

GENERAL DESCRIPTION

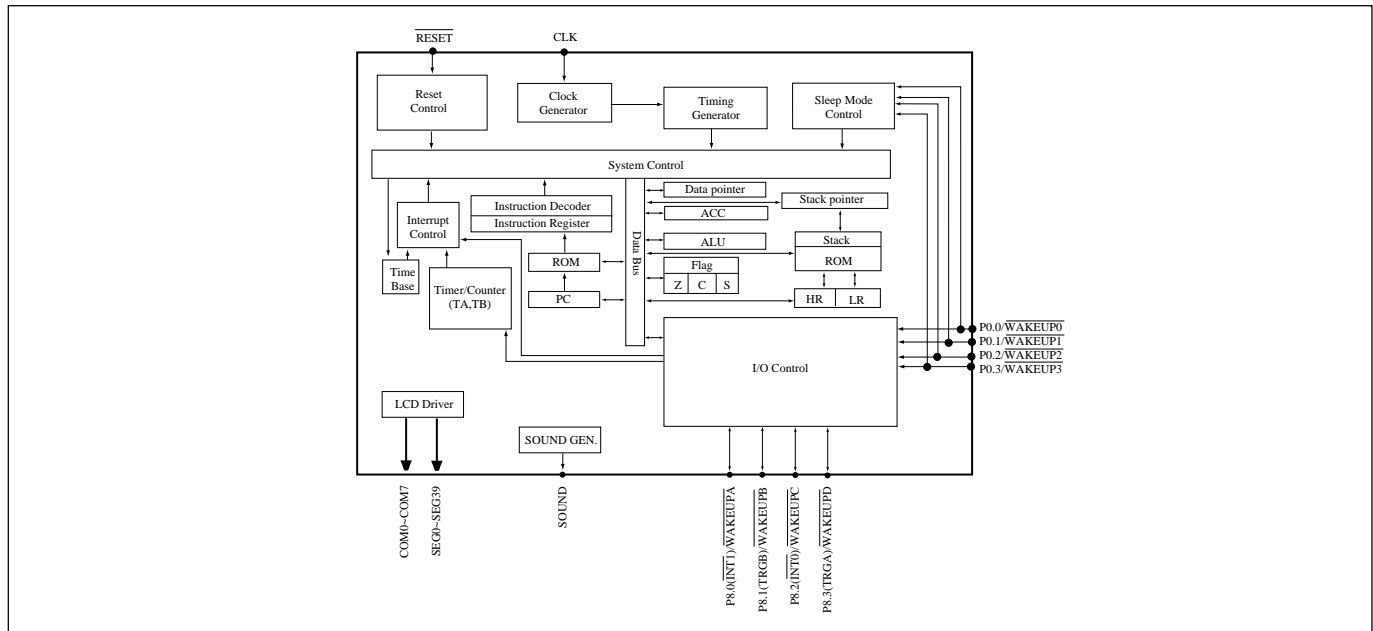
EM73962A is an advanced single chip CMOS 4-bit micro-controller. It contains 16K-byte ROM, 372-nibble RAM, 4-bit ALU, 13-level subroutine nesting, 22-stage time base, two 12-bit timer/counters for the kernel function. EM73962A also contains 5 interrupt sources, 3 I/O ports (including 1 input port and 2 bidirection ports), LCD display (40x8), built-in sound generator.

Except low-power consumption and high speed, EM73962A also have a sleep mode for power saving function. EM73962A is suitable for application in many fields, for example : family appliance, consumer products, handheld games and the toy controller ... etc.

FEATURES

- Operation voltage : 2.4V to 5.0V.
- Clock source : Single clock system using RC. oscillator.
External clock and internal clock is available by mask option.
- Oscillation frequency : 480K, 1M, 2M and 4M Hz is available by mask option.
- Instruction set : 107 powerful instructions.
- Instruction cycle time : Up to 2us for 4 MHz.
- ROM capacity : 16384 X 8 bits.
- RAM capacity : 372 X 4 bits.
- Input port : 1 port (P0.0-P0.3) and sleep/hold releasing function are available by mask option.
(each input pin is pull-up and pull-down resistor available by mask option).
- Bidirection port : 1 port (P8). P8(0..3) and sleep/hold releasing function are available by mask option.
- 12-bit timer/counter : Two 12-bit timer/counters are programmable for timer, event counter and pulse width measurement.
- Built-in time base counter : 22 stages.
- Subroutine nesting : Up to 13 levels.
- Interrupt : External 2 input interrupt sources.
Internal 2 Timer overflow interrupts.
1 Time base interrupt.
- LCD driver : 40 X 8 dots, 1/8 duty, LCD bias is 1/4 and 1/5 available by mask option, LCD bias resistor is 20K X 5 and 10K X 5 available by mask option.
- Sound effect : Tone generator, random generator and volume control.
- Power saving function: Sleep mode and Hold mode.
- Package type : EM73962AH Chip form 62 pins.

FUNCTION BLOCK DIAGRAM



PIN DESCRIPTIONS

Symbol	Pin-type	Function
V_{DD}		Power supply (+)
V_{SS}		Power supply (-)
\overline{RESET}	RESET-A	System reset input signal, low active mask option : none pull-up
CLK	OSC-C	RC or external clock source connecting pin
P0.(0..3)/ $\overline{WAKEUP0..3}$	INPUT-B	4-bit input port with Sleep/Hold releasing function mask option : wakeup enable, pull-up wakeup enable, none wakeup disable, pull-up wakeup disable, pull-down wakeup disable, none
P8.0($\overline{INT1}$)/ $\overline{WAKEUPA}$ P8.2($\overline{INT0}$)/ $\overline{WAKEUPC}$	I/O-L	2-bit bidirection I/O port with external interrupt sources input and Sleep/Hold releasing function mask option : wakeup enable, push-pull wakeup disable, push-pull wakeup disable, open-drain
P8.1(TRGB)/ $\overline{WAKEUPB}$ P8.3(TRGA)/ $\overline{WAKEUPD}$	I/O-L	2-bit bidirection I/O port with time/counter A,B external input and Sleep/Hold releasing function mask option : wakeup enable, push-pull wakeup disable, push-pull wakeup disable, open-drain
SOUND		Built-in sound effect output
COM0~COM7		LCD common output pins
SEG0~SEG39		LCD segment output pins
TEST		No connecting for COB

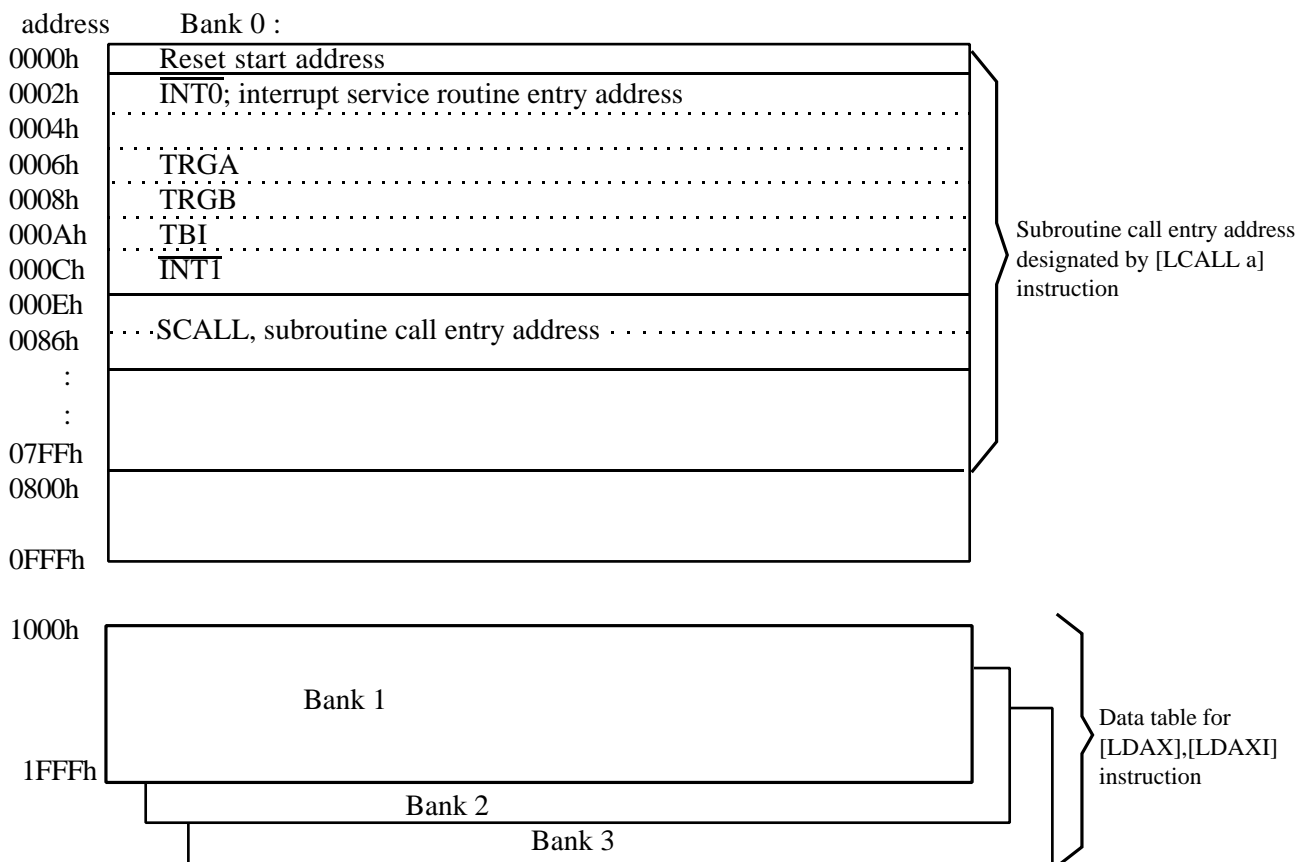
FUNCTION DESCRIPTIONS

PROGRAM ROM (16K X 8 bits) for EM73962A

16 K x 8 bits program ROM contains user's program and some fixed data.

The basic structure of program ROM can be divided into 4 parts.

1. Address 0000h: Reset start address.
2. Address 0002h - 000Ch : 5 kinds of interrupt service routine entry addresses.
3. Address 000Eh - 0086h : SCALL subroutine entry address, only available at 000Eh, 0016h, 001Eh, 0026h, 002Eh, 0036h, 003Eh, 0046h, 004Eh, 0056h, 005Eh, 0066h, 006Eh, 0076h, 007Eh, 0086h.
4. Address 0000h - 07FFh : LCALL subroutine entry address.
5. Address 0000h - 1FFFh : Except used as above function, the other region can be used as user's program region.



User's program and fixed data are stored in the program ROM. User's program is according the PC value to send next executed instruction code.

The 16Kx8 bits program ROM can be divided into 4 banks. There are 4Kx8 bits in each bank.

The bank of the program ROM is selected by P3(1..0). The program counter is a 13-bit binary counter. The PC and P3 are initialized to "0" during reset.

When P3(1..0)=00B, the bank0 and bank1 of program ROM will be selected. P3(1..0)=01B, the the bank0 and bank2 will be selected. P3(1..0)=10B, the bank0 and bank3 will be selected.

