Preliminary

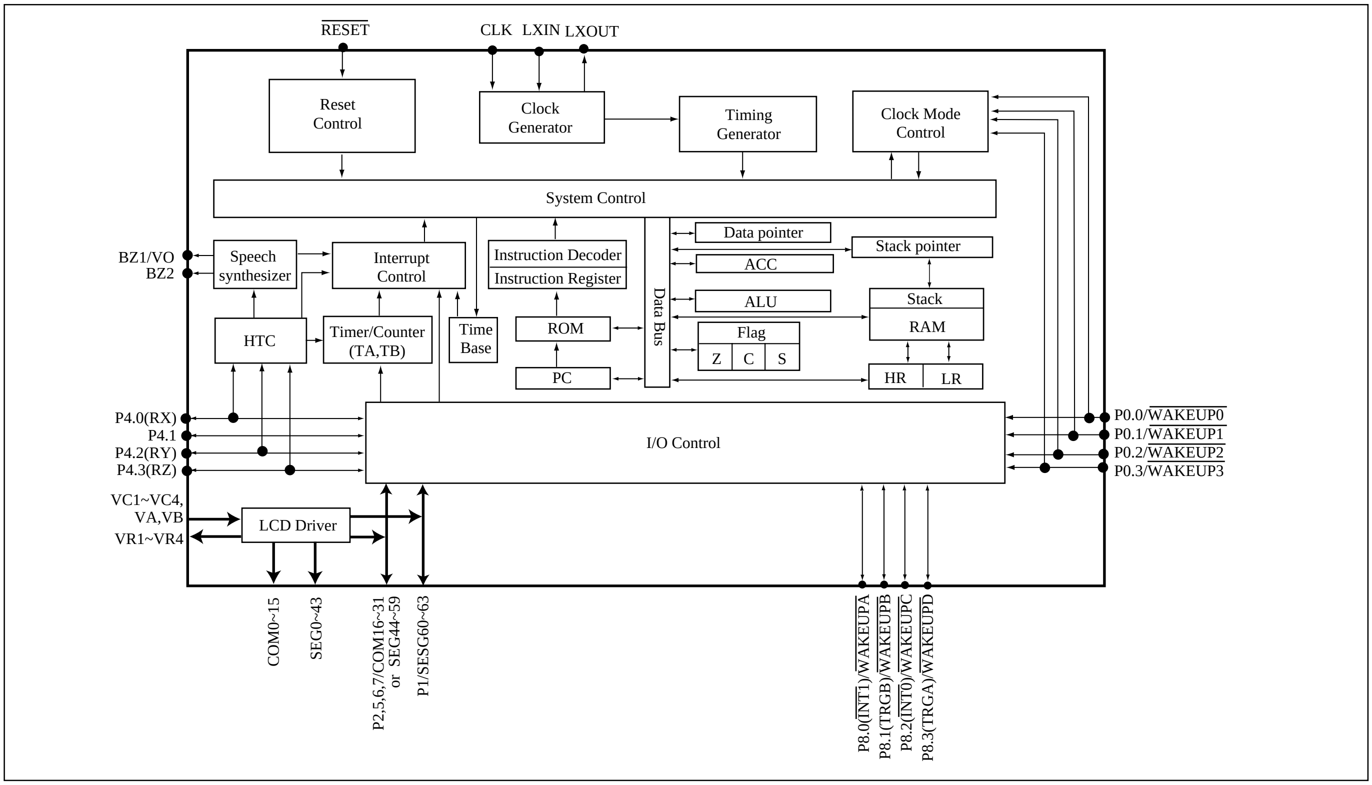
GENERAL DESCRIPTION

EM73A89B is an advanced single chip CMOS 4-bit micro-controller. It contains 16K-byte ROM, 1012-nibble RAM, 4-bit ALU, 13-level subroutine nesting, 22-stage time base, two 12-bit timer/counters for the kernel function, and one high speed conter. EM73A89B also equipped with 6 interrupt sources, 3~7 I/O ports (including 1 input port and 2~7 bidirection ports), LCD display (64x16 or 64x32), built-in watch-dog-timer and speech synthesizer.
It's low power consumption and high speed feature are further strengten with DUAL, SLOW, IDLE and STOP operation mode for optimized power saving.

FEATURES

- Operation voltage : 2.2V to 3.6V.
- Clock source : Dual clock system. Low-frequency oscillator is 32KHz. Crystal oscillator or RC oscillator by mask option and high-frequency oscillator is a built-in internal oscillator.
- Instruction set : 107 powerful instructions.
- Instruction cycle time : 0.85µs for 9.2M or 1.7µs for 4.6M Hz selected by mask option(high speed clock). 122µs for 32768 Hz (low speed clock, frequency double).
- ROM capacity : 16K x 8 bits.
- RAM capacity : 1012 x 4 bits.
- Input port : 1 port (P0.0-P0.3), IDLE/STOP releasing function is available by mask option. (each input pin has a pull-up and pull-down resistor available by mask option).
- Bidirection port : 2~7 ports (P1, P2, P4, P5, P6, P7, P8). IDLE/STOP release function for P8(0..3) is available by mask option. P1, P2, P5, P6, P7 are shared with LCD pins.
- Built-in watch-dog-timer counter : It is available by mask option.
- 12-bit timer/counter : Two 12-bit timer/counters are programmable for timer, event counter and pulse width measurement mode.
- Built-in time base counter : 22 stages.
- Subroutine nesting : Up to 13 levels.
- Interrupt : External interrupt ...... 2 input interrupt sources.
  Internal interrupt ...... 2 timer overflow interrupts, 1 time base interrupt.
  1 speech/HTC interrupt.
- High speed counter : The high speed counter includes one 8-bit high speed counter and a resistor to frequency oscillator. It has resistor to frequrncy oscillation mode, melody mode and auto load timer mode.
- LCD driver : 64x32 or 64x16 dots, 1/32 or 1/16 duty, 1/5 bias by mask option.
- Speech synthesizer : 992K speech data ROM (use as 992K nibbles data ROM).
- PWM or current D/A : Output selection by mask option.
- Power saving function : SLOW, IDLE, STOP operation modes.
- Package type : Chip form 126 pins.

FUNCTION BLOCK DIAGRAM



PIN DESCRIPTIONS

Symbol	Pin-type	Function
V_{DD}, V_{DD2}		Power supply (+)
V_{SS}		Power supply (-)
$\overline{\text{RESET}}$	RESET-A	System reset input signal, low active mask option : none pull-up
CLK	OSC-G	Capacitor connecting pin for internal high frequency oscillator.
LXIN	OSC-B/OSC-H	Crystal/Resistor connecting pin for low speed clock source.
LXOUT	OSC-B	Crystal connecting pin for low speed clock source.
P0(0..3)/$\overline{\text{WAKEUP0..3}}$	INPUT-B	4-bit input port with IDLE/STOP releasing function mask option : wakeup enable, pull-up wakeup enable, none wakeup disable, pull-up wakeup disable, pull-down wakeup disable, none
P4.0(RX),P4.2(RY), P4.3(RZ)	I/O-X1	3-bit bidirection I/O pins or RF oscillation input pins. mask option : open-drain (apply to RF oscillation) high current push-pull normal current push-pull low current push-pull
P4.1	I/O-Q1	1-bit bidirection I/O pin. mask option : open-drain high current push-pull normal current push-pull low current push-pull

Symbol	Pin-type	Function
P8.0($\overline{INT1}$)/$\overline{WAKEUPA}$ P8.2($\overline{INT0}$)/WAKEUPC	I/O-X1	2-bit bidirection I/O port with external interrupt sources input and IDLE /STOP releasing function mask option : wakeup enable, normal current push-pull wakeup ensable, low current push-pull wakeup disable, high current push-pull wakeup disable, normal current push-pull wakeup disable, low current push-pull wakeup disable, open drain
P8.1(TRGB)/$\overline{WAKEUPB}$ P8.3(TRGA)/$\overline{WAKEUPD}$	I/O-X1	2-bit bidirection I/O port with time/counter A,B external input and IDLE /STOP releasing function mask option : wakeup enable, normal current push-pull wakeup ensable, low current push-pull wakeup disable, high current push-pull wakeup disable, normal current push-pull wakeup disable, low current push-pull wakeup disable, open drain
VCA, VCB, V1~V6		LCD bias voltage pins
BZ1/VO		PWM or current D/A output pin for speech synthesizer by mask option
BZ2		PWM output pin for speech synthesizer
TEST		Tie Vss as package type, no connecting as COB type.

***16 COMMONS :**

COM0~COM15		LCD common output pins
SEG0~SEG59		LCD segment output pins
P1(0..3)/SEG63..60	I/O-P	4-bit bidirection I/O pins with LCD segment pins mask option : LCD segment pin push-pull open-drain
P2(0..3),P5(0..3), P6(0..3),P7(0..3)	I/O-P	16-bit bidirection I/O pins mask option : push-pull open-drain

***32 COMMONS :**

COM0~COM31		LCD common output pins
SEG0~SEG43		LCD segment output pins
P1(0..3)/SEG63..60, P2(0..3)/SEG59..56, P5(0..3)/SEG55..52, P6(0..3)/SEG51..48, P7(0..3)/SEG47..44	I/O-P	16-bit bidirection I/O pins with LCD segment pins mask option : LCD segment pin push-pull open-drain

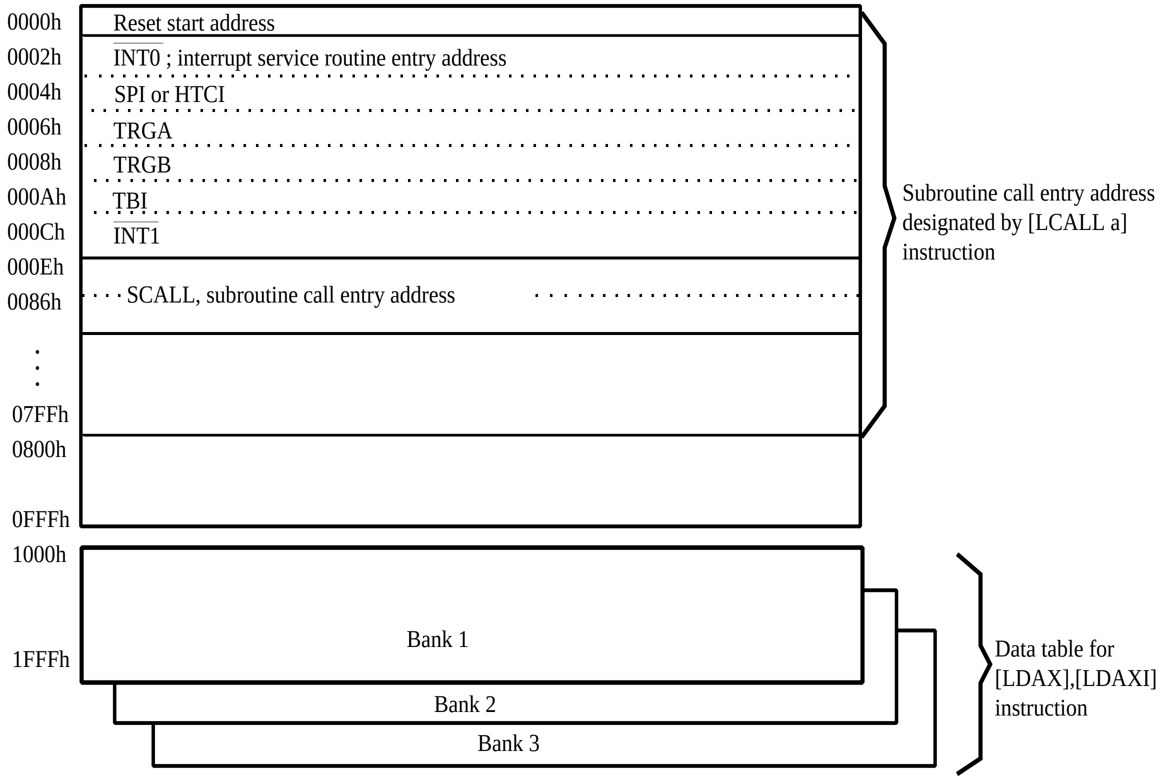
FUNCTION DESCRIPTIONS

PROGRAM ROM (16K X 8 bits)

16 K x 8 bits program ROM contains user's program and some fixed data.
The basic structure of the program ROM may be categorized into 5 partitions.

