and the stack is not full, the program will jump to the UART interrupt vector where it can be serviced before returning to the main program. Four of these conditions, have a corresponding USR register flag, which will generate a UART interrupt if its associated interrupt enable flag in the UCR2 register is set. The two transmitter interrupt conditions have their own corresponding enable bits, while the two receiver interrupt conditions have a shared enable bit. These enable bits can be used to mask out individual UART interrupt sources.

The address detect condition, which is also a UART interrupt source, does not have an associated flag, but will generate a UART interrupt when an address detect condition occurs if its function is enabled by setting the ADDEN bit in the UCR2 register. An RX pin



UART Interrupt Scheme

wake-up, which is also a UART interrupt source, does not have an associated flag, but will generate a UART interrupt if the microcontroller is woken up by a low going edge on the RX pin, if the WAKE and RIE bits in the UCR2 register are set. Note that in the event of an RX wake-up interrupt occurring, there will be a delay of 1024 system clock cycles before the system resumes normal operation.

Note that the USR register flags are read only and cannot be cleared or set by the application program, neither will they be cleared when the program jumps to the corresponding interrupt servicing routine, as is the case for some of the other interrupts. The flags will be cleared automatically when certain actions are taken by the UART, the details of which are given in the UART register section. The overall UART interrupt can be disabled or enabled by the EURI bit in the INTC1 interrupt control register to prevent a UART interrupt from occurring.

- **Address detect mode**
Setting the Address Detect Mode bit, ADDEN, in the UCR2 register, enables this special mode. If this bit is enabled then an additional qualifier will be placed on the generation of a Receiver Data Available interrupt, which is requested by the RXIF flag. If the ADDEN bit is enabled, then when data is available, an interrupt will only be generated, if the highest received bit has a high value. Note that the EURI and EMI interrupt enable bits must also be enabled for correct interrupt generation. This highest address bit is the 9th bit if BNO=1 or the 8th bit if BNO=0. If this bit is high, then the received word will be defined as an address rather than data. A Data Available interrupt will be generated every time the last bit of the received word is set. If the ADDEN bit is not enabled, then a Receiver Data Available interrupt will be generated each time the RXIF

flag is set, irrespective of the data last bit status. The address detect mode and parity enable are mutually exclusive functions. Therefore if the address detect mode is enabled, then to ensure correct operation, the parity function should be disabled by resetting the parity enable bit to zero.

ADDEN	Bit 9 if BNO=1, Bit 8 if BNO=0	UART Interrupt Generated
0	0	√
	1	√
1	0	X
	1	√

ADDEN Bit Function

- **UART operation in power down mode**
When the MCU is in the Power Down Mode the UART will cease to function. When the device enters the Power Down Mode, all clock sources to the module are shutdown. If the MCU enters the Power Down Mode while a transmission is still in progress, then the transmission will be terminated and the external TX transmit pin will be forced to a logic high level. In a similar way, if the MCU enters the Power Down Mode while receiving data, then the reception of data will likewise be terminated. When the MCU enters the Power Down Mode, note that the USR, UCR1, UCR2, transmit and receive registers, as well as the BRG register will not be affected.
The UART function contains a receiver RX pin wake-up function, which is enabled or disabled by the WAKE bit in the UCR2 register. If this bit, along with the UART enable bit, UARTEN, the receiver enable bit, RXEN and the receiver interrupt bit, RIE, are all set before the MCU enters the Power Down Mode,

then a falling edge on the RX pin will wake-up the MCU from the Power Down Mode. Note that as it takes 1024 system clock cycles after a wake-up, before normal microcontroller operation resumes, any data received during this time on the RX pin will be ignored.

For a UART wake-up interrupt to occur, in addition to the bits for the wake-up being set, the global interrupt enable bit, EMI, and the UART interrupt enable bit, EURI must also be set. If these two bits are not set then only a wake up event will occur and no interrupt will be generated. Note also that as it takes 1024 system clock cycles after a wake-up before normal microcontroller resumes, the UART interrupt will not be generated until after this time has elapsed.