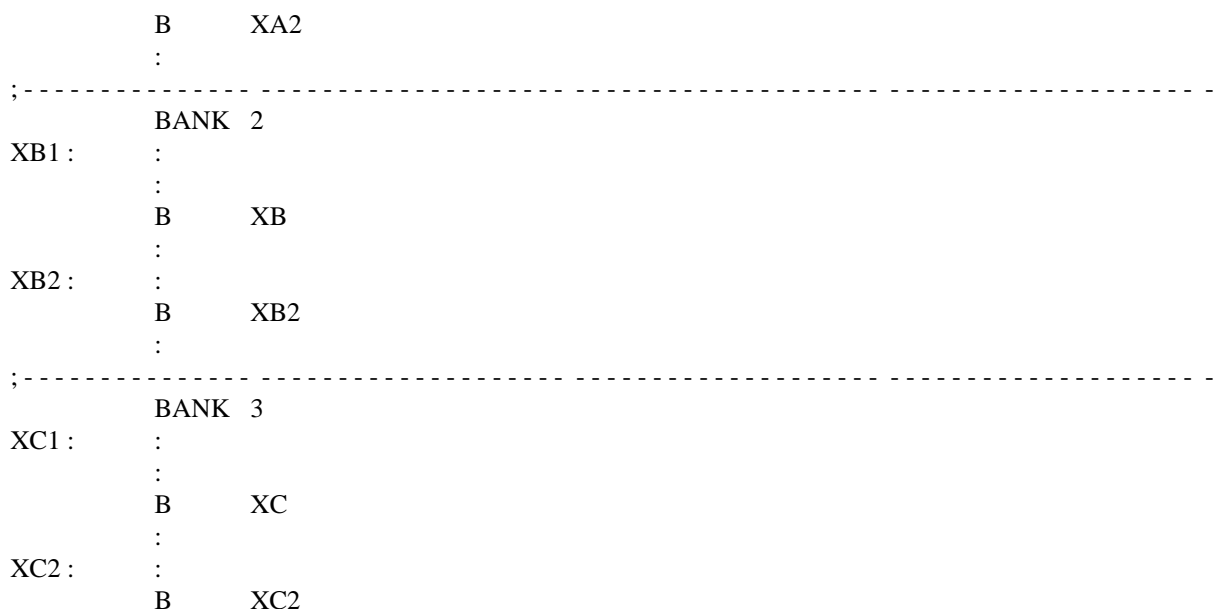
Address	P3=xx00B	P3=xx01B	P3=xx10b
0000h	Bank0	Bank0	Bank0
:			
:			
0FFFh	Bank1	Bank2	Bank3
1000h			
:			
:	Bank1	Bank2	Bank3
:			
1FFFh			

PROGRAM EXAMPLE:

```

      BANK 0
START:  :
        :
        :
        LDIA  #00H          ; set program ROM to bank1
        OUTA  P3
        B      XA1
XA :    :
        :
        :
        LDIA  #01H          ; set program ROM to bank2
        OUTA  P3
        B      XB1
XB :    :
        :
        :
        LDIA  #02H          ; set program ROM to bank3
        OUTA  P3
        B      XC1
XC :    :
        :
        :
        B      XD
XD :    :
        :
        :
        :
;-----
      BANK 1
XA1 :   :
        :
        :
        B      XA
        :
XA2 :   :

```



Fixed data can be read out by table-look-up instruction. Table-look-up instruction is depended on the Data Pointer (DP) to ROM address, then to get the ROM code data :

LDAX **Acc ← ROM[DP]_L**
LDAXI **Acc ← ROM[DP]_H, DP+1**

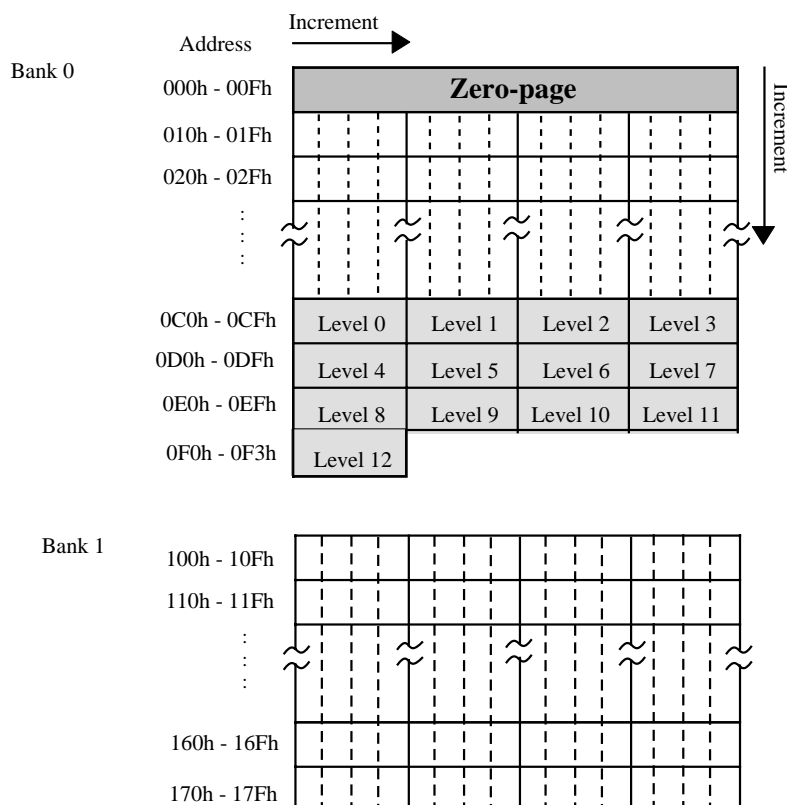
DP is a 12-bit data register which can store the program ROM address to be the pointer for the ROM code data. First, user load ROM address into DP by instruction "STADPL, STADPM, STADPH", then user can get the lower nibble of ROM code data by instruction "LDAX" and higher nibble by instruction "LDAXI"

PROGRAM EXAMPLE: Read out the ROM code of address 1777h by table-look-up instruction.

```
LDIA #07h;
STADPL   ; [DP]L ← 07h
STADPM   ; [DP]M ← 07h
STADPH   ; [DP]H ← 07h, Load DP=777h
:
LDL #00h;
LDH #03h;
LDAX     ; ACC ← 6h
STAMI    ; RAM[30] ← 6h
LDAXI    ; ACC ← 5h
STAM     ; RAM[31] ← 5h
;
ORG 1777h
DATA 56h;
```

DATA RAM (372-nibble)

There is total 372 - nibble data RAM from address 000 to 17Fh
 Data RAM includes 3 parts: zero page region, stacks and data area.



ZERO- PAGE:

From 000h to 00Fh is the location of zero-page. It is used as the pointer in zero -page addressing mode for the instruction of "STD #k,y; ADD #k,y; CLR y,b; CMP k,y".

PROGRAM EXAMPLE: To write immediate data "07h" to address "003h" of RAM and to clear bit 2 of RAM.

```
STD #07h, 03h ; RAM[03] ← 07h
CLR 0Eh,2 ; RAM[0Eh]2 ← 0
```

STACK:

There are 13 - level (maximum) stack for user using for subroutine (including interrupt and CALL). User can assign any level be the starting stack by giving the level number to stack pointer(SP).

When user using any instruction of CALL or subroutine, before entry the subroutine, the previous PC address will be saved into stack until return from those subroutines, the PC value will be restored by the data saved in stack.

DATA AREA:

Except the special area used by user, the whole RAM can be used as data area for storing and loading general data.

ADDRESSING MODE

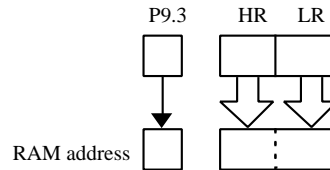
The 372 nibble data memory consists of two banks (bank 0 and bank 1). There are 244x4 bits (address 000h~0F3h) on bank 0 and 128x4 bits (address 100h~17Fh) on bank 1.

There are three addressing modes in the data memory :

(1) Indirect addressing mode:

The bank is selected by P9.3. When P9.3 is cleared to "0", the bank 0 is selected.

When P9.3 is set to "1", the bank 1 is selected. The address in the bank are specified by the HL registers.



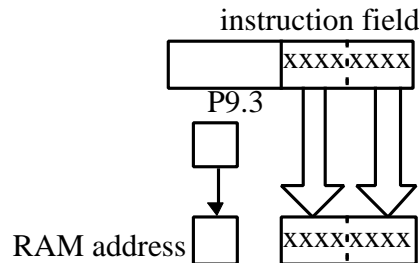
PROGRAM EXAMPLE: Load the data of RAM address "143h" to RAM address "023h".

```
SEP P9,3 ; P9.3 ← 1
LDL #3h ; LR ← 3
LDH #4h ; HR ← 4
LDAM ; Acc ← RAM[134h]
CLP P9,3 ; P9.3 ← 0
LDL #2h ; LR ← 2
LDH #3h ; HR ← 3
STAM ; RAM[023h] ← Acc
```

(2) Direct addressing mode:

The bank is selected by P9.3. When P9.3 is cleared to "0", the bank 0 is selected.

When P9.3 is set to "1", the bank 1 is selected. The address in the bank are directly specified by 8 bits of the second byte in the instruction field.

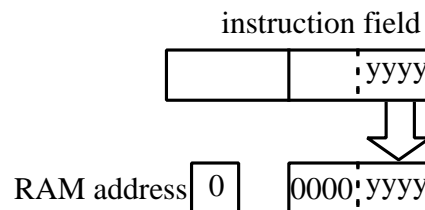


PROGRAM EXAMPLE: Load the data of RAM address "143h" to RAM address "023h".

```
SEP P9,3 ; P9.3 ← 1
LDA 43h ; Acc ← RAM[134h]
CLP P9,3 ; P9.3 ← 0
STA 23h ; RAM[023h] ← Acc
```

(3) Zero-page addressing mode:

The zero-page is the bank 0 (address 000h~00Fh). The address are the lower 4 bits of the second byte in the instruction field.



PROGRAM EXAMPLE: Write immediate "0Fh" to RAM address "005h".

```
STD #0Fh, 05h ; RAM[05h] ← 0Fh
```

PROGRAM COUNTER (16K ROM) for EM73962A

Program counter (PC) is composed by a 13-bit counter, which indicates the next executed address for the instruction of program ROM.

For a 8K - byte size ROM, PC can indicate address form 0000h - 1FFFh, for BRANCH and CALL instrcutions, PC is changed by instruction indicating.