1. Address 0000h : Reset start address.
2. Address 0002h - 000Ch : 6 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 and data region.

address Bank 0 :



User's program and fixed data are stored in the program ROM. User's program is executed using the PC value to fetch an instruction code.
The 16Kx8 bits program ROM can be divided into 4 banks. There are 4Kx8 bits per bank.
The program ROM bank 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 or 11B, the bank0 and bank1 of program ROM will be selected. P3(1..0)=01B, the bank0 and bank2 will be selected. P3(1..0)=10B, the bank0 and bank3 will be selected.

Address	P3=xx00B P3=xx11B	P3=xx01B	P3=xx10B
0000h : : 0FFFh	Bank0	Bank0	Bank0
1000h : : 1FFFh	Bank1	Bank2	Bank3

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 :   :
```

```
                B         XA2
                :
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                BANK  2
XB1 :           :
                :
                B         XB
                :
XB2 :           :
                B         XB2
                :
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                BANK  3
XC1 :           :
                :
                B         XC
                :
XC2 :           :
                B         XC2
```

Fixed data can be read out by table-look-up instruction. Table-look-up instruction is requires the Data point (DP) to indicate the ROM address in obtaining the ROM code data (Except bank 0) :

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

DP is a 12-bit data register that stores the program ROM address as pointer for the ROM code data.
User has to initially load ROM address into DP with instructions "STADPL", and "STADPM, STADPH", then to obtain 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 (1012-nibble)

A total 1012 - nibble data RAM is available from address 000 to 3FFh
Data RAM includes the zero page region, stacks and data areas.

Bank 0	Address	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
P9=xx00B	000-00Fh	ZERO PAGE															
	010-01Fh																
	020-02Fh																
	030-03Fh																
	040-04Fh																
	050-05Fh																
	060-06Fh																
	070-07Fh																
	080-08Fh																
	090-09Fh																
	0A0-0AFh																
	0B0-0BFh																
	0C0-0CFh	Level 0				Level 1				Level 2				Level 3			
	0D0-0DFh	Level 4				Level 5				Level 6				Level 7			
	0E0-0EFh	Level 8				Level 8				Level 10				Level 11			
	0F0-0FFh	Level 12															
Bank 1																	
P9=xx01B	100-10Fh																
	110-11Fh																
	:									:							
	1E0-1EFh																
	1F0-1FFh																
Bank 2																	
P9=xx10B	200-20Fh	COM0															
	210-21Fh	COM1															
	220-22Fh	COM2															
	230-23Fh	COM3															
	240-24Fh	COM4															
	250-25Fh	COM5															
	260-26Fh	COM6															
	270-27Fh	COM7															
	280-28Fh	COM8															
	290-29Fh	COM9															
	2A0-2AFh	COM10															
	2B0-2BFh	COM11															
	2C0-2CFh	COM12															
	2D0-2DFh	COM13															
	2E0-2EFh	COM14															
	2F0-2FFh	COM15															
Bank 3																	
P9=xx11B	300-30Fh	COM16															
	310-31Fh	COM17															
	320-32Fh	COM18															
	330-33Fh	COM19															
	340-34Fh	COM20															
	350-35Fh	COM21															
	360-36Fh	COM22															
	370-37Fh	COM23															
	380-38Fh	COM24															
	390-39Fh	COM25															
	3A0-3AFh	COM26															
	3B0-3BFh	COM27															
	3C0-3CFh	COM28															
	3D0-3DFh	COM29															
	3E0-3EFh	COM30															
	3F0-3FFh	COM31															
		SEG0 SEG1 SEG2 SEG3	SEG4 SEG5 SEG6 SEG7	SEG8 SEG9 SEG10 SEG11	SEG12 SEG13 SEG14 SEG15	SEG16 SEG17 SEG18 SEG19	SEG20 SEG21 SEG22 SEG23	SEG24 SEG25 SEG26 SEG27	SEG28 SEG29 SEG30 SEG31	SEG32 SEG33 SEG34 SEG35	SEG36 SEG37 SEG38 SEG39	SEG40 SEG41 SEG42 SEG43	SEG44 SEG45 SEG46 SEG47	SEG48 SEG49 SEG50 SEG51	SEG52 SEG53 SEG54 SEG55	SEG56 SEG57 SEG58 SEG59	SEG60 SEG61 SEG62 SEG63

ZERO- PAGE:

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

PROGRAM EXAMPLE: To write immediate data "07h" to RAM [03] and to clear bit 2 of RAM [0Eh].

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

STACK:

There are 13 - level (maximum) stack levels that user can use for subroutine (including interrupt and CALL). User can assign any level be the starting stack by providing the level number to stack pointer (SP).
When an instruction (CALL or interrupt) is invoked, before enter the subroutine, the previous PC address is saved into the stack until returned from those subroutines, the PC value is restored by the data saved in stack.

DATA AREA:

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

ADDRESSING MODE

The 1012 nibble data memory consists of four banks (bank 0 ~ bank 3). There are 244x4 bits (address 000h~0F3h) in bank 0 and 768x4 bits (address 100h ~ 3FFh) in bank 1 ~ bank 3.

The bank is selected by P9.

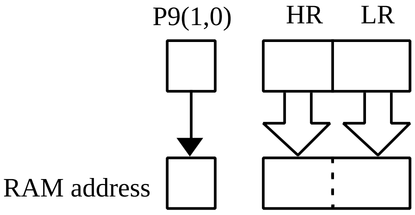
P9 Initial value : * * 0 0

*	*	RBK

RBK	RAM bank
0 0	Bank0
0 1	Bank1
1 0	Bank2
1 1	Bank3

The Data Memory consists of three Address mode, namely -

(1) Indirect addressing mode:
The address in the bank is specified by the HL registers.

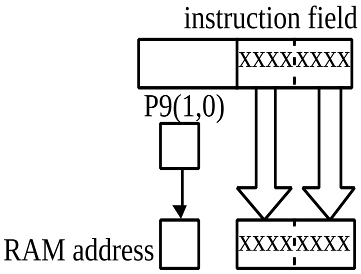


PROGRAM EXAMPLE: Load the data of RAM address "143h" to RAM address "032h".

```
OUT     #0001B,P9           ; RAM bank1
LDL     #3h                 ; LR← 3
LDH     #4h                 ; HR← 4
LDAM                        ; Acc← RAM[134h]
OUT     #0000B,P9           ; RAM bank0
LDL     #2h                 ; LR← 2
LDH     #3h                 ; HR← 3
STAM                        ; RAM[023h]← Acc
```

(2) Direct addressing mode:

The address in the bank is directly specified by 8 bits code of the second byte in the instruction field.

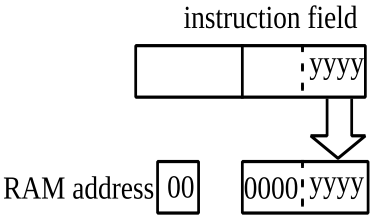


PROGRAM EXAMPLE: Load the data of RAM address "143h" to RAM address "023h".