Buzzer

The Buzzer function provides a means of producing a variable frequency output, suitable for applications such as Piezo-buzzer driving or other external circuits that require a precise frequency generator. The BZ and $\overline{\text{BZ}}$ pins form a complimentary pair, and are pin-shared with I/O pins, PB0 and PB1. A configuration option is used to select from one of three buzzer options. The first option is for both pins PB0 and PB1 to be used as normal I/Os, the second option is for both pins to be configured as BZ and $\overline{\text{BZ}}$ buzzer pins, the third option selects only the PB0 pin to be used as a BZ buzzer pin with the PB1 pin retaining its normal I/O pin function. Note that the $\overline{\text{BZ}}$ pin is the inverse of the BZ pin which together generate a differential output which can supply more power to connected interfaces such as buzzers.

The clock source of the BZ/ $\overline{\text{BZ}}$, can originate from the timer/event counter 0/1 overflow signal selected by configuration options. For using the BZ/ $\overline{\text{BZ}}$ functions, the timer/event counter 0/1 should be set properly to generate the buzzer signal.

If the configuration options have selected both pins PB0 and PB1 to function as a BZ and $\overline{\text{BZ}}$ complementary pair of buzzer outputs, then for correct buzzer operation it is essential that both pins must be setup as outputs by setting bits PBC0 and PBC1 of the PBC port control register to zero. The PB0 data bit in the PB data register must also be set high to enable the buzzer outputs, if set low, both pins PB0 and PB1 will remain low. In this way the single bit PB0 of the PB register can be used as an on/off control for both the BZ and $\overline{\text{BZ}}$ buzzer pin outputs. Note that the PB1 data bit in the PB register has no control over the $\overline{\text{BZ}}$ buzzer pin PB1.

If configuration options have selected that only the PB0 pin is to function as a BZ buzzer pin, then the PB1 pin can be used as a normal I/O pin. For the PB0 pin to function as a BZ buzzer pin, PB0 must be setup as an output by setting bit PBC0 of the PBC port control register to zero. The PB0 data bit in the PB data register must also be set high to enable the buzzer output, if set low pin PB0 will remain low. In this way the PB0 bit can be used as an on/off control for the BZ buzzer pin PB0. If the PBC0 bit of the PBC port control register is set high, then pin PB0 can still be used as an input even though the configuration option has configured it as a BZ buzzer output.

PBC Register PBC0	PBC Register PBC1	PB Data Register PB0	PB Data Register PB1	Output Function
0	0	0	X	PB0="0" PB1="0"
0	0	1	X	PB0=BZ PB1= $\overline{\text{BZ}}$
0	1	0	X	PB0="0" PB1=input line
0	1	1	X	PB0=BZ PB1=input line
1	0	1	X	PB0=input line PB1= $\overline{\text{BZ}}$
1	0	0	X	PB0=input line PB1=0
1	1	X	X	PB0=input line PB1=input line

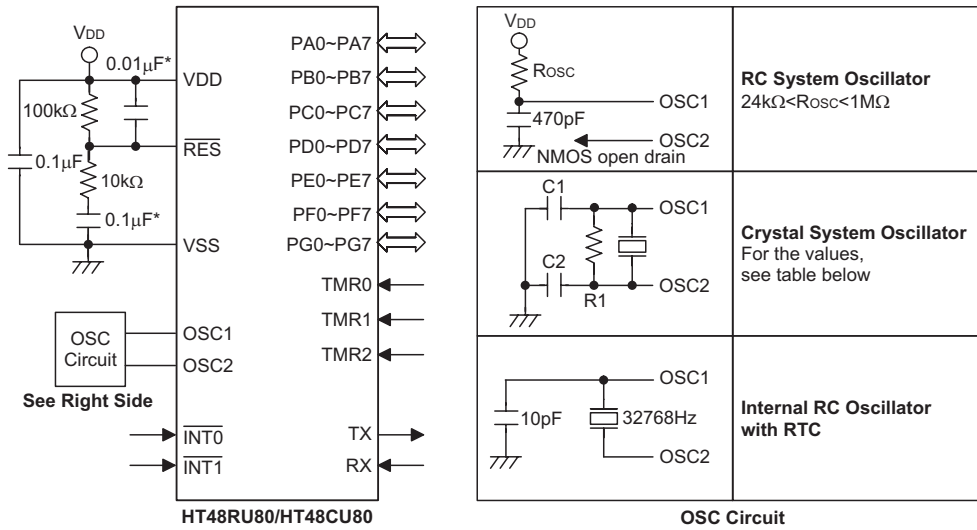
PB0/PB1 Pin Function Control

Note: "X" stand for don't care

Options

The following table shows all kinds of options in this microcontroller. All of the options must be defined to ensure having proper functioning system.