(1) Branch instruction:

SBR a

Object code: 00aa aaaa

Condition: SF=1; PC \leftarrow PC_{12-6,a} (branch condition satisfied)

PC

Hold original PC value+1	a	a	a	a	a	a
--------------------------	---	---	---	---	---	---

SF=0; PC \leftarrow PC + 1(branch condition not satisfied)

PC

Original PC value + 1

LBR a

Object code: 1100 aaaa aaaa aaaa

Condition: SF=1; PC \leftarrow PC_{12,a} (branch condition satisfied)

PC

Hold +2	a	a	a	a	a	a	a	a	a	a	a
------------	---	---	---	---	---	---	---	---	---	---	---

SF=0; PC \leftarrow PC + 2(branch condition not satisfied)

PC

Original PC value + 2

SLBR a

Object code: 0101 0101 1100 aaaa aaaa aaaa (a:1000h~1FFFh)

0101 0111 1100 aaaa aaaa aaaa (a:0000h~0FFFh)

Condition: SF=1; PC \leftarrow a (branch condition satisfied)

PC

a	a	a	a	a	a	a	a	a	a	a	a	a
---	---	---	---	---	---	---	---	---	---	---	---	---

SF=0 ; PC \leftarrow PC + 3 (branch condition not satisfied)

PC

Original PC value + 3

(2) Subroutine instruction:

SCALL a

Object code: 1110 nnnn

Condition : PC \leftarrow a ; a=8n+6 ; n=1..Fh ; a=86h, n=0

PC

0	0	0	0	0	0	a	a	a	a	a	1	1	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---

LCALL a

Object code: 0100 0aaa aaaa aaaa

Condition: PC \leftarrow a

PC

0	0	a	a	a	a	a	a	a	a	a	a	a
---	---	---	---	---	---	---	---	---	---	---	---	---

RET

Object code: 0100 1111

Condition: $PC \leftarrow \text{STACK}[SP]; SP + 1$

PC

The return address stored in stack											
------------------------------------	--	--	--	--	--	--	--	--	--	--	--

RTI

Object code: 0100 1101

Condition : $\text{FLAG}. PC \leftarrow \text{STACK}[SP]; EI \leftarrow 1; SP + 1$

PC

The return address stored in stack											
------------------------------------	--	--	--	--	--	--	--	--	--	--	--

(3) Interrupt acceptance operation:

When an interrupt is accepted, the original PC is pushed into stack and interrupt vector will be loaded into PC, The interrupt vectors are as following:

INT0 (External interrupt from P8.2)

PC

0	0	0	0	0	0	0	0	0	0	0	1	0
---	---	---	---	---	---	---	---	---	---	---	---	---

TRGA (Timer A overflow interrupt)

PC

0	0	0	0	0	0	0	0	0	0	1	1	0
---	---	---	---	---	---	---	---	---	---	---	---	---

TRGB (Time B overflow interrupt)

PC

0	0	0	0	0	0	0	0	0	1	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---

TBI (Time base interrupt)

PC

0	0	0	0	0	0	0	0	0	1	0	1	0
---	---	---	---	---	---	---	---	---	---	---	---	---

INT1 (External interrupt from P8.0)

PC

0	0	0	0	0	0	0	0	0	1	1	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---

(4) Reset operation:

PC

0	0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---

(5) Other operations:

For 1-byte instruction execution: $PC + 1$

For 2-byte instruction execution: $PC + 2$

For 3-byte instruction execution: $PC + 3$

ACCUMULATOR

Accumulator is a 4-bit data register for temporary data. For the arithmetic, logic and comparative operation ..., ACC plays a role which holds the source data and result.

FLAGS

There are three kinds of flag, CF (Carry flag), ZF (Zero flag), SF (Status flag), these 3 1-bit flags are affected by the arithmetic, logic and comparative operation.

All flags will be put into stack when an interrupt subroutine is served, and the flags will be restored after RTI instruction executed.

(1) Carry Flag (CF)

The carry flag is affected by following operation:

- a. Addition : CF as a carry out indicator, when the addition operation has a carry-out, CF will be "1", in another word, if the operation has no carry-out, CF will be "0".
- b. Subtraction : CF as a borrow-in indicator, when the subtraction operation must has a borrow, in the CF will be "0", in another word, if no borrow-in, CF will be "1".
- c. Comparison: CF is as a borrow-in indicator for Comparison operation as the same as subtraction operation.
- d. Rotation: CF shifts into the empty bit of accumulator for the rotation and holds the shift out data after rotation.
- e. CF test instruction : For TFCFC instruction, the content of CF sends into SF then clear itself "0". For TTSFC instruction, the content of CF sends into SF then set itself "1".

(2) Zero Flag (ZF)

ZF is affected by the result of ALU, if the ALU operation generate a "0" result, the ZF will be "1", otherwise, the ZF will be "0".

(3) Status Flag (SF)

The SF is affected by instruction operation and system status.

- a. SF is initiated to "1" for reset condition.
- b. Branch instruction is decided by SF, when SF=1, branch condition will be satisfied, otherwise, branch condition will not be satisfied by SF = 0.

PROGRAM EXAMPLE:

Check following arithmetic operation for CF, ZF, SF

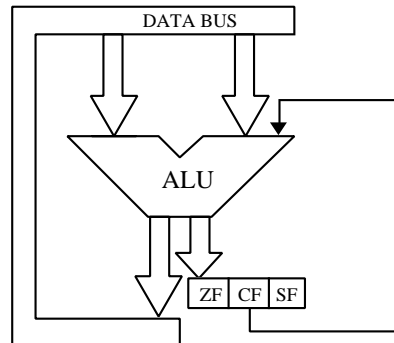
	CF	ZF	SF
LDIA #00h;	-	1	1
LDIA #03h;	-	0	1
ADDA #05h;	-	0	1
ADDA #0Dh;	-	0	0
ADDA #0Eh;	-	0	0

ALU

The arithmetic operation of 4 - bit data is performed in ALU unit. There are 2 flags can be affected by the result of ALU operation, ZF and SF. The operation of ALU can be affected by CF only.

ALU STRUCTURE

ALU supported user arithmetic operation function, including : addition, subtraction and rotaion.



ALU FUNCTION

(1) Addition:

For instruction ADDAM, ADCAM, ADDM #k, ADD #k,y ALU supports addition function. The addition operation can affect CF and ZF. For addition operation, if the result is "0", ZF will be "1", otherwise, not equal "0", ZF will be "0", When the addition operation has a carry-out. CF will be "1", otherwise, CF will be "0".

EXAMPLE:

Operation	Carry	Zero
3+4=7	0	0
7+F=6	1	0
0+0=0	0	1
8+8=0	1	1

(2) Subtraction:

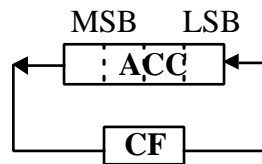
For instruction SUBM #k, SUBA #k, SBCAM, DECM... ALU supports user subtraction function. The subtraction operation can affect CF and ZF, For subtraction operation, if the result is negative, CF will be "0", it means a borrow out, otherwise, if the result is positive, CF will be "1". For ZF, if the result of subtraction operation is "0", the ZF will be "1", otherwise, ZF will be "1".

EXAMPLE:

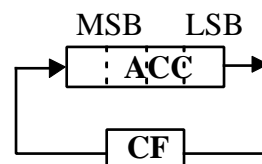
Operation	Carry	Zero
8-4=4	1	0
7-F=-8(1000)	0	0
9-9=0	1	1

(3) Rotation:

There are two kinds of rotation operation, one is rotation left, the other is rotation right.
RLCA instruction rotates Acc value to left, shift the CF value into the LSB bit of Acc and the shift out data will be hold in CF.



RRCA instruction operation rotates Acc value to right, shift the CF value into the MSB bit of Acc and the shift out data will be hold in CF.



PROGRAM EXAMPLE: To rotate Acc right and shift a "1" into the MSB bit of Acc.

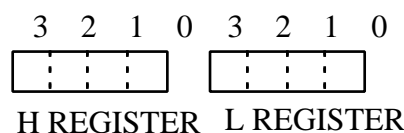
TTCFS; CF ← 1

RRCA; rotate Acc right and shift CF=1 into MSB.

HL REGISTER

HL register are two 4-bit registers, they are used as a pair of pointer for the address of RAM memory and also 2 independent temporary 4-bit data registers. For some instruction, L register can be a pointer to indicate the pin number (Port4).

HL REGISTER STRUCTURE



HL REGISTER FUNCTION

- (1) For instruction : LDL #k, LDH #k, THA, THL, INCL, DECL, EXAL, EXAH, HL register used as a temporary register.

PROGRAM EXAMPLE: Load immediate data "5h" into L register, "Dh" into H register.

LDL#05h;

LDH#0Dh;

- (2) For instruction LDAM, STAM, STAMI .., HL register used as a pointer for the address of RAM memory.

PROGRAM EXAMPLE: Store immediate data #Ah into RAM of address 35h.

```
LDL #5h;
LDH #3h;
STDMI #0Ah; RAM[35] ← Ah
```

(3) For instruction : SELP, CLPL, TFPL, L register be a pointer to indicate the bit of I/O port.

When LR = 0 indicate P4.0

PROGRAM EXAMPLE: To set bit 0 of Port4 to "1"

```
LDL #00h;
SEPL ; P4.0 ← 1
```

STACK POINTER (SP)

Stack pointer is a 4-bit register which stores the present stack level number.

Before using stack, user must set the SP value first, CPU will not initiate the SP value after reset condition.

When a new subroutine is accepted, the SP will be decreased one automatically, in another word, if returning from a subroutine, the SP will be increased one.

The data transfer between ACC and SP is by instruction of "LDASP" and "STASP".

DATA POINTER (DP)

Data pointer is a 12-bit register which stores the address of ROM can indicate the ROM code data specified by user (refer to data ROM).

CLOCK AND TIMING GENERATOR

The clock generator is supported by a single clock system, the clock source comes from RC oscillation, the working frequency range is 480 K Hz to 4 MHz depending on the external resistor.

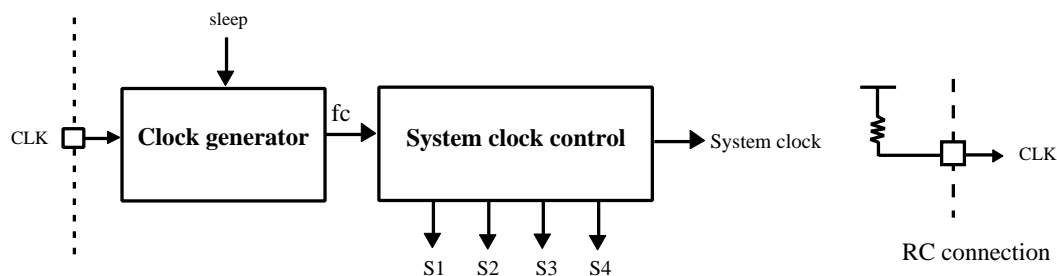
CLOCK AND TIMING GENERATOR STRUCTURE

The clock generator connects outside compoments (only a resistor connects to VDD and CLK pin).

The clock generator generates a basic system clock "fc".

When CPU sleeping, the clock generator will be stoped until the sleep condition released.

The system clock control generates 4 basic phase signals (S1, S2, S3, S4) and system clock.



CLOCK AND TIMING GENERATOR FUNCTION

The frequency of fc is the oscillation frequency for CLK by RC oscillator.

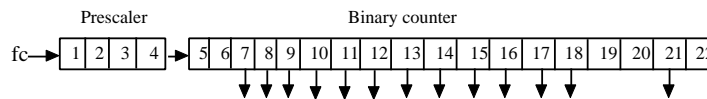
The instruction cycle equal 8 basic clock f_c .
1 instruction cycle = 8 / f_c

TIMING GENERATOR AND TIME BASE

The timing generator produces the system clock from basic clock pulse which can be normal mode or slow mode clock.

1 instruction cycle = 8 basic clock pulses

There are 22 stages time base.



When working in the single clock mode, the timebase clock source is come from f_c .