```
OUT     #0001B,P9
LDA     43h                 ; Acc← RAM[143h]
OUT     #0000B,P9
STA     23h                 ; RAM[023h]← Acc
```

(3) Zero-page addressing mode:

The zero-page is in the bank 0 (address 000h~00Fh). The address is the lower 4 bits code 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)

Program counter (PC) is composed by a 13-bit counter, which indicates the next executed address for the instruction of program ROM instruction.
For BRANCH and CALL instructions, PC is changed by instruction indicating. PC only can indicate the address from 0000h-1FFFh. The bank number is decided by P3.

(1) Branch instruction:

SBR a
Object code: 00aa aaaa
Condition: SF=1; PC $\leftarrow$ PC $_{12\text{-}6.a}$ (branch condition satisified)

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

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

PC	Original PC value + 1

LBR a
Object code: 1100 aaaa aaaa aaaa
Condition: SF=1; PC $\leftarrow$ PC $_{12.a}$ (branch condition satisified)

PC	Hold +2	a	a	a	a	a	a	a	a	a	a	a	a

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

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 satisified)

PC	a	a	a	a	a	a	a	a	a	a	a	a	a

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

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	a	a	a	a	a	a	a	a

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 ← STACK[SP]; SP + 1

PC	The return address stored in stack

RT I
Object code: 0100 1101
Condition : FLAG. PC ← STACK[SP]; EI ← 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 follows :

$\overline{\mathbf{INT0}}$ (External interrupt from P8.2)

PC	0	0	0	0	0	0	0	0	0	0	0	1	0

SPI (speech end interrupt)

PC	0	0	0	0	0	0	0	0	0	0	1	0	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

$\overline{\mathbf{INT1}}$ (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(ACC) is a 4-bit data register for temporary data storage. For the arithematic, logic and comparative opertion.., ACC plays a role which holds the source data and result.

FLAGS

There are three kinds of flag, CF (Carry flag), ZF (Zero flag) and SF (Status flag), these three 1-bit flags are included by the arithematic, 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 is executed.

(1) Carry Flag (CF)

The carry flag is affected by the following operations:
a. Addition : CF as a carry out indicator, under addition operation, when a carry-out occures, the CF is "1", likewise, if the operation has no carry-out, CF is "0".

b. Subtraction : CF as a borrow-in indicator, under subtraction operation, when a borrow occures, the CF is "0", likewise, if there is no borrow-in, the CF is "1".

c. Comparision : CF as a borrow-in indicator for Comparision operation as in the 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 : Under TFCFC instruction, the CF content is sent into SF then clear itself as "0". Under TTSFC instruction, the CF content is sent into SF then set itself as "1".

(2) Zero Flag (ZF)

ZF is affected by the result of ALU, if the ALU operation generates a "0" result, the ZF is "1", likewise, the ZF is "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 is satisified, likewise, when SF = 0, branch condition is unsatisified.

PROGRAM EXAMPLE:

Check following arithematic operation for CF, ZF, SF

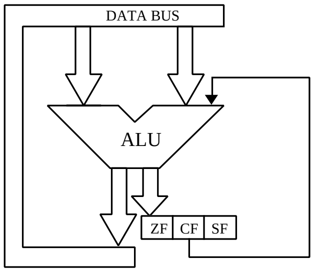
	CF	ZF	SF
LDIA #00h;	-	1	1
LDIA #03h;	-	0	1
ADDA #05h;	-	0	1
ADDA #0Dh;	-	0	0
ADDA #0Eh;	-	0	0

ALU

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

ALU STRUCTURE

ALU supported user arithematic operation functions, including Addition, Subtraction and Rotaion.



ALU FUNCTION

(1) Addition:

ALU supports addition function with instructions ADDAM, ADCAM, ADDM #k, ADD #k,y .... .
The addition operation affects CF and ZF. Under addition operation, if the result is "0", ZF will be "1", otherwise, 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:

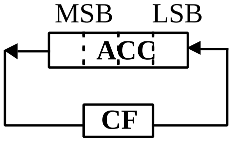
ALU supports subtraction function with instructions SUBM #k, SUBA #k, SBCAM, DECM... . The subtraction operation affects CF and ZF. Under subtraction operation, if the result is negative, CF will be "0", and a borrow out, otherwise, if the result is positive, CF will be "1". For ZF, if the result of subtraction operation is "0", the ZF is "1", likewise, ZF is "1".

EXAMPLE:

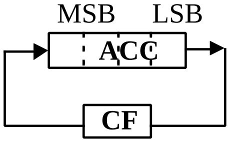
Operation	Carry	Zero
8-4=4	1	0
7-F= -8(1000)	0	0
9-9=0	1	1

(3) Rotation:

Two types of rotation operation are available, one is rotation left, the other is rotation right.
RLCA instruction rotates Acc value counter-clockwise, shift the CF value into the LSB bit of Acc and hold the shift out data in CF.



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

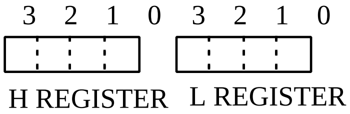


PROGRAM EXAMPLE: To rotate Acc clockwise (right) and shift a "1" into the MSB bit of Acc.
TTCFS; CF ← 1
RRCA; rotate Acc right and shift CF=1 into MSB.

HL REGISTER

HL register are two 4-bit registers, they are used as a pair of pointer for the RAM memoryaddress. They are used as also 2 independent temporary 4-bit data registers. For certain instructions, L register can be a pointer to indicate the pin number (Port4 only).

HL REGISTER STRUCTURE



HL REGISTER FUNCTION

(1) HL register is used as a temporary register for instructions : LDL #k, LDH #k, THA, THL, INCL, DECL, EXAL, EXAH.

PROGRAM EXAMPLE: Load immediate data "5h" into L register, "0Dh" into H register.
LDL #05h;
LDH #0Dh;

(2) HL register is used as a pointer for the address of RAM memory for instructions : LDAM, STAM, STAMI ..

PROGRAM EXAMPLE: Store immediate data "#0Ah" into RAM of address 35h.

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

(3) L register is used as a pointer to indicate the bit of I/O port for instructions : SELP, CLPL, TFPL, (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 that 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 received, the SP is decreased by one automatically, likewise, if returning from a subroutine, the SP is increased by one.
The data transfer between ACC and SP is done with instructions "LDASP" and "STASP".

DATA POINTER (DP)

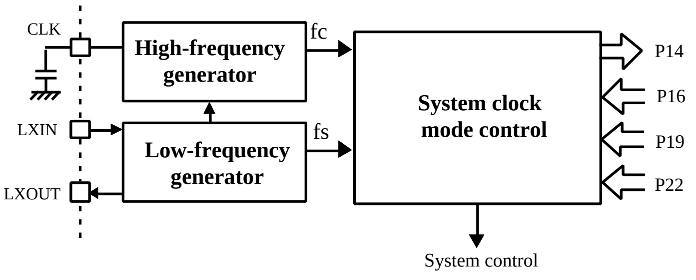
Data pointer is a 12-bit register that stores the ROM address can indicating the ROM code data specified by user (refer to data ROM).

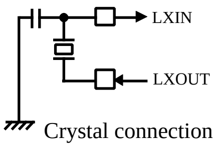
CLOCK AND TIMING GENERATOR

The clock generator is supported by a dual clock system. The high-frequency oscillator is internal oscillator. The low-frequency oscillator may be sourced from crystal, the working frequency is 32 KHz.

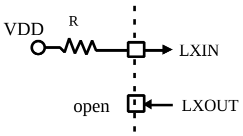
CLOCK GENERATOR STRUCTURE

There are two clock generator for system clock control unit, P14 is the status register that hold the CPU status. P16, P19 and P22 are the command register for system clock mode control.





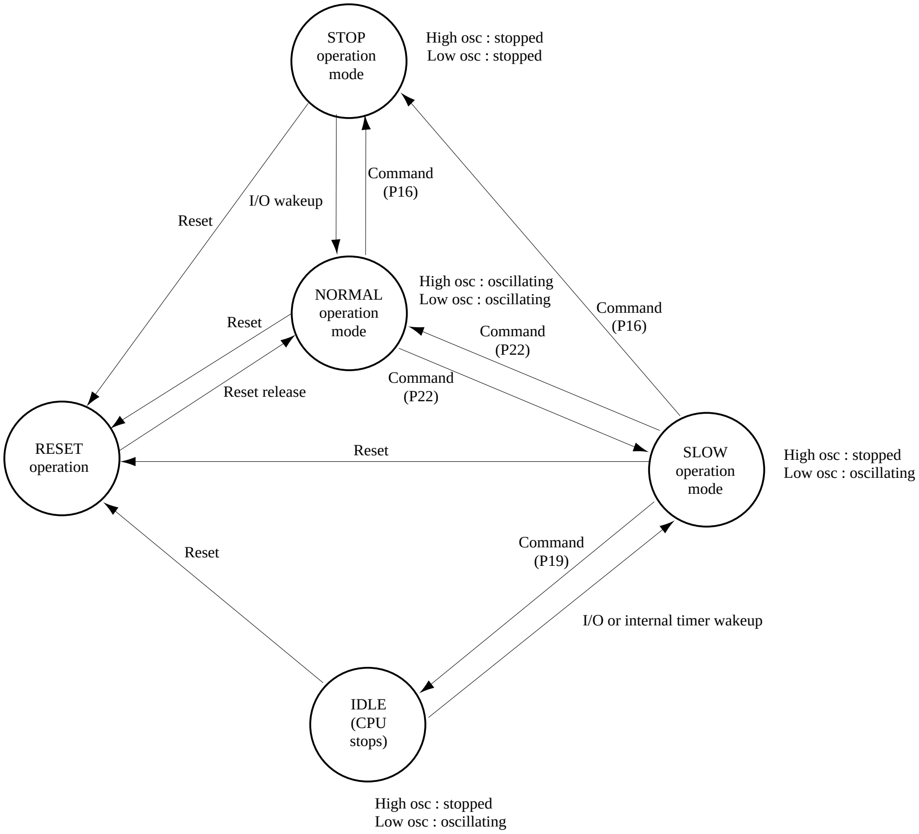
Crystal connection



RC oscillator connection
R=2.2MΩ

SYSTEM CLOCK MODE CONTROL

The system clock mode controller can start or stop the high-frequency and low-frequency clock oscillator and switch between the basic clocks. EM73A89B has four operation modes (DUAL, SLOW, IDLE and STOP operation modes).



Operation Mode	Oscillator	System Clock	Available function	One instruction cycle
NORMAL	High, Low frequency	High frequency clock	LCD, speech, HTC.	8 / fc
SLOW	Low frequency	Low frequency clock	LCD, HTC	4 / fs
IDLE	Low frequency	CPU stops	LCD	-
STOP	None	CPU stops	All disable	-

DUAL OPERATION MODE

The 4-bit μc is in the DUAL operation mode when the CPU is reseted. This mode is dual clock system (high-frequency and low-frequency clocks oscillating). It can be changed to SLOW or STOP operation mode with the command register (P22 or P16).
LCD display, speech synthesizer and sound generator are available for the DUAL operation mode.

SLOW OPERATION MODE

The SLOW operation mode is single clock system (low-frequency clock oscillating). It can be changed to the DUAL operation mode with the command register (P22), STOP operation mode with P16 and IDEL operation mode with P19.

LCD display is available for the SLOW operation mode. Speech synthesizer and sound generator are disabled in this mode.

P22 Initial value : ***0

3	2	1	0
*	*	*	SOM

SOM	Select operation mode
0	DUAL operation mode
1	SLOW operation mode

P14 Initial value : 0000

3	2	1	0
ACT	WKS	SINT	CPUS

CPUS	CPU status
0	DUAL operation mode
1	SLOW operation mode

WKS	Wakeup status
0	Wakeup not by internal timer
1	Wakeup by internal timer

Port14 is the status register for CPU. P14.0 (CPU status) is a read-only bit. P14.2 (wakeup status) will be set as "1" when CPU is waked by internal timer. P14.2 will be cleared as "0" when user out data to P14. P14.1 is the interrupt source selector (refer to interrupt). P14.3 is the speech acknowledge signal (refer to speech synthesizer control).

IDLE OPERATION MODE

The IDLE operation mode suspends all CPU functions except the low-frequency clock oscillation and the LCD driver. It keeps the internal status with low power consumption without stopping the slow clock oscillator and LCD display.

LCD display is available for the IDLE operation mode. The high speed counter and speech synthesizer are disabled in this mode. The IDLE operation mode will be wakeup and return to the SLOW operation mode by the internal timing generator or I/O pins (P0(0..3)/WAKEUP 0..3 and P8(0..3)/WAKEUPA..D).

P19 Initial value : 0000

3	2	1	0
IDME		SIDR	

IDME	Enable IDLE mode
0 1	Enable IDLE mode
* *	no function

SIDR	Select IDLE releasing condition
0 0	P0(0..3), P8(0..3) pin input
0 1	P0(0..3), P8(0..3) pin input and 1 sec signal
1 0	P0(0..3), P8(0..3) pin input and 0.5 sec signal
1 1	P0(0..3), P8(0..3) pin input and 15.625 ms signal

STOP OPERATION MODE

The STOP operation mode suspends system operation and holds the internal status immediately before the suspension with low power consumption. This mode will be released by reset or I/O pins (P0(0..3)/ WAKEUP 0..3 or P8(0..3)/WAKEUP A..D).

LCD display, high speed counter and speech synthesizer are disabled in this mode.

P16 Initial value : *000

3	2	1	0
*	SWWT		

SWWT	Enable STOP mode
1 0 1	Enable STOP mode
* * *	no function

GENERAL PURPOSE REGISTER (P10)

P10 is a 4-bit general purpose register which can be read, written and rested by all I/O instructions. (including : INA, INM, OUT, OUTA, OUTM, SEP, CLP, TTP, TFP)

PROGRAM EXAMPLE:

```
            CHIP    ROM16K
;--------RAM define area-----------------
            DSEG
            ORG     10H
HLBUF:      RES     2               ; HL buffer for interrupt
P9BUF:      RES     1               ; P9 (RAM bank) buffer for interrupt
            :
;----------Interrupt subroutine--------------------
            CSEG
            ORG     004H
            LBR     SPI
            :
SPI:        OUTA    P10             ; save Acc to general purpose register P10  \
            INA     P9                                                           |
            OUT     #0000B,P9                                                    >  10 instruction bytes
            STA     P9BUF           ; save RAM bank to P9BUF                     |
            EXHL    HLBUF           ; save HL to HLBUF                          /
            :
            :
            EXHL    HLBUF           ; restore HLBUF to HL                       \
            LDA     P9BUF           ; resotre P9BUF to RAM bank                  >  10 instruction bytes
            OUTA    P9                                                           |
            INA     P10             ; restore register P10 to Acc               /
            RTI
```

TIME BASE INTERRUPT (TBI)

The time base can be used to generate a single fixed frequency interrupt. Eight types of frequencies can be selected with the "P25" setting.

P25 3 2 1 0

initial value : 0000

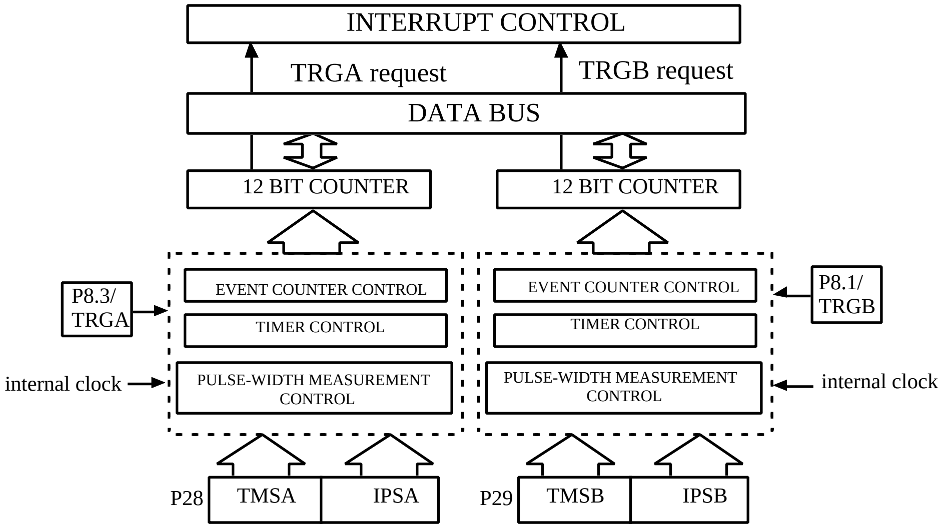
P25	NORMAL operation mode	SLOW operation mode
0 0 x x	Interrupt disable	Interrupt disable
0 1 0 0	Interrupt frequency LXIN / 2^{3} Hz	Reserved
0 1 0 1	Interrupt frequency LXIN / 2^{15} Hz	Interrupt frequency LXIN / 2^{15} Hz
0 1 1 0	Interrupt frequency LXIN / 2^{5} Hz	Reserved
0 1 1 1	Interrupt frequency LXIN / 2^{14} Hz	Interrupt frequency LXIN / 2^{14} Hz
1 1 0 0	Interrupt frequency LXIN / 2^{1} Hz	Reserved
1 1 0 1	Interrupt frequency LXIN / 2^{6} Hz	Interrupt frequency LXIN / 2^{6} Hz
1 1 1 0	Interrupt frequency LXIN / 2^{8} Hz	Interrupt frequency LXIN / 2^{8} Hz
1 1 1 1	Interrupt frequency LXIN / 2^{10} Hz	Interrupt frequency LXIN / 2^{10} Hz
1 0 x x	Reserved	Reserved

TIMER / COUNTER (TIMERA, TIMERB)

Timer/counters support three special functions:

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

These three functions can be executed by 2 timer/counter independently.
With timerA, the counter data is saved in timer register TAH, TAM, TAL. User can set counter initial value and read the counter value by instruction "LDATAH(M,L)" and "STATAH(M,L)". With timer B register is TBH, TBM, TBL and the W/R instruction are "LDATBH (M,L)" and "STATBH (M,L)".
The basic structure of timer/counter is composed by two identical counter module, these two modules can be set initial timer or counter value to the timer registers, P28 and P29 are the command registers for timerA and timer B, user can choose different operation modes and internal clock rates by setting these two registers. When timer/counter overflows, 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.

P28, P29	3	2	1	0
	TMSA(B)		IPSA(B)	

Initial value : 0000

TMSA(B)	Mode selection
0 0	Stop
0 1	Event counter mode
1 0	Timer mode
1 1	Pulse width measurement mode

IPSA	Clock rate selection	
	NORMAL mode	SLOW mode
0 0	LXIN/2^3 HZ	Reserved
0 1	LXIN/2^7 HZ	LXIN/2^7 HZ
1 0	LXIN/2^{11} HZ	LXIN/2^{11} HZ
1 1	LXIN/2^{15} HZ	LXIN/2^{15} HZ

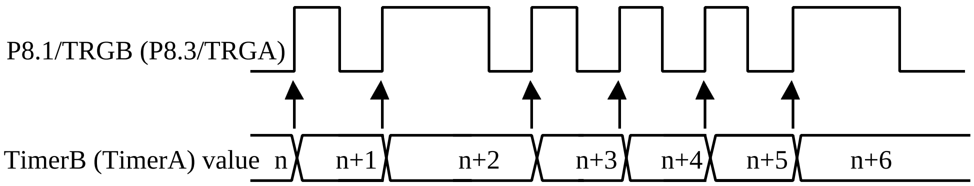
IPSB	Clock rate selection	
	NORMAL mode	SLOW mode
0 0	Depend on high speed timer/counter	
0 1	LXIN/2^5 HZ	LXIN/2^5 HZ
1 0	LXIN/2^9 HZ	LXIN/2^9 HZ
1 1	LXIN/2^{13} HZ	LXIN/2^{13} HZ

TIMER/COUNTER FUNCTION

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

EVENT COUNTER MODE

Under event counter mode, the timer/counter is increased by one at any rising edge of P8.1/TRGB for timerB (P8.3/TRGA for timer A). When timerB (timerA) counts overflow, it will provide an interrupt request TRGB (TRGA) to interrupt control unit.

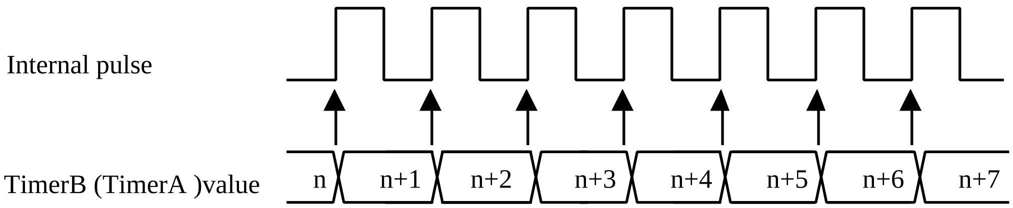


PROGRAM EXAMPLE: Enable timerA with P28

```
LDIA      #0100b;
OUTA      P28              ; Enable timerA with event counter mode
```

TIMER MODE

Under timer mode, the timer/counter is increased by one at any rising edge of internal pulse. User can choose up to 4 types of internal pulse rate by setting IPSB for timerB (IPSA for timerA).
When timer/counter counts overflow, an interrupt request will be sent to interrupt control unit.



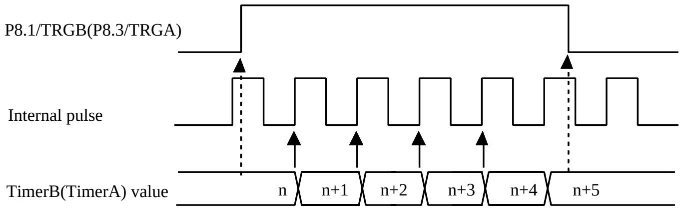
PROGRAM EXAMPLE: To generate TRGA interrupt request after 60 ms with system clock LXlN=32KHz

```
LDIA    #0100B     ;
EXAE               ; enable mask 2
EICIL   110111b    ; interrupt latch ←0, enable EI
LDIA    #0Ah;
STATAL;
LDIA    #00h;
STATAM;
LDIA    #0Fh;
STATAH;
LDIA    #1000B;
OUTA    P28        ; enable timerA with internal pulse rate: LXIN/2^3 Hz
```

NOTE: The preset value of timer/counter register is calculated as following procedure.
Internal pulse rate: LXIN/2^3 ; LXIN = 32KHz
The time of timer counter count one = 2^3 /LXIN = 8/32768=0.244ms
The number of internal pulse to get timer overflow = 60 ms/0.244ms = 245.901= 0F6h
The preset value of timer/counter register = 1000h - 0F6h = F0Ah

PULSE WIDTH MEASUREMENT MODE

Under the pulse width measurement mode, the counter is incresed at the rising edge of internal pulse during external timer/counter input (P8.1/TRGB, P8.3/TRGA) in high level, interrupt request is generated as soon as timer/counter count overflow.



PROGRAM EXAMPLE: Enable timerA by pulse width measurement mode.

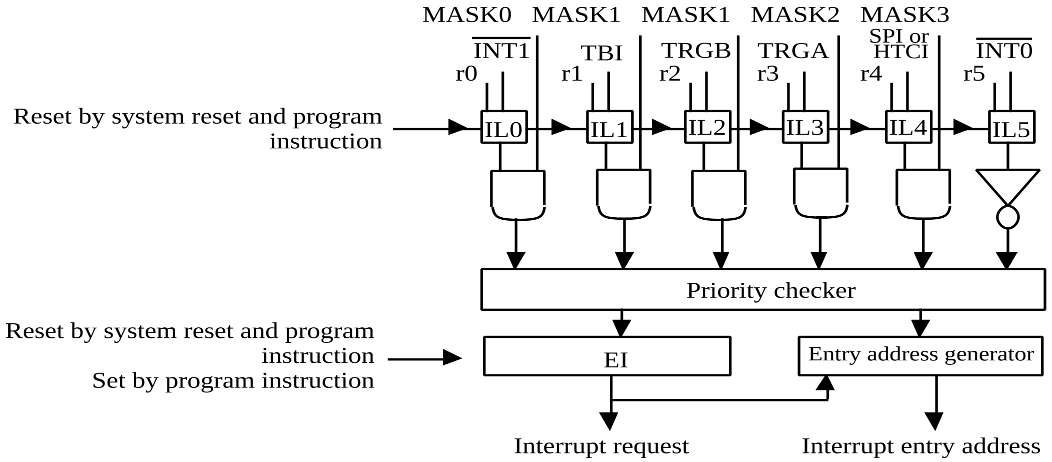
```
LDIA    #1100b  ;
OUTA    P28     ; Enable timerA with pulse width measurement mode.
```

INTERRUPT FUNCTION

Six interrupt sources are available, 2 from external interrupt sources and 4 from internal interrupt sources. Multiple interrupts are admitted according to their priority.

Type	Interrupt source	Priority	Interrupt Latch	Interrupt Enable condition	Program ROM entry address
External	External interrupt ($\overline{\text{INT0}}$)	1	IL5	EI=1	002h
Internal	Speech or HTC interrupt (SPI or HTCI)	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	External interrupt($\overline{\text{INT1}}$)	6	IL0	EI=1, MASK0=1	00Ch

INTERRUPT STRUCTURE



Interrupt controller:

IL0-IL5	: Interrupt latch. Hold all interrupt requests from all interrupt sources. IL's can not be set by program, but can be reset by program or system reset, so IL can only decide which interrupt source can be accepted.
MASK0-MASK3	: Except $\overline{\text{INT0}}$, MASK register may permit or inhibit all interrupt sources.
EI	: Enable interrupt Flip-Flop may promit or inhibit all interrupt sources, when interrupt occurs, EI is auto cleared to "0", after RTI instruction is executed, EI is auto set to "1" again.
Priority checker	: Check interrupt priority when multiple interrupts occur.

INTERRUPT OPERATION

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 occur.
5. Clear the IL with which interrupt source has already been accepted.
6. 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     #0100B  ;
EXAE             ; set mask register "0100b"
EICIL    010111B ; enable interrupt F.F. and clear IL3 and IL5
```

INTERRUPT SOURCE SELECTION REGISTER

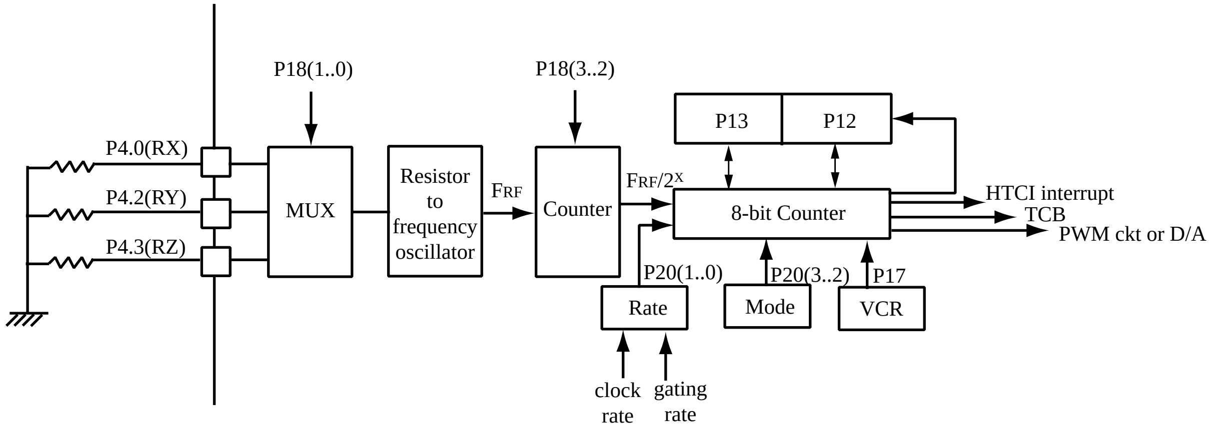
P14	3	2	1	0
	ACT	WKS	SINT	CPUS

Initial value : 0000

P14.1 is the interrupt source selection register for speech ending interrupt (SPI) and high speed counter overflow interrupt (HTCI) selection. When SINT=0, the program address "0004H" is the interrupt entry address of SPI. When SINT=1, the program address "0004H" is the interrupt entry address of HTCI. P14.0 and P14.2 are the CPU flages (refer to system operation mode). P14.3 is the speech acknowledge signal (refer to speech synthesizer control).