No.	Options
1	WDT clock source: WDT oscillator or $f_{SYS}/4$ or RTC oscillator or disable
2	CLRWDT instructions: 1 or 2 instructions
3	Timer/Event Counter 0 clock sources: $f_{SYS}/4$ or RTCOSC
4	Timer/Event Counter 1 clock sources: $f_{SYS}/4$ or RTCOSC
5	PA bit wake-up enable or disable
6	PA CMOS or Schmitt input
7	PA, PB, PC, PD, PE, PF, PG pull-high enable or disable (by port)
8	System oscillator Ext. RC, Ext. crystal, Int. RC+RTC
9	Buzzer output enable: enabled or disabled
10	Buzzer clock selection: TMR0 or TMR1
11	Int. RC frequency selection: 3.2MHz, 1.6MHz, 800kHz or 400kHz
12	LVR enable or disable

Application Circuits


Note: The resistance and capacitance for reset circuit should be designed to ensure that the VDD is stable and remains in a valid range of the operating voltage before bringing RES high.

*** Make the length of the wiring, which is connected to the RES pin as short as possible, to avoid noise interference.

The following table shows the C1, C2 and R1 values corresponding to the different crystal values. (For reference only)

Crystal or Resonator	C1, C2	R1
4MHz Crystal	0pF	10kΩ
4MHz Resonator	10pF	12kΩ
3.58MHz Crystal	0pF	10kΩ
3.58MHz Resonator	25pF	10kΩ
2MHz Crystal & Resonator	25pF	10kΩ
1MHz Crystal	35pF	27kΩ
480kHz Resonator	300pF	9.1kΩ
455kHz Resonator	300pF	10kΩ
429kHz Resonator	300pF	10kΩ

The function of the resistor R1 is to ensure that the oscillator will switch off should low voltage conditions occur. Such a low voltage, as mentioned here, is one which is less than the lowest value of the MCU operating voltage. Note however that if the LVR is enabled then R1 can be removed.