Time base provides basic frequency for following function:

1. TBI (time base interrupt).
2. Timer/counter, internal clock source.
3. Warm-up time for sleep - mode releasing.

TIME BASE INTERRUPT (TBI)

The time base can be used to generate a fixed frequency interrupt. There are 8 kinds of frequencies can be selected by setting "P25"

Single clock mode

P25

3	2	1	0
---	---	---	---

(initial value 0000)

- 0 0 x x: Interrupt disable
- 0 1 0 0: Interrupt frequency $f_c / 2^{10}$ Hz
- 0 1 0 1: Interrupt frequency $f_c / 2^{11}$ Hz
- 0 1 1 0: Interrupt frequency $f_c / 2^{12}$ Hz
- 0 1 1 1: Interrupt frequency $f_c / 2^{13}$ Hz
- 1 1 0 0: Interrupt frequency $f_c / 2^9$ Hz
- 1 1 0 1: Interrupt frequency $f_c / 2^8$ Hz
- 1 1 1 0: Interrupt frequency $f_c / 2^{15}$ Hz
- 1 1 1 1: Interrupt frequency $f_c / 2^{17}$ Hz
- 1 0 x x: Reserved

TIMER / COUNTER (TIMERA, TIMERB)

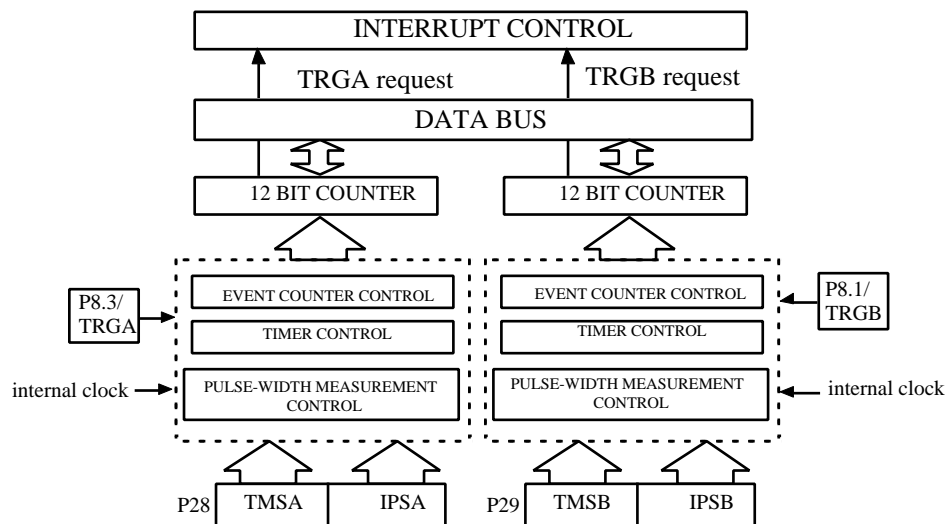
Timer/counters can support user three special functions:

1. Even counter
2. Timer.
3. Pulse-width measurement.

These three functions can be executed by 2 timer/counter independently.

For timerA, the counter data is saved in timer register TAH, TAM, TAL, which user can set counter initial value and read the counter value by instruction "LDATAH(M,L), STATAH(M,L)" and timer register is TBH, TBM, TBL and W/R instruction "LDATBH (M,L), STATBH (M,L)".

The basic structure of timer/counter is composed by two same structure counter, these two counters can be set initial value and send counter value to timer register, P28 and P29 are the command ports for timerA and timer B, user can choose different operation mode and different internal clock rate by setting these two ports. When timer/counter overflow, it will generate a TRGA(B) interrupt request to interrupt control unit.



TIMER/COUNTER CONTROL

P8.1/TRGB, P8.3/TRGA are the external timer inputs for timerB and timerA, they are used in event counter and pulse-width measurement mode.

Timer/counter command port: P28 is the command port for timer/counterA and P29 is for the timer/counterB.

Port 28 3 2 1 0
 TMSA IPSA
 Initial state : 0000

Timer/Counter mode selection	
TMSA(B)	Function description
00	Stop
01	Event counter mode
10	Timer mode
11	Pulse width measurement mode

Port 29 3 2 1 0
 TMSB IPSB
 Initial state : 0000

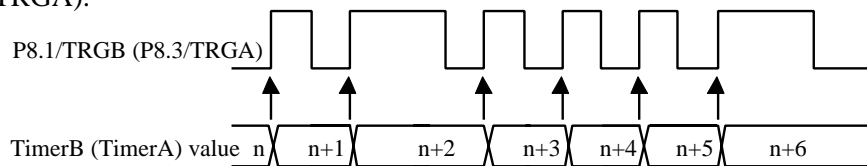
Internal Pulse-rate selection	
IPSA(B)	Function description
00	$f_c/2^{10}\text{Hz}$
01	$f_c/2^{14}\text{Hz}$
10	$f_c/2^{18}\text{Hz}$
11	$f_c/2^{22}\text{Hz}$

TIMER/COUNTER FUNCTION

Timer/counterA can be programmable for timer, event counter and pulse width measurement. Each timer/counter can execute any one of these functions independently.

EVENT COUNTER MODE

For event counter mode, timer/counter increases one at any rising edge of P8.1/TRGB for timerB (P8.3/TRGA for timer A). When timerB (timerA) counts overflow, it will give interrupt control an interrupt request TRGB (TRGA).



PROGRAM EXAMPLE: Enable timerA with P28

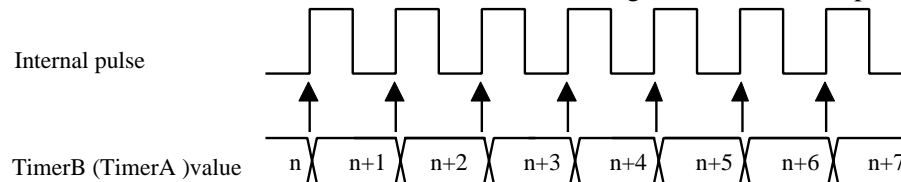
```
LDIA #0100B;
```

```
OUTA P28; Enable timerA with event counter mode
```

TIMER MODE

For timer mode, timer/counter increase one at any rising edge of internal pulse. User can choose 4 kinds of internal pulse rate by setting IPSB for timerB (IPSA for timerA).

When timer/counter counts overflow, TRGB (TRGA) will be generated to interrupt control unit.



PROGRAM EXAMPLE: To generate TRGA interrupt request after 60 ms with system clock $f_c=4\text{MHz}$

```
LDIA    #0100B    ;
EXAE                    ; enable mask 2
EICIL    110111B    ; interrupt latch ← 0, enable EI
LDIA    #06H        ;
STATAL                    ;
LDIA    #01H        ;
STATAM                    ;
LDIA    #0FH        ;
STATAH                    ;
LDIA    #1000B       ;
OUTA    P28          ; enable timerA with internal pulse rate:  $f_c/2^{10}$  Hz
```

NOTE: The preset value of timer/counter register is calculated as following procedure.

Internal pulse rate: $f_c/2^{10}$; $f_c = 4\text{MHz}$

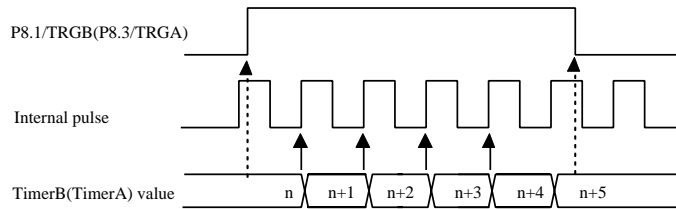
The time of timer counter count one = $2^{10} / f_c = 1024/4000 = 0.256\text{ms}$

The number of internal pulse to get timer overflow = $60\text{ ms} / 0.256\text{ms} = 234.375 = 0\text{EAH}$

The preset value of timer/counter register = $1000\text{H} - 0\text{EAH} = 0\text{F16H}$

PULSE WIDTH MEASUREMENT MODE

For the pulse width measurement mode, the counter only increased by the rising edge of internal pulse rate as external timer/counter input (P8.1/TRGB, P8.3/TRGA), interrupt request will be generated as soon as timer/counter count overflow.



PROGRAM EXAMPLE: Enable timerA by pulse width measurement mode.

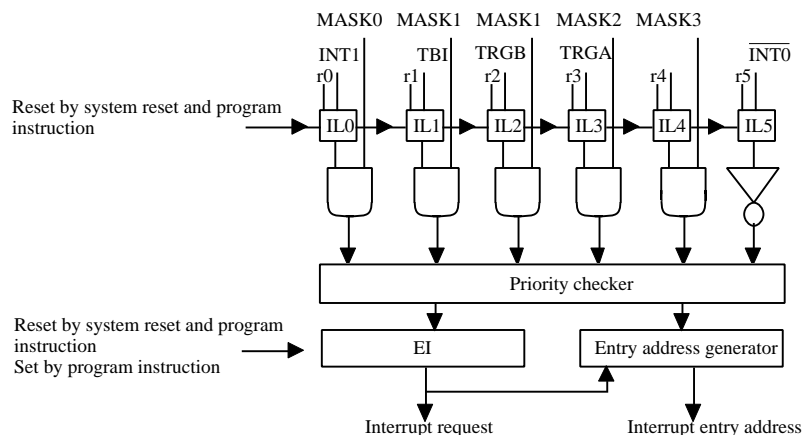
```
LDIA    #1100b    ;
OUTA    P28        ; Enable timerA with pulse width measurement mode.
```

INTERRUPT FUNCTION

There are 5 interrupt sources, 2 external interrupt sources, 3 internal interrupt sources. Multiple interrupts are admitted according the priority.

Type	Interruptsource	Priority	Interrupt Latch	Interrupt Enablecondition	ProgramROM entry address
External	Externalinterrupt($\overline{\text{INT0}}$)	1	IL5	EI=1	002h
Internal	Reserved	2	IL4	EI=1,MASK3=1	004h
Internal	TimerA overflow interrupt (TRGA)	3	IL3	EI=1,MASK2=1	006h
Internal	TimerB overflow interrupt (TRGB)	4	IL2	EI=1,MASK1=1	008h
Internal	Time base interrupt(TBI)	5	IL1		00Ah
External	Externalinterrupt(INT1)	6	IL0	EI=1,MASK0=1	00Ch

INTERRUPT STRUCTURE



Interrupt controller:

IL0-IL5 : Interrupt latch. Hold all interrupt requests from all interrupt sources. ILr can not be set by program, but can be reset by program or system reset, so IL only can decide which interrupt source can be accepted.

MASK0-MASK3 : Except $\overline{\text{INT0}}$, MASK register can permit or inhibit all interrupt sources.

EI : Enable interrupt Flip-Flop can permit or inhibit all interrupt sources, when interrupt happened, EI is cleared to "0" automatically, after RTI instruction happened, EI will be set to "1" again.

Priority checker : Check interrupt priority when multiple interrupts happened.

INTERRUPT FUNCTION

The procedure of interrupt operation:

1. Push PC and all flags to stack.
2. Set interrupt entry address into PC.
3. Set SF= 1.
4. Clear EI to inhibit other interrupts happened.
5. Clear the IL for which interrupt source has already be accepted.
6. To excute interrupt subroutine from the interrupt entry address.
7. CPU accept RTI, restore PC and flags from stack. Set EI to accept other interrupt requests.

PROGRAM EXAMPLE: To enable interrupt of "INT0, TRGA"

```
LDIA    #1100B;
EXAE          ; set mask register "1100B"
EICIL    11111B ; enable interrupt F.F.
```

POWER SAVING FUNCTION (Sleep / Hold function)

During sleep and hold condition, CPU holds the system's internal status with a low power consumption, for the sleep mode, the system clock will be stoped in the sleep condition and system need a warm up time for the stability of system clock running after wakeup. In the other way, for the hold mode, the system clock does not stop at all and it does not need a warm-up time any way.

The sleep and hold mode is controlled by Port 16 and released by P0(0..3)/WAKEUP0..3 or P8(0..3)/WAKEUPA..D.

P16 3 2 1 0

WM	SE	SWWT
----	----	------

initial value :0000

SWWT	Set wake-up warm-up time
0 0	$2^{18} / f_c$
0 1	$2^{14} / f_c$
1 0	$2^{16} / f_c$
1 1	Hold mode

WM	Set wake-up release mode
0	Wake-up in edge release mode
1	Wake-up in level release mode

SE	Enable sleep/hold
0	Reserved
1	Enable sleep / hold mode

Sleep and hold condition:

1. Osc stop (sleep only) and CPU internal status held.
2. Internal time base clear to "0".
3. CPU internal memory, flags, register, I/O held original states.
4. Program counter hold the executed address after sleep release.