HIGH SPEED COUNTER

EM73A89B has one high speed counter for resistor to frequency oscillation mode, melody mode and auto load timer mode. This function is available for the DUAL and SLOW operation mode. The resistor to frequency oscillation (RFO) circuit as show below :



CONTROL OF HIGH SPEED COUNTER

The high speed counter is controlled by the command registers (P20, P18) :

P20 3 2 1 0 Initial value : 0000

MODE	RATE

MODE	Selection of HTC mode
0 0	Disable HTC
0 1	Auto load timer mode
1 0	Melody mode
1 1	Resistor to frequency oscillation mode

RATE (Hz)	Internal pulse rate / Counter start request frequency	
	Resistor to frequency oscillation mode	Auto load timer mode / Melody mode internal pulse rate
0 0	LXIN / 2^6	CLK / 2^4
0 1	LXIN / 2^{10}	CLK / 2^5
1 0	LXIN / 2^{14}	CLK / 2^6
1 1	LXIN / 2^{15}	CLK / 2^7

P18 3 2 1 0 Initial value : 0000

RFIP	RFIN

RFIP	Input frequency of RFO	RFIN	Selection of RFO Pin
0 0	F_{RF}	0 0	Normal I/O
0 1	F_{RF} / 4	0 1	P4.0 (RX) for RFO
1 0	F_{RF} / 16	1 0	P4.2 (RY) for RFO
1 1	F_{RF} / 64	1 1	P4.3 (RZ) for RFO

P12 and P13 are the 8-bit binary counter registers of the HTC. P12 is lower nibble register and P13 is higher nibble register.

P13 3 2 1 0 — Higher nibble register

P12 3 2 1 0 — Lower nibble register

Initial value : 0000 0000

The HTC can be set initial value and send counter value to counter registers (P13 and P12), P20 and P18 are the command ports for HTC, user can choose different operation mode and different internal clockrate by setting the port. The timer/counter increase one at the rising edge of internal pulse. The HTC can generate an overflow interrupt (HTCI) when it overflows. The HTCI can't be generated when the HTC is in the melody mode or disabled.

8-BIT BINARY COUNTER

Write the preset value to the registers

The value of 8-bit binary counter can be presetted by P13 and P12. The value of registers can be loaded into the 8-bit binary counter when the counter starts counting or occurs overflow. When the 8-bit binary counter overflows, the HTCI interrupt will be generated. If you write values to the registers before the next overflow occurs, the preset value can be changed.

Read the count value from the registers

The count value of 8-bit binary counter can be read out from P13 and P12. The value is unstable when you read out the value during counting. Thus, you must disable the counter before reading out the value.

20-BIT COUNTER FUNCTION

The 8-bit binary counter is connected to TCB which is one 12-bit general counter and becomes to the 20-bit counter. The TCB increases one when the 8-bit binary counter overflows and generats an overflow interrupt (TRGB) when the TCB overflows. The TRGB cannot be generated when the HTC is in the melody or disable.

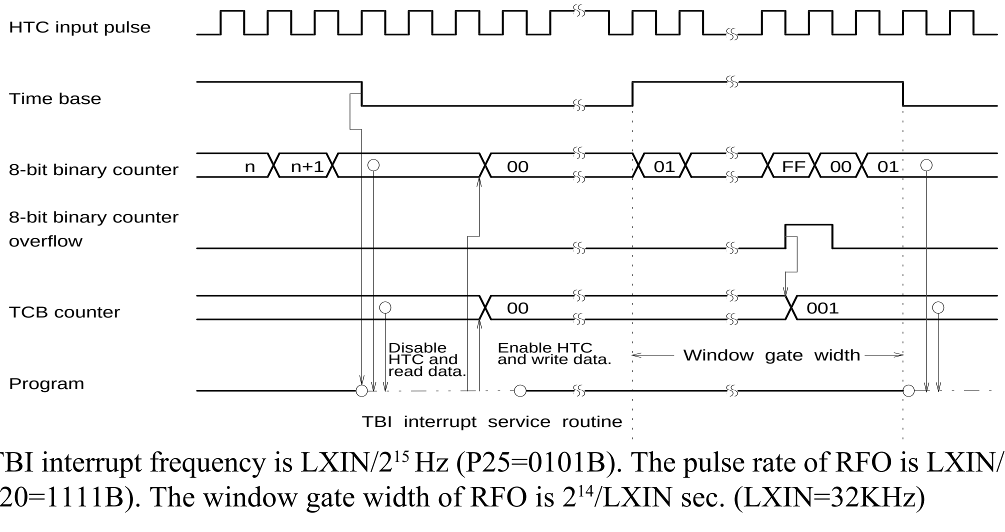
FUNCTION OF HIGH SPEED COUNTER

The HTC has three modes which are RFO mode, melody mode and auto load timer mode.

The HTC is disabled when the CPU is reseted or in the STOP/IDLE operation mode. Users must enable it by yourself when the CPU is waked up.

Resistor to frequency oscillation mode

In this mode, the HTC is counted by the rising edges of input pulses from P4.1 (CS) and the value of window gate width is specified by P20. In this case, the window gate width interval is from the time base output fall to rise and the value of window gate width setting is the same as the time base interrupt frequency. The time base can be generated a fixed frequency interrupt when the time base interrupt (TBI) is enabled. The content of the HTC can be read and initialized by the TBI interrupt service routine.



ex. TBI interrupt frequency is LXIN/2^{15} Hz (P25=0101B). The pulse rate of RFO is LXIN/2^{15} Hz (P20=1111B). The window gate width of RFO is 2^{14}/LXIN sec. (LXIN=32KHz)

PROGRAM EXAMPLE

```
        DSEG
        ORG     00H

HLBUF:  RES     2

P9BUF:  RES     1

RFCON:  RES     1
        :
        CSEG
        ORG     00H
        LBR     MAIN            ; initial jump
        ORG     0AH
        LBR     TBI             ; timebase interrupt vector address
        :
                                ; timebase interrupt service routine
TBI:    OUTA    P10
        INA     P9
        OUT     #0,P9
        STA     P9BUF
        EXHL    HLBUF
        CMP     #00H,RFCON
        B       TBI1
        STD     #01H,RFCON
        LDIA    #00H            ; initial TCB & HTC register
        OUTA    P13
        OUTA    P12
        STATBL
        STATBM
        STATBH
        B       TBIEND
```

Preliminary

```
TBI1:    OUTA     P10
         INA      P9
         OUT      #0,P9
         STA      P9BUF
         EXHL     HLBUF
         LDIA     #00H              ; disable RFO before reading the counter value
         OUTA     P20
         INA      P12               ; store the counter value to RAM[00] - RAM[04]
         STA      00H
         INA      P13
         STA      01H
         LDATBL
         STA      02H
         LDATBM
         STA      03H
         LDATBH
         STA      04H

TBIEND:  EXHL     HLBUF
         LDA      P9BUF
         OUTA     P9
         INA      P10
         RTI
                                    ; main program
MAIN:    STD      #00H,RFCON
         LDIA     #0001B            ; P4.0 (RX) output
         OUTA     P18
         LDIA     #0010B            ; enable timebase interrupt
         EXAE
         EICIL    0
         LDIA     #1111B            ; the pulse rate of RFO=2^15/LXIN sec.
         OUTA     P20
         LDIA     #0101B            ; enable timebase, interrupt frequency : LXIN / 2^15 Hz
         OUTA     P25
         :
```

Auto load timer mode

In this mode, there are four different internal pulse rates can be selected by P20. The HTC loads the initial values by the counter registers (P12, P13) and increases at the rising edges of internal pulse generated by the time base. The value of TCB increases one when the high speed counter overflows and generates an overflow interrupt (TRGB) when the TCB overflows. This mode is only available for DUAL operation mode.

PROGRAM EXAMPLE :

```
LDIA        #00H        ; initial TCB & HTC register
STATBL
STATBM
STATBH
OUTA        P13
OUTA        P12
OUTA        P18
LDIA        #0111B      ; enable timer mode, internal pulse rate : CLK/2^7
OUTA        P20
:
LDIA        #00H        ; disable timer mode
OUTA        P20
INA         P12         ; store the counter value to RAM[00] - RAM[04]
STA         00H
INA         P13
STA         01H
LDATBL
STA         02H
LDATBM
STA         03H
LDATBH
STA         04H
```

Melody mode

In the melody mode, HTC will output the square wave to the PWM circuit or D/A converter.
The 8-bit tone frequency register is P13 and P12. The tone frequency will be changed when users output the different data to P12. Thus, the data must be output to P13 before P12 when users want to change the 8-bit tone frequency (TF). This mode is only available for DUAL operation mode.

P13				P12				
3	2	1	0	3	2	1	0	Initial value : 0000 0000 (TF)
Higher nibble register				Lower nibble register				

** F_{TONE} = [(CLK / 2^X) / (100H - TF)] / 2, TF = 0 ~ 255

** Example : CLK = 4.6MHz, RATE = 10, TF = 11001110 B= 0CEH.

F_{TONE} = [(4.6MHz / 2^5) / (100H - 0CEH)] / 2 = 1430 Hz.

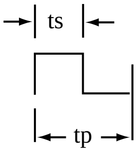
Volume control register (P17)

The are 16 levels of volume for sound generator. P17 is the volume control register.

Port17 Initial value : 0000

3	2	1	0
VCR			

VCR				ts/tp
1	1	1	1	15/16
1	1	1	0	14/16
:				:
0	0	0	1	1/16
0	0	0	0	0/16



$tp=\frac{1}{CLK/64}$ (CLK=4.6MHz)

PROGRAM EXAMPLE:

```
LDIA        #0CH
OUTA        P13
LDIA        #0EH
OUTA        P12
LDIA        #0111B              ; volume control
OUTA        P17
LDIA        #1010B              ; 1430 Hz tone output
OUTA        P20
```

LCD DRIVER

It can directly drive the liquid crystal display (LCD) and has 64 segment pins, 16 or 32 common pins by mask option. There are total 64x16 or 64x32 dots can be display. The V1~V5, VA and VB pins have to connect the capacitors for LCD voltage multiplier.

	16 common pins	**32 common pins**
Display dots	16x64 dots	32x64 dots
Bias	1/5 bias	1/5 bias
Duty	1/16 duty	1/32 duty
LCD display RAM	Bank2 (P9=xx10B)	Bank2(P9=xx10B), Bank3(P9=xx11B)
I/O or LCD pin by mask option	COM0..15, SEG0..59, P1[0..3]/SEG63..60	COM0..31, SEG0..43, P7[0..3]/SEG47..44, P6[0..3]/SEG51..48, P5[0..3]/SEG55..52, P2[0..3]/SEG59..56, P1[0..3]/SEG63..60

LCD driver control command register (P27) :

Port27	3	2	1	0	Initial value : 0000
	LDC	VREF			

LDC	LCD display control
0	LCD display disable
1	LCD display enable

* : Don't care.

*[1] : V5 is LCD working voltage (suggestion only).