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 0.5 μ s and branch or call instructions would be implemented within 1 μ s. 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 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	1 ^{Note}	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	1 ^{Note}	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	1 ^{Note}	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	1 ^{Note}	Z, C, AC, OV
DAA [m]	Decimal adjust ACC for Addition with result in Data Memory	1 ^{Note}	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	1 ^{Note}	Z
ORM A,[m]	Logical OR ACC to Data Memory	1 ^{Note}	Z
XORM A,[m]	Logical XOR ACC to Data Memory	1 ^{Note}	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	1 ^{Note}	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	1 ^{Note}	Z
DECA [m]	Decrement Data Memory with result in ACC	1	Z
DEC [m]	Decrement Data Memory	1 ^{Note}	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	1 ^{Note}	None
RRCA [m]	Rotate Data Memory right through Carry with result in ACC	1	C
RRC [m]	Rotate Data Memory right through Carry	1 ^{Note}	C
RLA [m]	Rotate Data Memory left with result in ACC	1	None
RL [m]	Rotate Data Memory left	1 ^{Note}	None
RLCA [m]	Rotate Data Memory left through Carry with result in ACC	1	C
RLC [m]	Rotate Data Memory left through Carry	1 ^{Note}	C
Data Move			
MOV A,[m]	Move Data Memory to ACC	1	None
MOV [m],A	Move ACC to Data Memory	1 ^{Note}	None
MOV A,x	Move immediate data to ACC	1	None
Bit Operation			
CLR [m].i	Clear bit of Data Memory	1 ^{Note}	None
SET [m].i	Set bit of Data Memory	1 ^{Note}	None
Branch			
JMP addr	Jump unconditionally	2	None
SZ [m]	Skip if Data Memory is zero	1 ^{Note}	None
SZA [m]	Skip if Data Memory is zero with data movement to ACC	1 ^{note}	None
SZ [m].i	Skip if bit i of Data Memory is zero	1 ^{Note}	None
SNZ [m].i	Skip if bit i of Data Memory is not zero	1 ^{Note}	None
SIZ [m]	Skip if increment Data Memory is zero	1 ^{Note}	None
SDZ [m]	Skip if decrement Data Memory is zero	1 ^{Note}	None
SIZA [m]	Skip if increment Data Memory is zero with result in ACC	1 ^{Note}	None
SDZA [m]	Skip if decrement Data Memory is zero with result in ACC	1 ^{Note}	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	2 ^{Note}	None
TABRDL [m]	Read table (last page) to TBLH and Data Memory	2 ^{Note}	None
Miscellaneous			
NOP	No operation	1	None
CLR [m]	Clear Data Memory	1 ^{Note}	None
SET [m]	Set Data Memory	1 ^{Note}	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	1 ^{Note}	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	$ACC \leftarrow ACC + [m] + C$
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	$[m] \leftarrow ACC + [m] + C$
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	$ACC \leftarrow ACC + [m]$
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	$ACC \leftarrow ACC + x$
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	$[m] \leftarrow ACC + [m]$
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	$ACC \leftarrow ACC \text{ "AND" } [m]$
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	$ACC \leftarrow ACC \text{ "AND" } x$
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	$[m] \leftarrow ACC \text{ "AND" } [m]$
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 \leftarrow Program Counter + 1 Program Counter \leftarrow addr
Affected flag(s)	None
CLR [m]	Clear Data Memory
Description	Each bit of the specified Data Memory is cleared to 0.
Operation	[m] \leftarrow 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 \leftarrow 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 \leftarrow 0 PDF \leftarrow 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. Repeatedly executing this instruction without alternately executing CLR WDT2 will have no effect.
Operation	WDT cleared TO \leftarrow 0 PDF \leftarrow 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. Repeatedly executing this instruction without alternately executing CLR WDT1 will have no effect.
Operation	WDT cleared TO \leftarrow 0 PDF \leftarrow 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	$[m] \leftarrow [m] + 1$
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	$ACC \leftarrow [m] + 1$
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	$Program\ Counter \leftarrow addr$
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	$ACC \leftarrow [m]$
Affected flag(s)	None
MOV A,x	Move immediate data to ACC
Description	The immediate data specified is loaded into the Accumulator.
Operation	$ACC \leftarrow x$
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	$[m] \leftarrow ACC$
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	$ACC \leftarrow ACC \text{ "OR" } [m]$
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	$[m].(i+1) \leftarrow [m].i; (i = 0\sim6)$ $[m].0 \leftarrow C$ $C \leftarrow [m].7$
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	$ACC.(i+1) \leftarrow [m].i; (i = 0\sim6)$ $ACC.0 \leftarrow C$ $C \leftarrow [m].7$
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	$[m].i \leftarrow [m].(i+1); (i = 0\sim6)$ $[m].7 \leftarrow [m].0$
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	$ACC.i \leftarrow [m].(i+1); (i = 0\sim6)$ $ACC.7 \leftarrow [m].0$
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	$[m].i \leftarrow [m].(i+1); (i = 0\sim6)$ $[m].7 \leftarrow C$ $C \leftarrow [m].0$
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	$ACC.i \leftarrow [m].(i+1); (i = 0\sim6)$ $ACC.7 \leftarrow C$ $C \leftarrow [m].0$
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	$ACC \leftarrow ACC - [m] - \bar{C}$
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	$[m] \leftarrow ACC - [m] - \bar{C}$
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	$[m] \leftarrow [m] - 1$ 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	$ACC \leftarrow [m] - 1$ 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	$[m] \leftarrow FFH$
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	$[m].i \leftarrow 1$
Affected flag(s)	None