Release condition:

1. Osc start to oscillating.(sleep only).
2. Warm-up time passing (sleep only).
3. According PC to execute the following program.

There is one kind of sleep/hold release mode.

Edge release mode:

Release sleep/hold condition by the falling edge of any one of P0(0..3)/WAKEUP0..3 or P8(0..3)/WAKEUPA..D.

Note : There are 8 independent mask options for wakeup function in EM73962A. So, the wakeup function of P0(0..3)/WAKEUP0..3 and P8(0..3)/WAKEUPA..D are enabled or disabled independently.

LCD DRIVER

It can directly drive the liquid crystal display (LCD) and has 40 segments, 8 commons output pins. There are total 40x8 dots can be display.

(1) LCD driver control command register:

Port27 3 2 1 0 Initial value: 0h

LDC	*	*
LCD DISPLAY CONTROL		
LDC	Function description	
0 0	LCD display disable	
0 1	Blanking, change COMMON pin output	
1 0	Reserved	
1 1	LCD display enable	

* : Don't care.

P27 is the LDC driver control command register . The initial value is 0000.

When LDC (bit2 and bit3 of P27) is set to "00", the LCD display is disabled.

When LDC is set to "01", the LCD is blanking, the COM pins are inactive and the SEG pins continuously output the display data.

The power switch of LCD driver is turned off when the CPU is reseted.

When LDC is set to "11", the LCD display is enabled, the power switch is turned on and it can not be turned off forever except the CPU is reseted again.

The power switch is also turned off during the sleep operation. Users must enable the LCD display again by self when the CPU is waked up.

(2) LCD display data area:

The LCD display data is stored in the display data area of the data memory (RAM).

The display data area begins with address 20H during reset. The LCD display data area is as below:

RAM	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
20H				C	O	M	0									
30H				C	O	M	1									
40H				C	O	M	2									
50H				C	O	M	3									
60H				C	O	M	4									
70H				C	O	M	5									
80H				C	O	M	6									
90H				C	O	M	7									

SSSS SSSS SSSS SSSS SSSS SSSS SSSS SSSS SSSS SSSS

EEEE EEEEEEEEE EEEE EEEE EEEE EEEE EEEE EEEE

GGGG GGGGGGG GGGG GGGG GGGG GGGG GGGG GGGG

0123 4567 8911 1111 1111 2222 2222 2233 3333 3333

01 2345 6789 0123 4567 8901 2345 6789

bbbb

iiii

tttt

0123

Read automatically the display data from the display data area and send to the LCD driver by the hardware. Therefore, the display patterns can be changed only by overwriting the contents of the display data area with the software.

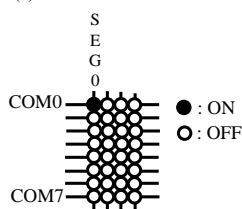
The data memory which is not used to store the LCD display data and the addresses are not connected to the LCD can be used to store the ordinary user's processing data.

PROGRAM EXAMPLE:

```
LDIA    #1100B    ; LCD display enable
OUTA    P27
LDIA    #1010B
STA     24H
```

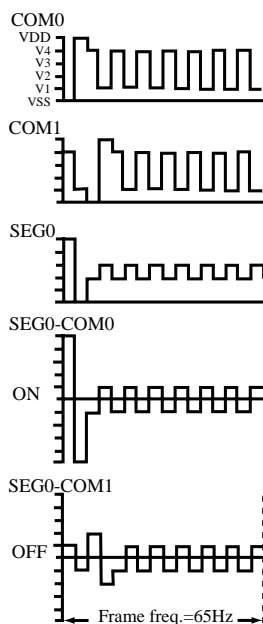
(3) LCD waveform : (1/5 bias)

(3) LCD waveform :

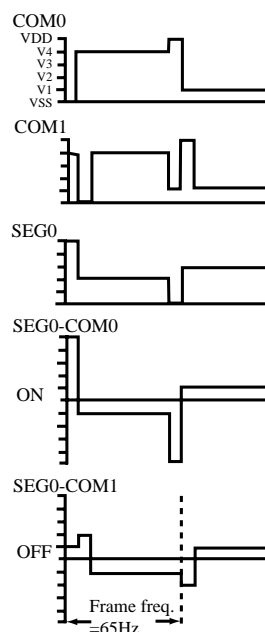


BIAS	Modify 1/4	1/4
VDD / VDD	1	1
V4 / VDD	17/23	
V3 / VDD	12/23	3/4
V2 / VDD	11/23	1/2
V1 / VDD	6/23	1/4
VSS = 0	0	0

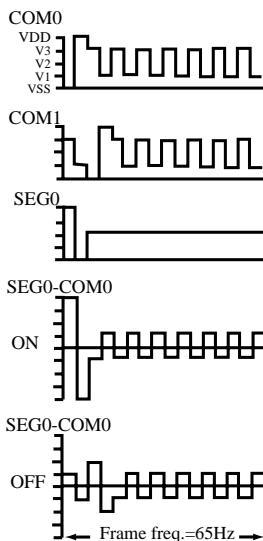
* TYPE A, modify 1/4 bias :



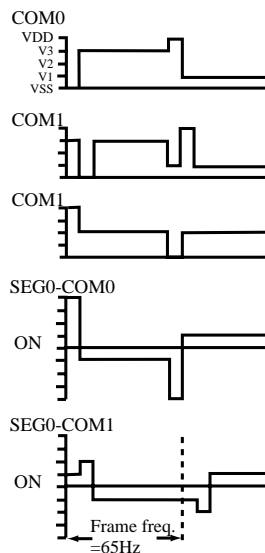
* TYPE B, modify 1/4 bias :



* TYPE A, 1/4 bias :

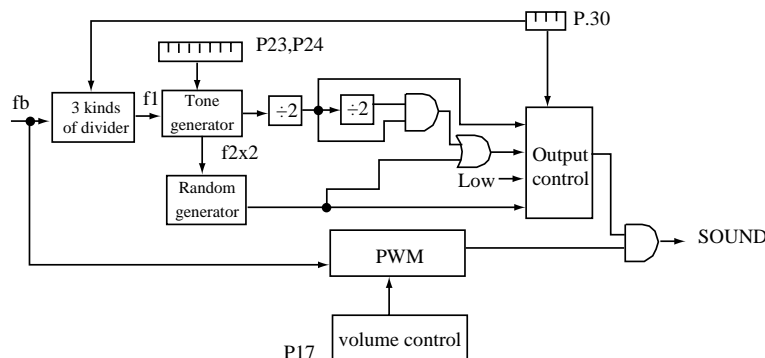


* TYPE B, 1/4 bias :



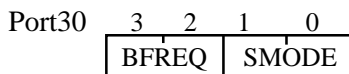
SOUND EFFECT

EM73962A has a built-in sound generator. It includes the tone generator, random generator and volume control. The tone generator is a binary down counter and the random generator is a 9-bit linear feedback shift register. When the CPU is reseted or sleeping, the sound generator is disabled and the output pin (SOUND) is low.



Sound generator command register

There are 3 kinds of basic frequency for sound generator which can be selected by P30. The output of sound effect is tone and random combination.



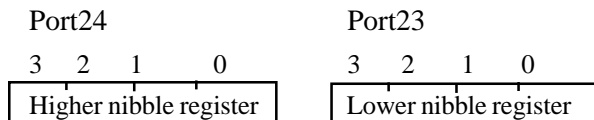
Initial value : 0000

BFREQ	Basic frequency (f1) select
0 0	240 KHz
0 1	120 KHz
1 0	60 KHz
1 1	don't care

SMODE	Sound generator mode
0 0	Disable
0 1	Tone output
1 0	Random output
1 1	Tone+random output

Tone frequency register

The 8-bit tone frequency register is P24 and P23. The tone frequency will be changed when user output the different data to P23. Thus, the data must be output to P24 before P23 when user want to change the 8-bit tone frequency (TF).



Initial value : 1111 1111

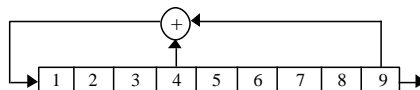
** $f1=240K/2^x$, $f2=f1/(TF+1)/2$, $TF=1\sim255$, $TF\neq0$

** Example : BFREQ=10, TF=00110001B.

$\Rightarrow f1=60K\text{ Hz}$, $f2=60K\text{ Hz}/50/2=600\text{ Hz}$

Random generator

$$f(x)=x^9+x^4+1$$



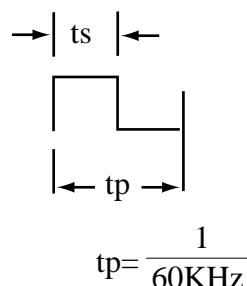
Volume control register

The are 8 levels of volume for sound generator. P17 is the volume control register.

Port17

Initial value : * 1111

3	2	1	0
*	VCR		
VCR			ts/tp
1	1	1	8/8
1	1	0	7/8
1	0	1	6/7
1	0	0	5/8
0	1	1	4/8
0	1	0	3/8
0	0	1	2/8
0	0	0	1/8



PROGRAM EXAMPLE:

```
LDIA    #1001B ; basic frequency : 60 KHz tone output
OUTA    P30
LDIA    #0011B ; 600 Hz tone output
OUTA    P24
LDIA    #0001B
OUTA    P23
```

RESETTING FUNCTION

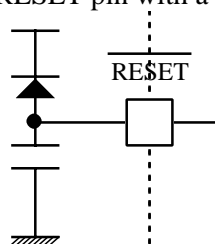
When CPU in normal working condition and RESET pin holds in low level for three instruction cycles at least, then CPU begins to initialize the whole internal states, and when RESET pin changes to high level, CPU begins to work in normal condition.

The CPU internal state during reset condition is as following table :

Hardware condition in RESET (f1) state	Initial value
Program counter	0000h
Status flag	01h
Interrupt enable flip-flop (EI)	00h
MASK0 ,1, 2, 3	00h
Interrupt latch (IL)	00h
P3, P9, 16, 25, 27, 28, 29, 30	00h
P4, 8, 17, 23, 24	0Fh
RC oscillator	Start oscillation

The RESET pin is a hysteresis input pin and it has a pull-up resistor available by mask option.

The simplest RESET circuit is connect RESET pin with a capacitor to V_{SS} and a diode to V_{DD} .