VREF	Reference voltage	V5(1/5bias)*[1]
0 0 0	0.85V	4.25V
0 0 1	0.90V	4.50V
0 1 0	0.95V	4.75V
0 1 1	1.00V	5.00V
1 0 0	1.05V	5.25V
1 0 1	Reserved	Reserved
1 1 *	Reserved	Reserved

Example :

```
LDIA    #1001B      ; enable LCD.
OUTA    P27
:
LDIA    #0000B      ; disable LCD.
OUTA    P27
```

LCD display data area:

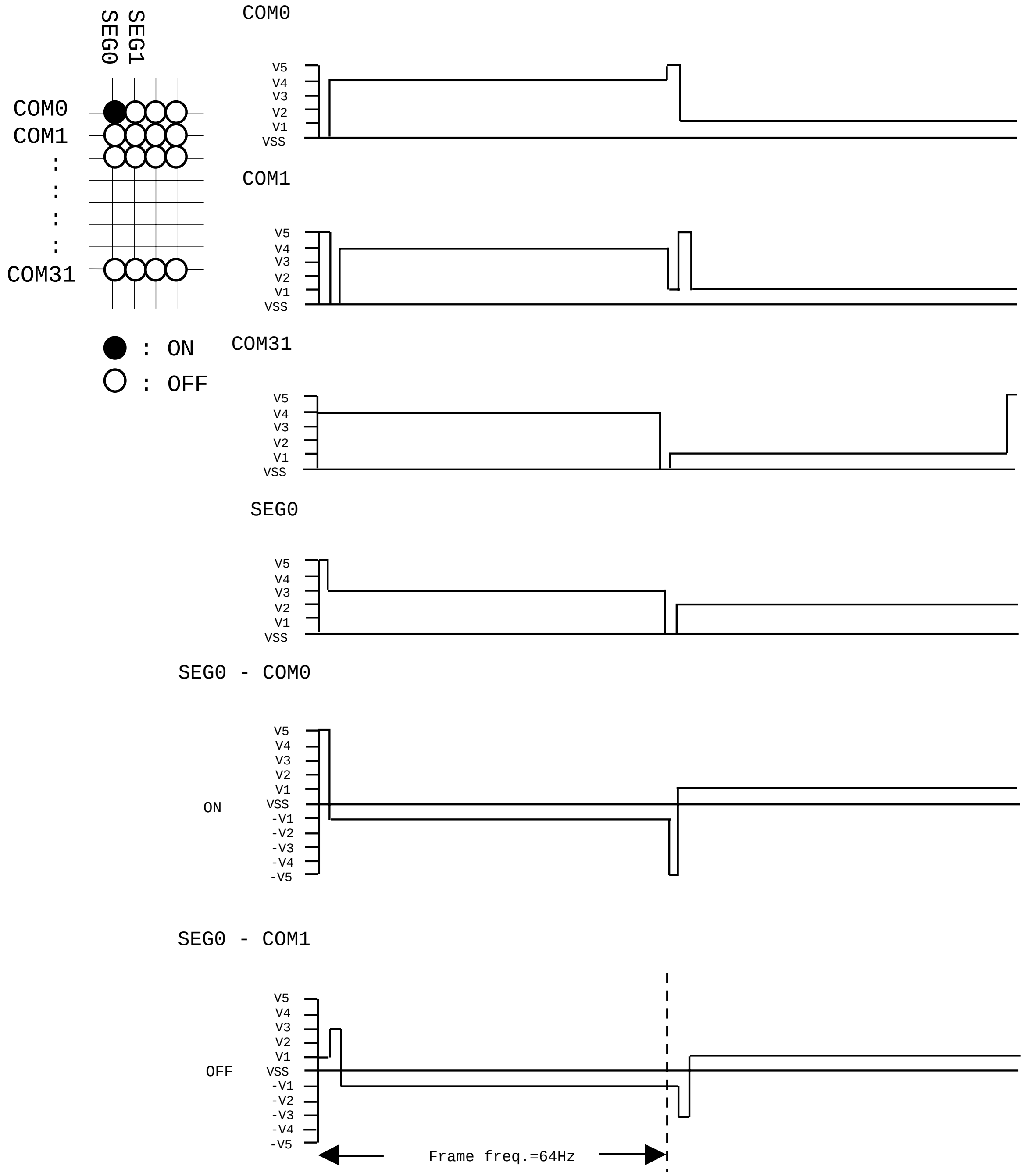
The LCD display data is stored in the display data area of the data memory (RAM).

Bank 2	Address	0 1 2 3 4 5 6 7 8 9 A B C D E F
P9=xx10B	200-20Fh	COM0
	210-21Fh	COM1
	220-22Fh	COM2
	230-23Fh	COM3
	240-24Fh	COM4
	250-25Fh	COM5
	260-26Fh	COM6
	270-27Fh	COM7
	280-28Fh	COM8
	290-29Fh	COM9
	2A0-2AFh	COM10
	2B0-2BFh	COM11
	2C0-2CFh	COM12
	2D0-2DFh	COM13
	2E0-2EFh	COM14
	2F0-2FFh	COM15
Bank 3		
P9=xx11B	300-30Fh	COM16
	310-31Fh	COM17
	320-32Fh	COM18
	330-33Fh	COM19
	340-34Fh	COM20
	350-35Fh	COM21
	360-36Fh	COM22
	370-37Fh	COM23
	380-38Fh	COM24
	390-39Fh	COM25
	3A0-3AFh	COM26
	3B0-3BFh	COM27
	3C0-3CFh	COM28
	3D0-3DFh	COM29
	3E0-3EFh	COM30
	3F0-3FFh	COM31

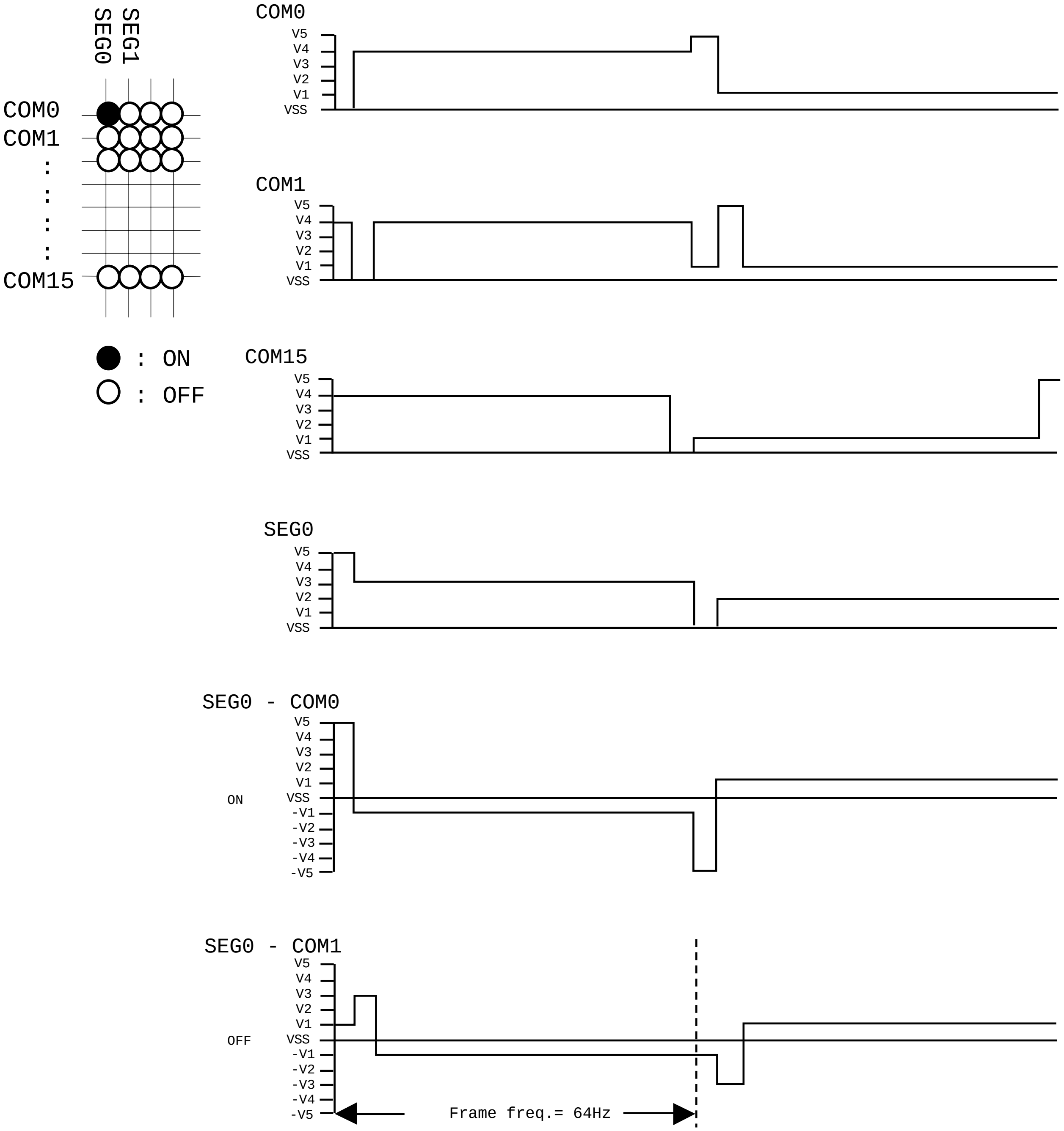
SEG0 SEG1 SEG2 SEG3 SEG4 SEG5 SEG6 SEG7 SEG8 SEG9 SEG10 SEG11 SEG12 SEG13 SEG14 SEG15 SEG16 SEG17 SEG18 SEG19 SEG20 SEG21 SEG22 SEG23 SEG24 SEG25 SEG26 SEG27 SEG28 SEG29 SEG30 SEG31 SEG32 SEG33 SEG34 SEG35 SEG36 SEG37 SEG38 SEG39 SEG40 SEG41 SEG42 SEG43 SEG44 SEG45 SEG46 SEG47 SEG48 SEG49 SEG50 SEG51 SEG52 SEG53 SEG54 SEG55 SEG56 SEG57 SEG58 SEG59 SEG60 SEG61 SEG62 SEG63

LCD waveform :

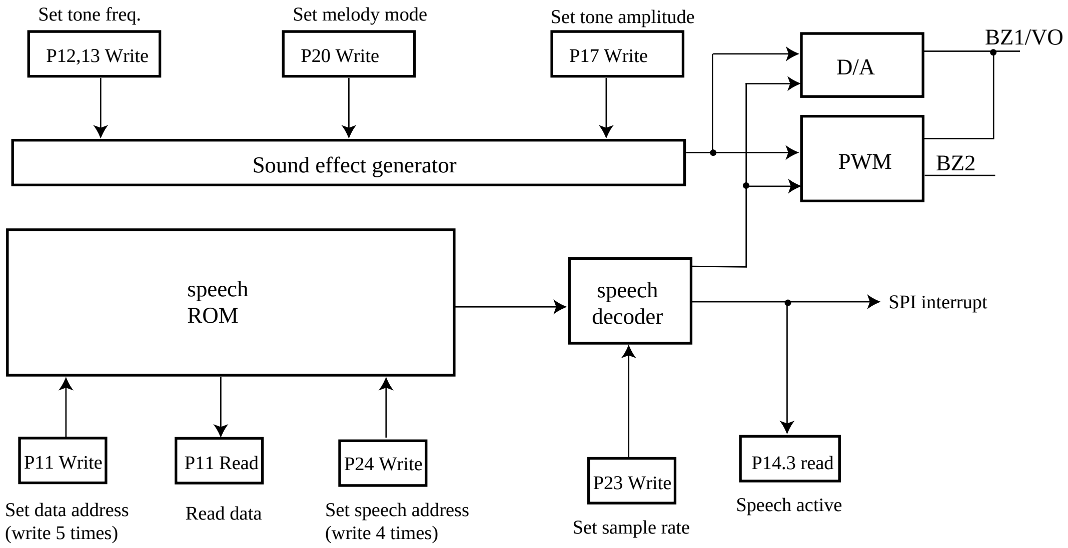
(1)1/32 duty, 1/5 bias



(2)1/16 duty, 1/5 bias



SPEECH SYNTHESIZER



Block diagram of speech and sound effect

EM73A89B speech synthesizer operates as following :

1. Send the speech start address to the address latch by writing P24 four times.
2. Choose the sampling rate, enable the speech synthesizer by writing P23.
3. The ROM address counters send the ROM address A6 .. A19 to the speech ROM.
4. ACT is the speech acknowledge signal. When the speech synthesizer has voice output. ACT is high. When ACT is changed from high to low, the speech synthesizer can generate the speech ending interrupt SPI. The ACT signal can be read from P14.3.