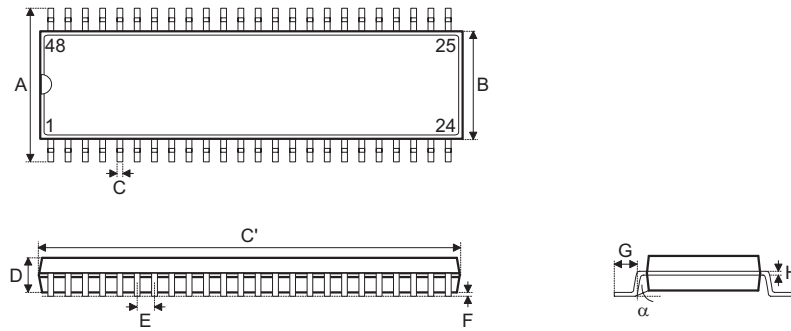
SIZ [m]	Skip if increment Data Memory is 0
Description	The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	$[m] \leftarrow [m] + 1$ 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	$ACC \leftarrow [m] + 1$ 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 $[m].i \neq 0$
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	$ACC \leftarrow ACC - [m]$
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	$[m] \leftarrow ACC - [m]$
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	$ACC \leftarrow ACC - x$
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	$[m].3 \sim [m].0 \leftrightarrow [m].7 \sim [m].4$
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	$ACC.3 \sim ACC.0 \leftarrow [m].7 \sim [m].4$ $ACC.7 \sim ACC.4 \leftarrow [m].3 \sim [m].0$
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	$ACC \leftarrow [m]$ 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	$[m] \leftarrow$ program code (low byte) $TBLH \leftarrow$ 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	$[m] \leftarrow$ program code (low byte) $TBLH \leftarrow$ 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

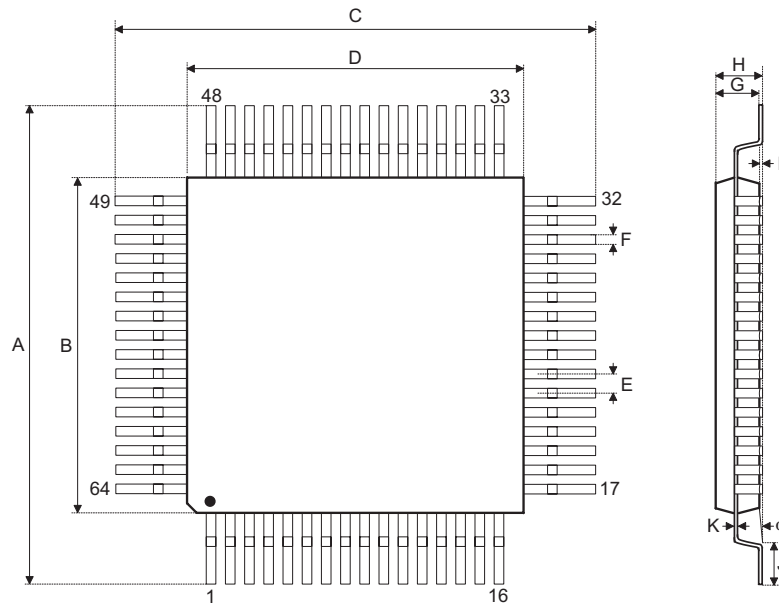
Package Information

48-pin SSOP (300mil) Outline Dimensions



Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	395	—	420
B	291	—	299
C	8	—	12
C'	613	—	637
D	85	—	99
E	—	25	—
F	4	—	10
G	25	—	35
H	4	—	12
α	0°	—	8°