EM73962A I/O PORT DESCRIPTION :

Port		Input function		Output function	Note
0	E	Input port , wakeup function			
1		--		--	
2		--		--	
3		--	I	P3(1..0) : ROM bank selection	
4		--		--	
5		--		--	
6		--		--	
7		--		--	
8	E	Input port, wakeup function, external interrupt input	E	Output port	
9		--	I	P9.3 : RAM bank selection	
10		--		--	
11		--		--	
12		--		--	
13		--		--	
14		--		--	
15		--		--	
16			I	Sleep/Hold mode control register	
17			I	Sound effect volume control register	
18				--	
19				--	
20				--	
21				--	
22				--	
23			I	Sound effect frequency register	low nibble
24			I	Sound effect command register	high nibble
25			I	Timebase control register	
26				--	
27			I	LCD control register	
28			I	Timer/counter A control register	
29			I	Timer/counter B control register	
30			I	Sound effect command register	
31				--	

ABSOLUTE MAXIMUM RATINGS

Items	Sym.	Ratings	Conditions
Supply Voltage	V_{DD}	-0.5V to 6V	
Input Voltage	V_{IN}	-0.5V to $V_{DD}+0.5V$	
Output Voltage	V_O	-0.5V to $V_{DD}+0.5V$	
Power Dissipation	P_D	300mW	$T_{OPR}=50^{\circ}C$
Operating Temperature	T_{OPR}	0°C to 50°C	
Storage Temperature	T_{STG}	-55°C to 125°C	

RECOMMENDED OPERATING CONDITIONS

Items	Sym.	Ratings	Condition
Supply Voltage	V_{DD}	2.4V to 5.0V	
Input Voltage	V_{IH}	$0.90 \times V_{DD}$ to V_{DD}	
	V_{IL}	0V to $0.10 \times V_{DD}$	
Operating Frequency	F_C	480K to 4MHz	CLK (RC osc)

DC ELECTRICAL CHARACTERISTICS ($V_{DD}=3\pm0.3V$, $V_{SS}=0V$, $T_{OPR}=25^{\circ}C$)

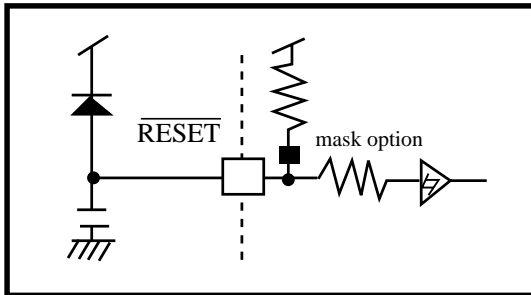
Parameters	Sym.	Min.	Typ.	Max.	Unit	Conditions
Supply current	I_{DD}	-	0.5	1	mA	$V_{DD}=3.3V$, no load, $F_C=4MHz$ ($R=91K\Omega$)
		-	0.1	1	μA	$V_{DD}=3.3V$, sleep mode
Hysteresis voltage	V_{HYS+}	$0.5V_{DD}$	-	$0.75V_{DD}$	V	RESET, P0, P8
	V_{HYS-}	$0.2V_{DD}$	-	$0.4V_{DD}$	V	
Input current	I_{IH}	-	-	± 1	μA	P0, RESET, $V_{DD}=3.3V$, $V_{IH}=3.3/0V$
		-	-	± 1	μA	Open-drain, $V_{DD}=3.3V$, $V_{IH}=3.3/0V$
	I_{IL}	-	-	-500	μA	Push-pull, $V_{DD}=3.3V$, $V_{IL}=0.4V$
Output voltage	V_{OH}	2.4	-	-	V	Push-pull, $V_{DD}=2.7V$, SOUND, $I_{OH}=-0.9mA$
		2.0	-	-	V	Push-pull, $V_{DD}=2.7V$, P8, $I_{OH}=-40\mu A$
	V_{OL}	-	-	0.3	V	$V_{DD}=2.7V$, $I_{OL}=0.9mA$
Leakage current	I_{LO}	-	-	1	μA	Open-drain, $V_{DD}=3.3V$, $V_O=3.3V$
Input resistor	R_{IN}	100	200	300	$K\Omega$	P0
		300	600	900	$K\Omega$	RESET
Frequency stability		-	15	-	%	$F_C=4MHz$, RC osc, $[F(3V)-F(2.4V)]/F(3V)$
Frequency variation		-	20	-	%	$F_C=4MHz$, $V_{DD}=3V$, RC osc, $[F(\text{typical})-F(\text{worse case})]/F(\text{typical})$

($V_{DD}=4.5\pm0.5V$, $V_{SS}=0V$, $T_{OPR}=25^{\circ}C$)

Parameters	Sym.	Min.	Typ.	Max.	Unit	Conditions
Supply current	I_{DD}	-	0.7	1.5	mA	$V_{DD}=5V$, no load, $F_c=4MHz$ ($R=91K\Omega$)
		-	0.1	1	μA	$V_{DD}=5V$, sleep mode
Hysteresis voltage	V_{HYS+}	$0.5V_{DD}$	-	$0.75V_{DD}$	V	RESET, P0, P8
	V_{HYS-}	$0.2V_{DD}$	-	$0.4V_{DD}$	V	
Input current	I_{IH}	-	-	± 1	μA	P0, RESET, $V_{DD}=5V$, $V_{IH}=5/0V$
		-	-	± 1	μA	Open-drain, $V_{DD}=5V$, $V_{IH}=5/0V$
	I_{IL}	-	-	-1	mA	Push-pull, $V_{DD}=5V$, $V_{IL}=0.4V$
Output voltage	V_{OH}	3.0	-	-	V	Push-pull, SOUND, $V_{DD}=4V$, $I_{OH}=-4mA$
		2.4	-	-	V	Push-pull, P8, $V_{DD}=4V$, $I_{OH}=-200\mu A$
	V_{OL}	-	-	1.0	V	$V_{DD}=4V$, $I_{OL}=4mA$
Leakage current	I_{LO}	-	-	1	μA	Open-drain, $V_{DD}=5V$, $V_O=5V$
Input resistor	R_{IN}	30	90	150	$K\Omega$	P0
		100	300	450	$K\Omega$	RESET
Frequency stability		-	10	-	%	$F_c=4MHz$, RC osc, $[F(4.5V)-F(3.6V)]/F(4.5V)$
Frequency variation		-	20	-	%	$F_c=4MHz$, $V_{DD}=4.5V$, RC osc, $[F(\text{typical})-F(\text{worse case})]/F(\text{typical})$