SPEECH SYNTHESIZER CONTROL

Speech sample rate control register (P23 write) :

P23 3 2 1 0 Initial value : 1111

SR

SR	Sample rate selection
0000	CLK/64/2/3
0001	CLK/64/2/4
0010	CLK/64/3/3
0011	CLK/64/3/4
0100	CLK/64/2/7
0101	CLK/64/4/4
0110	CLK/64/6/3
0111	CLK/64/6/4
1***	Disable speech

port 23 -- initialization is "1111".
port 24 -- initialization is pointed to the low-nibble of start address latch.

The frequency of CLK is decided by mask option.

Speech active flag (P14.3 read) :

Initial value : 0000

P14	3	2	1	0
	ACT	WKS	SINT	CPUS

ACT is the speech acknowledge signal. When the speech synthesizer has voice output, ACT is high. When ACT is high → low, the speech synthesizer can generate the speech ending interrupt SPI.
P14(0,2) are CPU status flags (refer to CPU status). P14.1 is the interrupt source selector (refer to interrupt).

Speech start address register (P24 write) :

Initial value : 1111

P24	3	2	1	0
	Port 24			

P24L1				P24L2				P24L3				P24L4			
A9	A8	A7	A6	A13	A12	A11	A10	A17	A16	A15	A14	-	-	A19	A18

Send the speech start address to the speech synthesizer by writing P24 four times. There is a pointer counter to point the address latch (P24L1, P24L2, P24L3, P24L4). It will increase one when write P24. So, the first time writing P24 to P24L1, the second time is P24L2, the third time is P24L3, the fourth time is P24L4 and the fifth time is P24L1 latch again, ... etc. The pointer counter point to P24L1 when CPU is reset or P23 is written. In the DUAL operation mode, the speech synthesizer is available. In the other operation modes, it is disable.

PROGRAM EXAMPLE:

```
                CHIP    ROM16K
;--------RAM define area-----------------
                DSEG
                ORG     10H
HLBUF:          RES     2                   ; HL buffer for interrupt
P9BUF:          RES     1                   ; P9 (RAM bank) buffer for interrupt
                :
;----------Constant-------------------------
ACT             EQU     143
SPEECH          EQU     43200H
                :
;----------Interrupt subroutine-----------
                CSEG
                ORG     004H
                LBR     SPI
                :
SPI:            OUTA    P10                 ; save Acc to general purpose register P10  \
                INA     P9                                                               |
                OUT     #0000B,P9                                                        > 10 instruction bytes
                STA     P9BUF               ; save RAM bank to P9BUF                     |
                EXHL    HLBUF               ; save HL to HLBUF                          /
                :
                :
                EXHL    HLBUF               ; restore HLBUF to HL                        \
                LDA     P9BUF               ; resotre P9BUF to RAM bank                  > 10 instruction bytes
                OUTA    P9                                                               |
                INA     P10                 ; restore register P10 to Acc               /
                RTI
```

```
;----------Mainprogram-------------------
MAIN :
            :
            LDIA    #0000B
            OUTA    P14              ; select SPI interrupt
            LDIA    #SPEECH/40H      ; set speech start address
            OUTA    P24
            LDIA    #SPEECH/400H
            OUTA    P24
            LDIA    #SPEECH/4000H
            OUTA    P24
            LDIA    #SPEECH/40000H
            OUTA    P24
            LDIA    #0011B           ; set sampling rate and start playing
            OUTA    P23
            :
WAIT :
            TTP     P14,3            ; wait speed end
            B       WAIT
            :
```

USING SPEECH ROM AS DATA ROM

The speech ROM can be used for speech synthesizer and for data ROM simutaneously.
First, write initial address to P11 five times, then you can read P11 to get data, and the address counter increases one automatically.
The read operation should be all done before you leave normal mode and change to slow mode.

Get speech ROM data (P11 read) :

3	2	1	0
Port 11			

Set speech ROM address (P11 write) :

3	2	1	0
Port 11			

P11L1	P11L2	P11L3	P11L4	P11L5
A3 A2 A1 A0	A7 A6 A5 A4	A11 A10 A9 A8	A15 A14 A13 A12	A19 A18 A17 A16

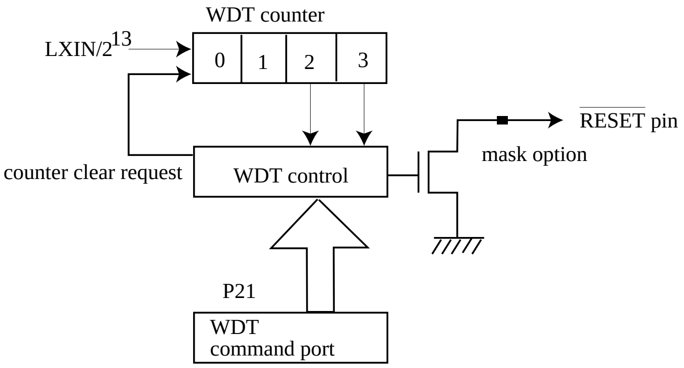
PROGRAM EXAMPLE:

```
DATA_ADR  EQU     12345H               ; the start address of the speech ROM
          :
          LDIA    #DATA_ADR
          OUTA    P11
          LDIA    #DATA_ADR/10H
          OUTA    P11
          LDIA    #DATA_ADR/100H
          OUTA    P11
          LDIA    #DATA_ADR/1000H
          OUTA    P11
          LDIA    #DATA_ADR/10000H
          OUTA    P11
```

```
                                        ; READ DATA
INA              P11                    ; read DATA_ADR
STA              TEMP
INA              P11
STA              TEMP+1
:
```

WATCH-DOG-TIMER (WDT)

Watch-dog-timer can help user to detect the malfunction (runaway) of CPU and give system a timeup signal every certain time. User can use the time up signal to give system a reset signal when system is fail.
This function is available by mask option. If the mask option of WDT is enabled, it will stop counting when CPU is reseted or in the STOP operation mode.
The basic structure of Watch-Dog-Timer control is composed by a 4-stage binary counter and a control unit. The WDT counter counts for a certain time to check the CPU status, if there is no malfunction happened, the counter will be cleared and continue counting. Otherwise, if there is a malfunction happened, the WDT control will send a WDT signal (low active) to reset CPU. The WDT checking period is assign by P21 (WDT command port).



P21 is the control port of watch-dog-timer, and the WDT time up signal is connected to $\overline{\text{RESET}}$.

Port 21 Initial value :0000

3	2	1	0
CWC	*	*	WDT

CWC	Clear watchdog timer counter
0	Clear counter then return to 1
1	Nothing

WDT	Set watch-dog-timer detect time
0	3×2^{13}/LXIN = 3×2^{13}/32K Hz = 0.75 sec
1	7×2^{13}/LXIN = 7×2^{13}/32K Hz = 1.75 sec

PROGRAM EXAMPLE

To enable WDT with 7 x 2^{13}/LXIN detection time.

```
LDIA    #0001B
OUTA    P21        ; set WDT detection time and clear WDT counter
:
:
```

RESETTING FUNCTION

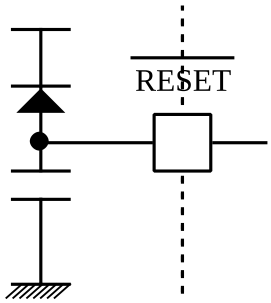
When CPU in normal working condition and $\overline{\text{RESET}}$ pin is held in low level for three instruction cycles at least, then CPU begins to initialize the whole internal states, when $\overline{\text{RESET}}$ pin changes to high level, CPU begins to work in normal condition.

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

Hardware condition in RESET 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, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 21, 22, 25, 27, 28, 29	00h
P0, 1, 2, 4, 5, 6, 7, 8, 17, 23, 24	0Fh
CLK, LXIN	Start oscillation

The $\overline{\text{RESET}}$ pin is a hysteresis input pin and it has a pull-up resistor available by mask option.

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

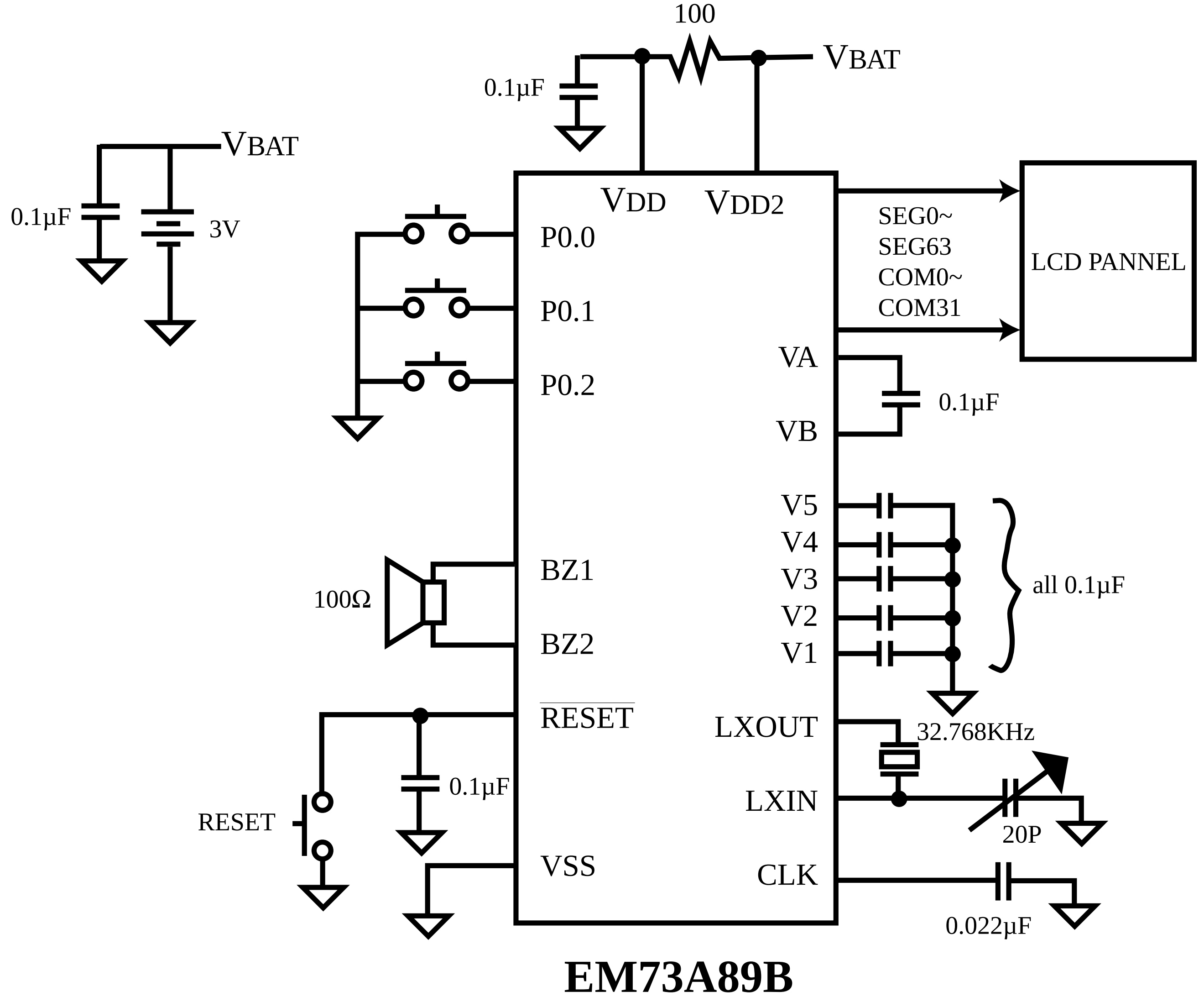


EM73A89B I/O PORT DESCRIPTION :