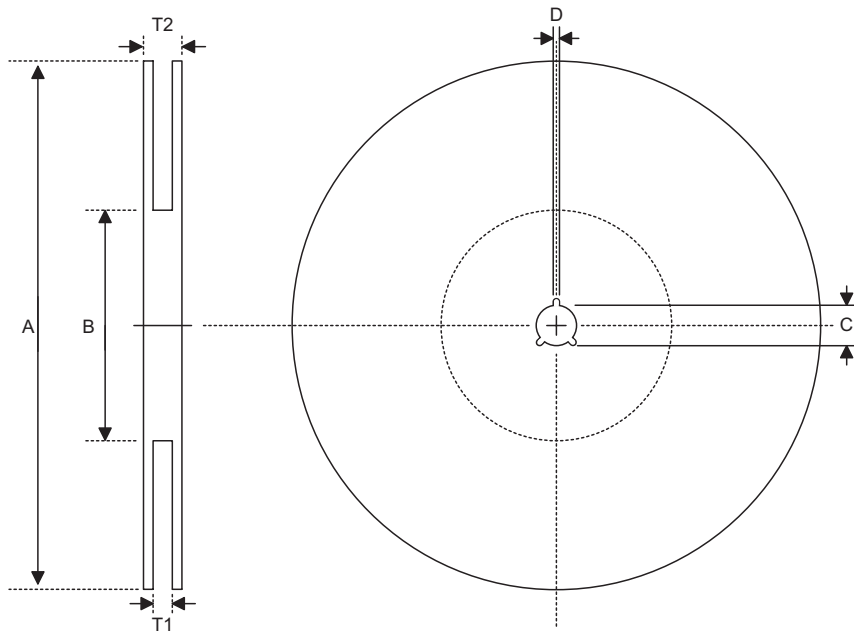
64-pin LQFP (7mm×7mm) Outline Dimensions



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	8.9	—	9.1
B	6.9	—	7.1
C	8.9	—	9.1
D	6.9	—	7.1
E	—	0.4	—
F	0.13	—	0.23
G	1.35	—	1.45
H	—	—	1.6
I	0.05	—	0.15
J	0.45	—	0.75
K	0.09	—	0.20
α	0°	—	7°

Product Tape and Reel Specifications

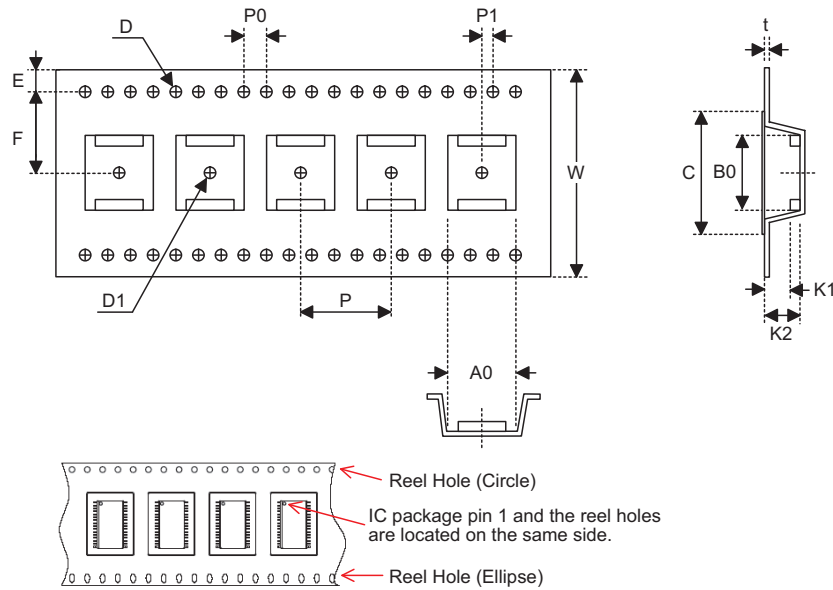
Reel Dimensions



SSOP 48W

Symbol	Description	Dimensions in mm
A	Reel Outer Diameter	330.0±1.0
B	Reel Inner Diameter	100.0±0.1
C	Spindle Hole Diameter	13.0 ^{+0.5/-0.2}
D	Key Slit Width	2.0±0.5
T1	Space Between Flange	32.2 ^{+0.3/-0.2}
T2	Reel Thickness	38.2±0.2

Carrier Tape Dimensions



SSOP 48W

Symbol	Description	Dimensions in mm
W	Carrier Tape Width	32.0±0.3
P	Cavity Pitch	16.0±0.1
E	Perforation Position	1.75±0.10
F	Cavity to Perforation (Width Direction)	14.2±0.1
D	Perforation Diameter	2 Min.
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	12.0±0.1
B0	Cavity Width	16.2±0.1
K1	Cavity Depth	2.4±0.1
K2	Cavity Depth	3.2±0.1
t	Carrier Tape Thickness	0.35±0.05
C	Cover Tape Width	25.5±0.1

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