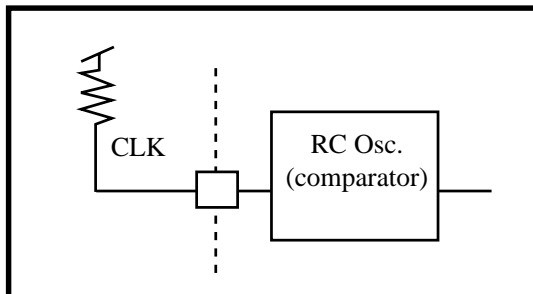
RESET PIN TYPE

TYPE RESET-A



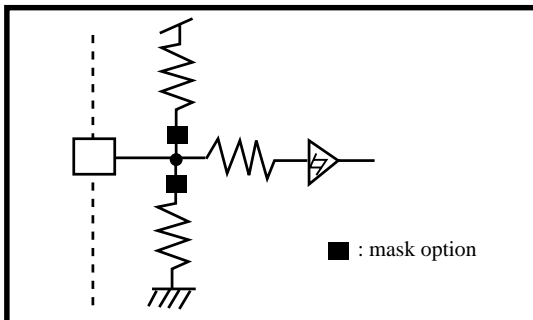
OSCILLATION PIN TYPE

TYPE OSC-C

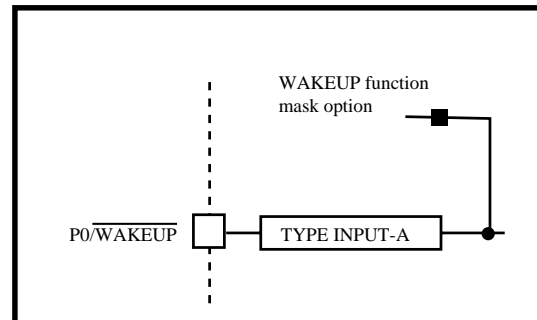


INPUT PIN TYPE

TYPE INPUT-A

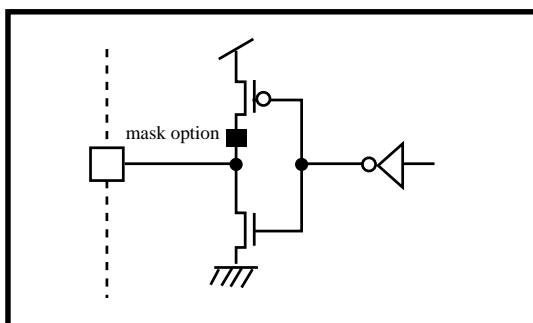


TYPE INPUT-B

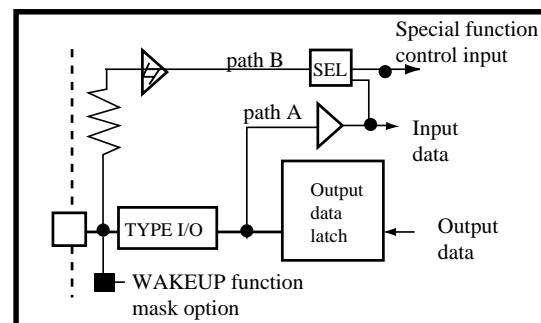


I/O PIN TYPE

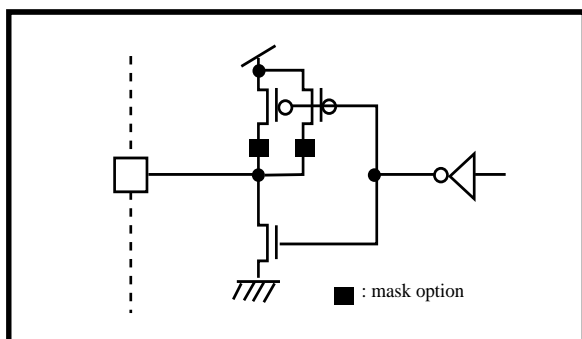
TYPE I/O



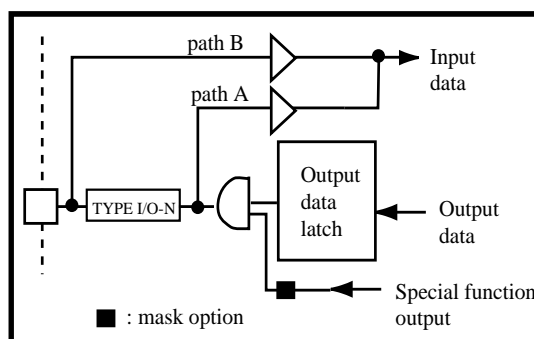
TYPE I/O-L



TYPE I/O-N

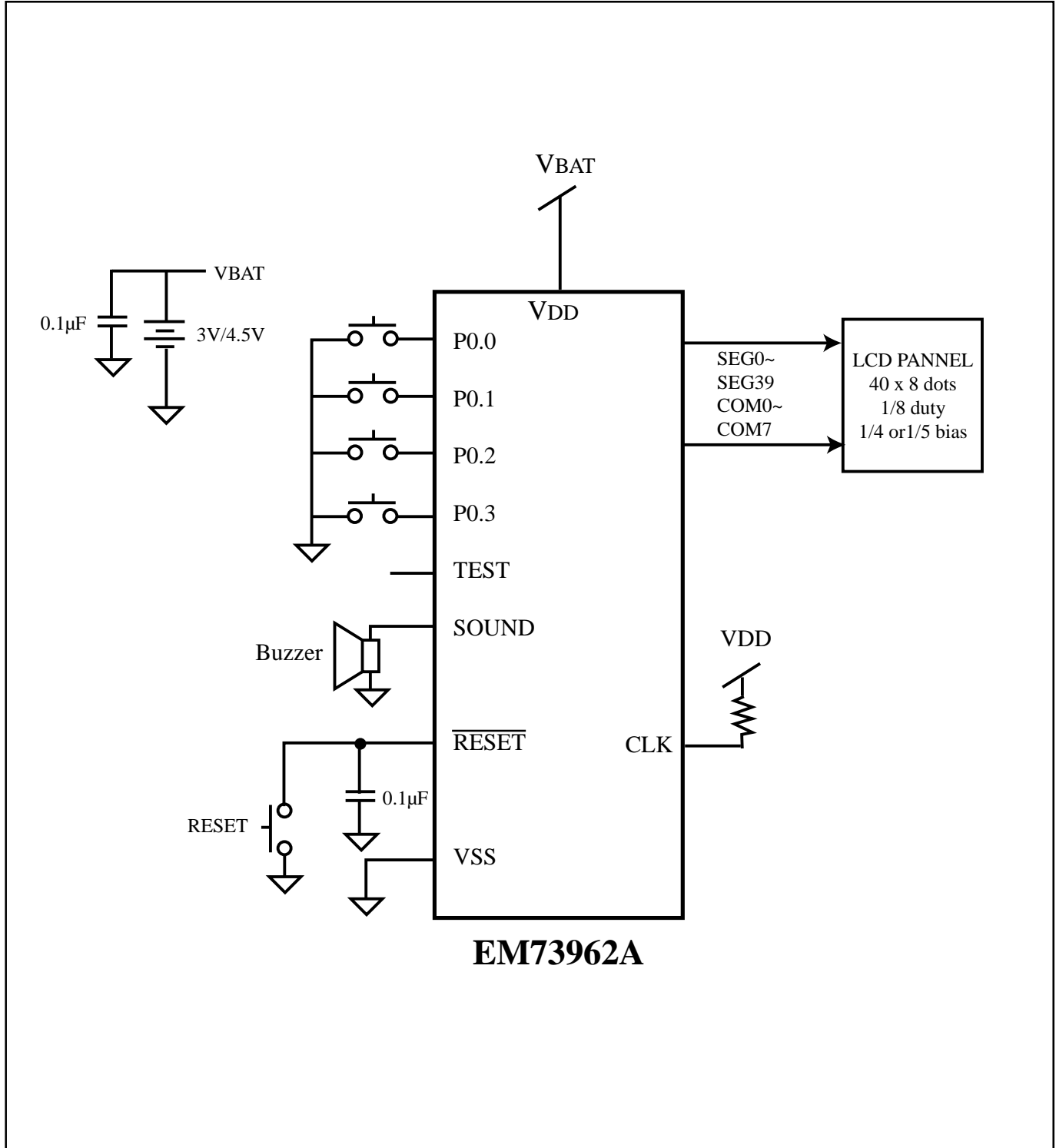


TYPE I/O-O

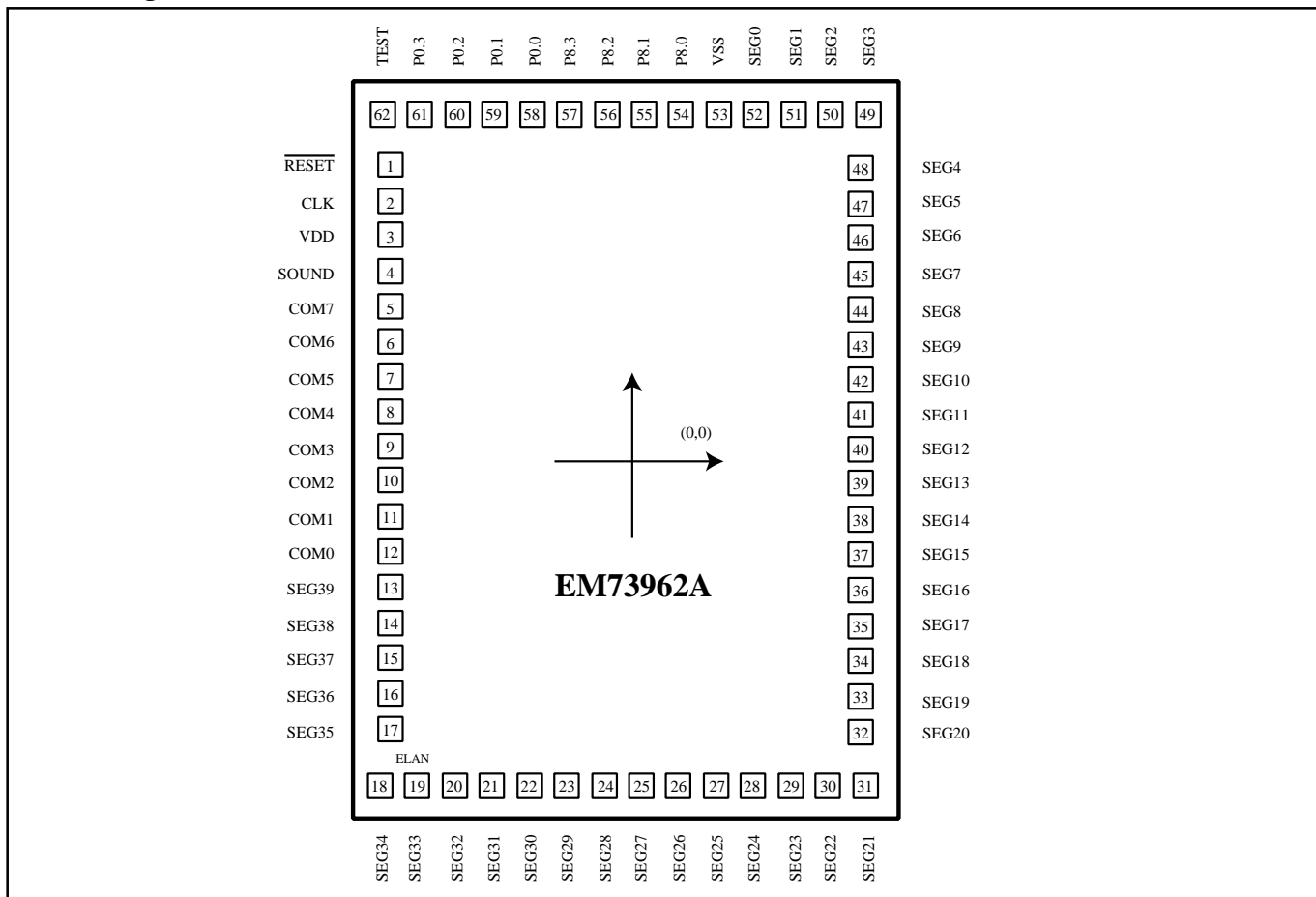


- Path A : For set and clear bit of port instructions, data goes through path A from output data latch to CPU.
 Path B : For input and test instructions, data from output pin go through path B to CPU and the output data latch will be set to high.

APPLICATION CIRCUIT



PAD DIAGRAM



Chip Size : 1740 x 2460 μm

Pad No.	Symbol	X	Y
1	RESET	-702.7	891.1
2	CLK	-702.7	780.7
3	VDD	-702.7	658.4
4	SOUND	-702.7	540.7
5	COM7	-702.7	430.2
6	COM6	-702.7	319.7
7	COM5	-702.7	209.3
8	COM4	-702.7	98.8
9	COM3	-702.7	-11.6
10	COM2	-702.7	-122.1
11	COM1	-702.7	-232.6
12	COM0	-702.7	-343.0
13	SEG39	-702.7	-453.5
14	SEG38	-702.7	-563.9
15	SEG37	-702.7	-674.4
16	SEG36	-702.7	-784.9
17	SEG35	-702.7	-895.3
18	SEG34	-728.0	-1062.8

Pad No.	Symbol	X	Y
19	SEG33	-617.6	-1062.8
20	SEG32	-507.1	-1062.8
21	SEG31	-396.6	-1062.8
22	SEG30	-286.2	-1062.8
23	SEG29	-175.7	-1062.8
24	SEG28	-65.3	-1062.8
25	SEG27	45.2	-1062.8
26	SEG26	155.7	-1062.8
27	SEG25	266.1	-1062.8
28	SEG24	376.6	-1062.8
29	SEG23	487.0	-1062.8
30	SEG22	597.5	-1062.8
31	SEG21	708.0	-1062.8
32	SEG20	700.4	-877.7
33	SEG19	700.4	-767.3
34	SEG18	700.4	-656.8
35	SEG17	700.4	-546.3
36	SEG16	700.4	-435.9
37	SEG15	700.4	-325.4
38	SEG14	700.4	-215.0
39	SEG13	700.4	-104.5
40	SEG12	700.4	6.0
41	SEG11	700.4	116.4
42	SEG10	700.4	226.9
43	SEG9	700.4	337.3
44	SEG8	700.4	447.8
45	SEG7	700.4	558.3
46	SEG6	700.4	668.7
47	SEG5	700.4	779.2
48	SEG4	700.4	889.6
49	SEG3	724.6	1062.2
50	SEG2	614.1	1062.2
51	SEG1	503.7	1062.2
52	SEG0	393.2	1062.2
53	VSS	269.3	1062.2
54	P8.0	145.8	1062.2
55	P8.1	35.4	1062.2
56	P8.2	-75.1	1062.2
57	P8.3	-185.6	1062.2
58	P0.0	-296.0	1062.2
59	P0.1	-406.5	1062.2
60	P0.2	-516.9	1062.2
61	P0.3	-627.4	1062.2
62	TEST	-737.9	1062.2

Unit : μm

For PCB layout, IC substrate must be floated or connected to Vss.

** This specification are subject to be changed without notice.*

INSTRUCTION TABLE

(1) Data Transfer

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
LDA x	0110 1010 xxxx xxxx	$Acc \leftarrow RAM[x]$	2	2	-	Z	1
LDAM	0101 1010	$Acc \leftarrow RAM[HL]$	1	1	-	Z	1
LDAX	0110 0101	$Acc \leftarrow ROM[DP]_L$	1	2	-	Z	1
LDAXI	0110 0111	$Acc \leftarrow ROM[DP]_H, DP+1$	1	2	-	Z	1
LDH #k	1001 kkkk	$HR \leftarrow k$	1	1	-	-	1
LDHL x	0100 1110 xxxx xx00	$LR \leftarrow RAM[x], HR \leftarrow RAM[x+1]$	2	2	-	-	1
LDIA #k	1101 kkkk	$Acc \leftarrow k$	1	1	-	Z	1
LDL #k	1000 kkkk	$LR \leftarrow k$	1	1	-	-	1
STA x	0110 1001 xxxx xxxx	$RAM[x] \leftarrow Acc$	2	2	-	-	1
STAM	0101 1001	$RAM[HL] \leftarrow Acc$	1	1	-	-	1
STAMD	0111 1101	$RAM[HL] \leftarrow Acc, LR-1$	1	1	-	Z	C
STAMI	0111 1111	$RAM[HL] \leftarrow Acc, LR+1$	1	1	-	Z	C'
STD #k,y	0100 1000 kkkk yyyy	$RAM[y] \leftarrow k$	2	2	-	-	1
STDMI #k	1010 kkkk	$RAM[HL] \leftarrow k, LR+1$	1	1	-	Z	C'
THA	0111 0110	$Acc \leftarrow HR$	1	1	-	Z	1
TLA	0111 0100	$Acc \leftarrow LR$	1	1	-	Z	1

(2) Rotate

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
RLCA	0101 0000	$\overleftarrow{CF} \leftarrow Acc \leftarrow \overleftarrow{CF}$	1	1	C	Z	C'
RRCA	0101 0001	$\overrightarrow{CF} \leftarrow Acc \leftarrow \overrightarrow{CF}$	1	1	C	Z	C'

(3) Arithmetic operation

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
ADCAM	0111 0000	$Acc \leftarrow Acc + RAM[HL] + CF$	1	1	C	Z	C'
ADD #k,y	0100 1001 kkkk yyyy	$RAM[y] \leftarrow RAM[y] + k$	2	2	-	Z	C'
ADDA #k	0110 1110 0101 kkkk	$Acc \leftarrow Acc + k$	2	2	-	Z	C'
ADDAM	0111 0001	$Acc \leftarrow Acc + RAM[HL]$	1	1	-	Z	C'
ADDH #k	0110 1110 1001 kkkk	$HR \leftarrow HR + k$	2	2	-	Z	C'
ADDL #k	0110 1110 0001 kkkk	$LR \leftarrow LR + k$	2	2	-	Z	C'
ADDM #k	0110 1110 1101 kkkk	$RAM[HL] \leftarrow RAM[HL] + k$	2	2	-	Z	C'
DECA	0101 1100	$Acc \leftarrow Acc - 1$	1	1	-	Z	C
DECL	0111 1100	$LR \leftarrow LR - 1$	1	1	-	Z	C
DECM	0101 1101	$RAM[HL] \leftarrow RAM[HL] - 1$	1	1	-	Z	C
INCA	0101 1110	$Acc \leftarrow Acc + 1$	1	1	-	Z	C'

INCL	0111 1110	$LR \leftarrow LR + 1$	1	1	-	Z	C'
INCM	0101 1111	$RAM[HL] \leftarrow RAM[HL] + 1$	1	1	-	Z	C'
SUBA #k	0110 1110 0111 kkkk	$Acc \leftarrow k - Acc$	2	2	-	Z	C
SBCAM	0111 0010	$Acc \leftarrow RAM[HL] - Acc - CF'$	1	1	C	Z	C
SUBM #k	0110 1110 1111 kkkk	$RAM[HL] \leftarrow k - RAM[HL]$	2	2	-	Z	C

(4) Logical operation

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
ANDA #k	0110 1110 0110 kkkk	$Acc \leftarrow Acc \& k$	2	2	-	Z	Z'
ANDAM	0111 1011	$Acc \leftarrow Acc \& RAM[HL]$	1	1	-	Z	Z'
ANDM #k	0110 1110 1110 kkkk	$RAM[HL] \leftarrow RAM[HL] \& k$	2	2	-	Z	Z'
ORA #k	0110 1110 0100 kkkk	$Acc \leftarrow Acc \vee k$	2	2	-	Z	Z'
ORAM	0111 1000	$Acc \leftarrow Acc \vee RAM[HL]$	1	1	-	Z	Z'
ORM #k	0110 1110 1100 kkkk	$RAM[HL] \leftarrow RAM[HL] \vee k$	2	2	-	Z	Z'
XORAM	0111 1001	$Acc \leftarrow Acc \wedge RAM[HL]$	1	1	-	Z	Z'

(5) Exchange

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
EXA x	0110 1000 xxxx xxxx	$Acc \leftrightarrow RAM[x]$	2	2	-	Z	1
EXAH	0110 0110	$Acc \leftrightarrow HR$	1	2	-	Z	1
EXAL	0110 0100	$Acc \leftrightarrow LR$	1	2	-	Z	1
EXAM	0101 1000	$Acc \leftrightarrow RAM[HL]$	1	1	-	Z	1
EXHL x	0100 1100 xxxx xx00	$LR \leftrightarrow RAM[x],$ $HR \leftrightarrow RAM[x+1]$	2	2	-	-	1

(6) Branch

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
SBR a	00aa aaaa	If SF=1 then $PC \leftarrow PC_{12-6}, a_{5-0}$ else null	1	1	-	-	1
LBR a	1100 aaaa aaaa aaaa	If SF= 1 then $PC \leftarrow a$ else null	2	2	-	-	1
SLBR a	0101 0101 1100 aaaa aaaa aaaa (a:1000~1FFFh)	If SF=1 then $PC \leftarrow a$ else null	3	3	-	-	1
	0101 0111 1100 aaaa aaaa aaaa (a:0000~0FFFh)						

(7) Compare

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
CMP #k,y	0100 1011 kkkk yyyy	$k - RAM[y]$	2	2	C	Z	Z'
CMPA x	0110 1011 xxxx xxxx	$RAM[x] - Acc$	2	2	C	Z	Z'

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
CMPAM	0111 0011	RAM[HL] - Acc	1	1	C	Z	Z'
CMPH #k	0110 1110 1011 kkkk	k - HR	2	2	-	Z	C
CMPIA #k	1011 kkkk	k - Acc	1	1	C	Z	Z'
CMPL #k	0110 1110 0011 kkkk	k-LR	2	2	-	Z	C

(8) Bit manipulation

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
CLM b	1111 00bb	RAM[HL] _b ← 0	1	1	-	-	1
CLP p,b	0110 1101 11bb pppp	PORT[p] _b ← 0	2	2	-	-	1
CLPL	0110 0000	PORT[LR ₃₋₂ +4]LR ₁₋₀ ← 0	1	2	-	-	1
CLR y,b	0110 1100 11bb yyyy	RAM[y] _b ← 0	2	2	-	-	1
SEM b	1111 01bb	RAM[HL] _b ← 1	1	1	-	-	1
SEP p,b	0110 1101 01bb pppp	PORT[p] _b ← 1	2	2	-	-	1
SEPL	0110 0010	PORT[LR ₃₋₂ +4]LR ₁₋₀ ← 1	1	2	-	-	1
SET y,b	0110 1100 01bb yyyy	RAM[y] _b ← 1	2	2	-	-	1
TF y,b	0110 1100 00bb yyyy	SF ← RAM[y] _b '	2	2	-	-	*
TFA b	1111 10bb	SF ← Acc _b '	1	1	-	-	*
TFM b	1111 11bb	SF ← RAM[HL] _b '	1	1	-	-	*
TFP p,b	0110 1101 00bb pppp	SF ← PORT[p] _b '	2	2	-	-	*
TFPL	0110 0001	SF ← PORT[LR ₃₋₂ +4]LR ₁₋₀ '	1	2	-	-	*
TT y,b	0110 1100 10bb yyyy	SF ← RAM[y] _b	2	2	-	-	*
TTP p,b	0110 1101 10bb pppp	SF ← PORT[p] _b	2	2	-	-	*

(9) Subroutine

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
LCALL a	0100 0aaa aaaa aaaa	STACK[SP] ← PC, SP ← SP - 1, PC ← a	2	2	-	-	-
SCALL a	1110 nnnn	STACK[SP] ← PC, SP ← SP - 1, PC ← a, a = 8n + 6 (n = 1~15), 0086h (n = 0)	1	2	-	-	-
RET	0100 1111	SP ← SP + 1, PC ← STACK[SP]	1	2	-	-	-

(10) Input/output

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
INA p	0110 1111 0100 pppp	Acc ← PORT[p]	2	2	-	Z	Z'
INM p	0110 1111 1100 pppp	RAM[HL] ← PORT[p]	2	2	-	-	Z'
OUT #k,p	0100 1010 kkkk pppp	PORT[p] ← k	2	2	-	-	1
OUTA p	0110 1111 000p pppp	PORT[p] ← Acc	2	2	-	-	1
OUTM p	0110 1111 100p pppp	PORT[p] ← RAM[HL]	2	2	-	-	1

(11) Flag manipulation

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
TFCFC	0101 0011	$SF \leftarrow CF'$, $CF \leftarrow 0$	1	1	0	-	*
TTCFS	0101 0010	$SF \leftarrow CF$, $CF \leftarrow 1$	1	1	1	-	*
TZS	0101 1011	$SF \leftarrow ZF$	1	1	-	-	*

(12) Interrupt control

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
CIL r	0110 0011 11rr rrrr	$IL \leftarrow IL \& r$	2	2	-	-	1
DICIL r	0110 0011 10rr rrrr	$EIF \leftarrow 0$, $IL \leftarrow IL \& r$	2	2	-	-	1
EICIL r	0110 0011 01rr rrrr	$EIF \leftarrow 1$, $IL \leftarrow IL \& r$	2	2	-	-	1
EXAE	0111 0101	$MASK \leftrightarrow Acc$	1	1	-	-	1
RTI	0100 1101	$SP \leftarrow SP + 1$, $FLAG.PC \leftarrow STACK[SP]$, $EIF \leftarrow 1$	1	2	*	*	*

(13) CPU control

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
NOP	0101 0110	no operation	1	1	-	-	-

(14) Timer/Counter & Data pointer & Stack pointer control

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
LDADPL	0110 1010 1111 1100	$Acc \leftarrow [DP]_L$	2	2	-	Z	1
LDADPM	0110 1010 1111 1101	$Acc \leftarrow [DP]_M$	2	2	-	Z	1
LDADPH	0110 1010 1111 1110	$Acc \leftarrow [DP]_H$	2	2	-	Z	1
LDASP	0110 1010 1111 1111	$Acc \leftarrow SP$	2	2	-	Z	1
LDATAL	0110 1010 1111 0100	$Acc \leftarrow [TA]_L$	2	2	-	Z	1
LDATAM	0110 1010 1111 0101	$Acc \leftarrow [TA]_M$	2	2	-	Z	1
LDATAH	0110 1010 1111 0110	$Acc \leftarrow [TA]_H$	2	2	-	Z	1
LDATBL	0110 1010 1111 1000	$Acc \leftarrow [TB]_L$	2	2	-	Z	1
LDATBM	0110 1010 1111 1001	$Acc \leftarrow [TB]_M$	2	2	-	Z	1
LDATBH	0110 1010 1111 1010	$Acc \leftarrow [TB]_H$	2	2	-	Z	1
STADPL	0110 1001 1111 1100	$[DP]_L \leftarrow Acc$	2	2	-	-	1
STADPM	0110 1001 1111 1101	$[DP]_M \leftarrow Acc$	2	2	-	-	1
STADPH	0110 1001 1111 1110	$[DP]_H \leftarrow Acc$	2	2	-	-	1
STASP	0110 1001 1111 1111	$SP \leftarrow Acc$	2	2	-	-	1
STATAL	0110 1001 1111 0100	$[TA]_L \leftarrow Acc$	2	2	-	-	1
STATAM	0110 1001 1111 0101	$[TA]_M \leftarrow Acc$	2	2	-	-	1
STATAH	0110 1001 1111 0110	$[TA]_H \leftarrow Acc$	2	2	-	-	1
STATBL	0110 1001 1111 1000	$[TB]_L \leftarrow Acc$	2	2	-	-	1
STATBM	0110 1001 1111 1001	$[TB]_M \leftarrow Acc$	2	2	-	-	1
STATBH	0110 1001 1111 1010	$[TB]_H \leftarrow Acc$	2	2	-	-	1

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****** SYMBOL DESCRIPTION**

Symbol	Description	Symbol	Description
HR	H register	LR	L register
PC	Program counter	DP	Data pointer
SP	Stack pointer	STACK[SP]	Stack specified by SP
A _{cc}	Accumulator	FLAG	All flags
CF	Carry flag	ZF	Zero flag
SF	Status flag	EI	Enable interrupt register
IL	Interrupt latch	MASK	Interrupt mask
PORT[p]	Port (address : p)	TA	Timer/counter A
TB	Timer/counter B	RAM[HL]	Data memory (address : HL)
RAM[x]	Data memory (address : x)	ROM[DP] _L	Low 4-bit of program memory
ROM[DP] _H	High 4-bit of program memory	[DP] _L	Low 4-bit of data pointer register
[DP] _M	Middle 4-bit of data pointer register	[DP] _H	High 4-bit of data pointer register
[TA] _L ([TB] _L)	Low 4-bit of timer/counter A (timer/counter B) register	[TA] _M ([TB] _M)	Middle 4-bit of timer/counter A (timer/counter B) register
[TA] _H ([TB] _H)	High 4-bit of timer/counter A (timer/counter B) register	LR ₁₋₀	Contents of bit assigned by bit 1 to 0 of LR
LR ₃₋₂	Bit 3 to 2 of LR	a ₅₋₀	Bit 5 to 0 of destination address for branch instruction
PC ₁₂₋₆	Bit 12 to 6 of program counter	←	Transfer
↔	Exchange	+	Addition
-	Substraction	&	Logic AND
	Logic OR	^	Logic XOR
!	Inverse operation	.	Concatenation
#k	4-bit immediate data	x	8-bit RAM address
y	4-bit zero-page address	p	4-bit or 5-bit port address
b	Bit address	r	6-bit interrupt latch