Port	Input function		Output function		Note
0	E	Input port , wakeup function			
1	E	Input port	E	Output port / LCD segment pins	
2	E	Input port	E	Output port / LCD pins	
3	I	ROM bank selection	I	ROM bank selection	
4	E	Input port	E	Output port / RFO pins	
5	E	Input port	E	Output port / LCD pins	
6	E	Input port	E	Output port / LCD pins	
7	E	Input port	E	Output port / LCD pins	
8	E	Input port, wakeup function, external interrupt input	E	Output port	
9	I	RAM bank selection	I	RAM bank selection	
10	I	General purpose register	I	General purpose register	
11	I	Read data register	I	Data ROM address register	
12		--	I	High speed counter register	Low nibble
13		--	I	High speed counter register	High nibble
14	I	CPU status, ACT flag	I	CPU status, interrupt souce selector	
15		--		--	
16			I	STOP mode control register	
17			I	TONE volume control register	
18			I	HTC control register	
19			I	IDLE mode control register	
20			I	HTC control register	
21			I	WDT control register	
22			I	DUAL/SLOW mode control register	
23			I	Speech sampling rate register	
24			I	Speech start address register	
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				--	
31				--	

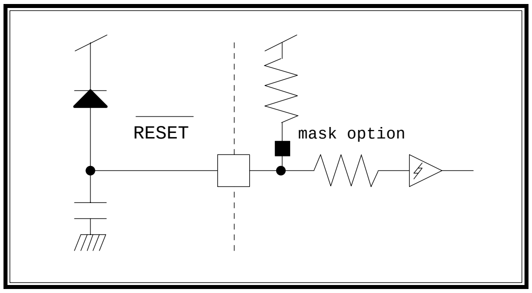
Preliminary

APPLICATION CIRCUIT



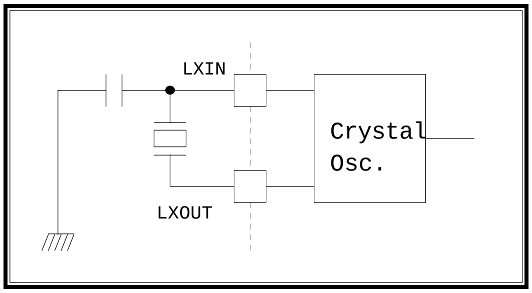
RESET PIN TYPE

TYPE RESET-A

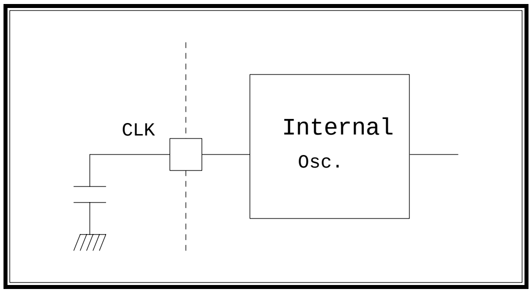


OSCILLATION PIN TYPE

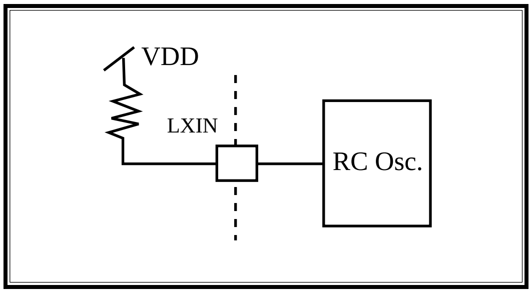
TYPE OSC-B



TYPE OSC_G

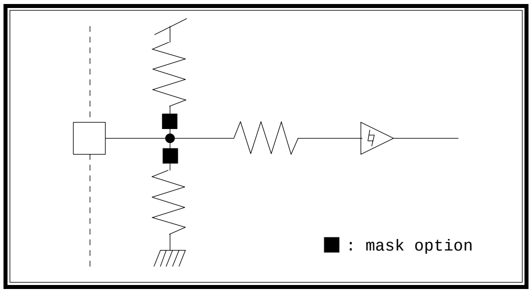


TYPE OSC-H

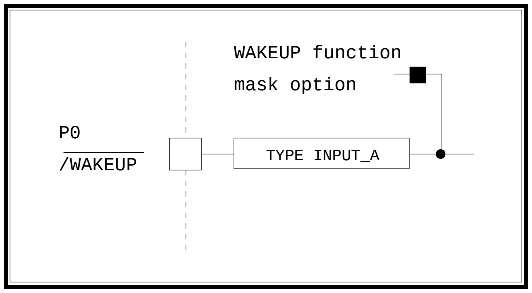


INPUT PIN TYPE

TYPE INPUT-A

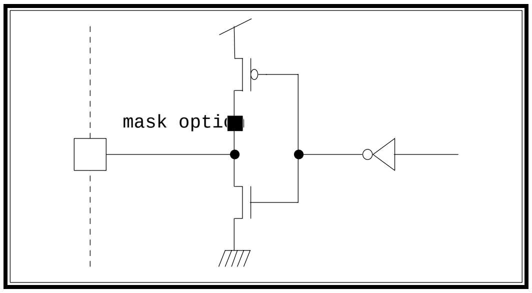


TYPE INPUT-B

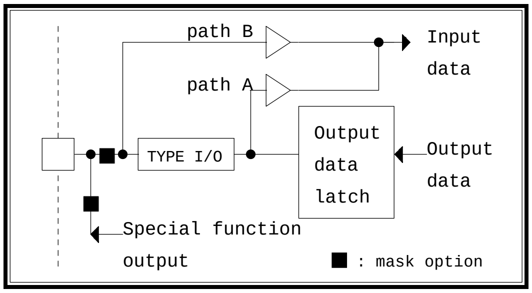


I/O PIN TYPE

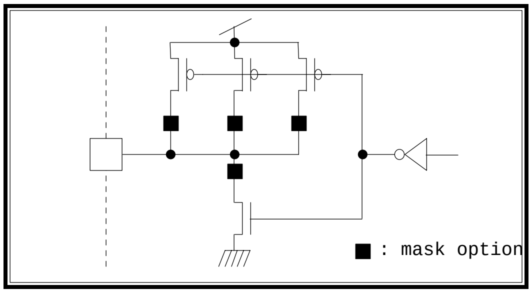
TYPE I/O



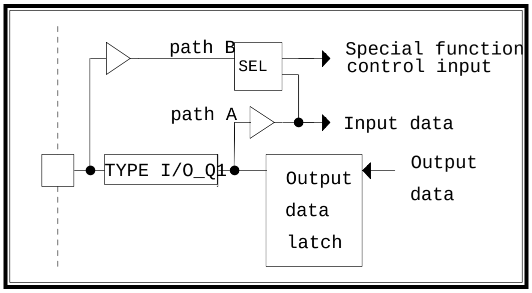
TYPE I/O-P



TYPE I/O-Q1



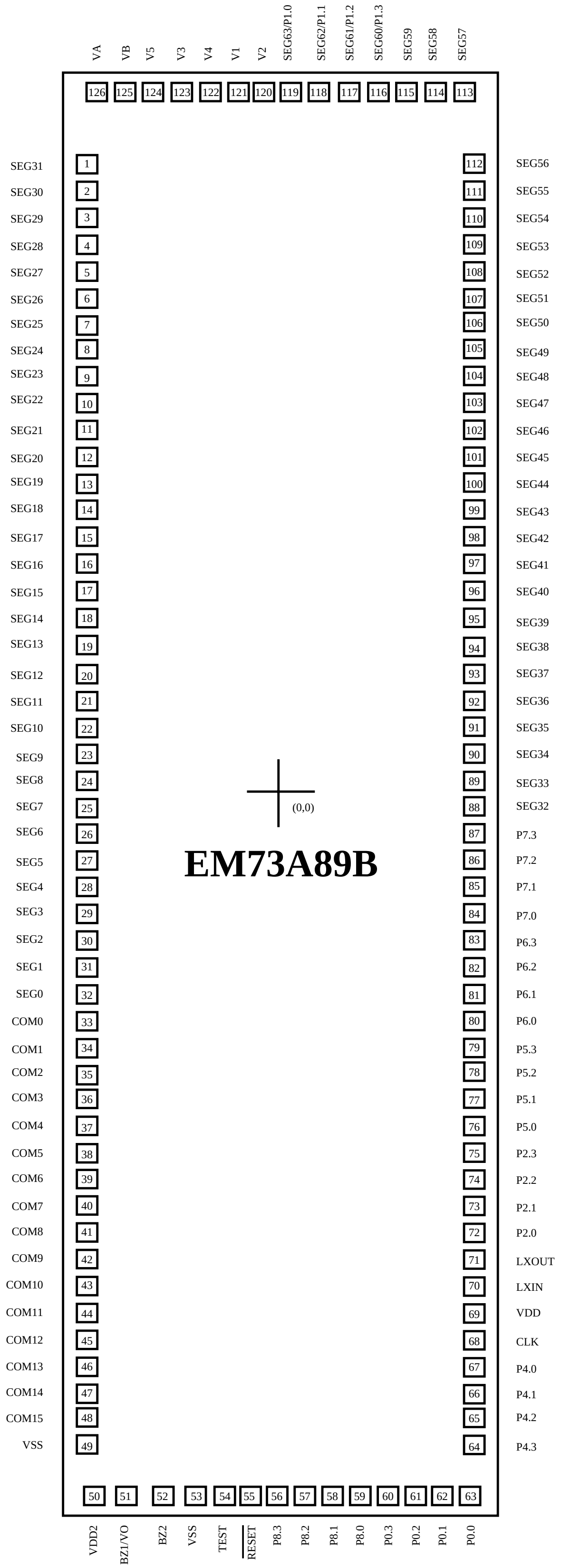
TYPE I/O-X1



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.

PAD DIAGRAM (16 COMMONS)



Preliminary

Pad No.	Symbol	X	Y
1	SEG31	-780.0	2753.9
2	SEG30	-780.0	2623.9
3	SEG29	-780.0	2496.4
4	SEG28	-780.0	2371.4
5	SEG27	-780.0	2246.4
6	SEG26	-780.0	2121.4
7	SEG25	-780.0	1996.4
8	SEG24	-780.0	1873.9
9	SEG23	-780.0	1753.9
10	SEG22	-780.0	1633.9
11	SEG21	-780.0	1513.9
12	SEG20	-780.0	1393.9
13	SEG19	-780.0	1276.4
14	SEG18	-780.0	1161.4
15	SEG17	-780.0	1046.4
16	SEG16	-780.0	931.4
17	SEG15	-780.0	816.4
18	SEG14	-780.0	703.9
19	SEG13	-780.0	593.9
20	SEG12	-780.0	483.9
21	SEG11	-780.0	373.9
22	SEG10	-780.0	263.9
23	SEG9	-780.0	156.4
24	SEG8	-780.0	51.4
25	SEG7	-780.0	-53.6
26	SEG6	-780.0	-158.6
27	SEG5	-780.0	-263.6
28	SEG4	-780.0	-371.1
29	SEG3	-780.0	-481.1
30	SEG2	-780.0	-591.1
31	SEG1	-780.0	-701.1
32	SEG0	-780.0	-811.1
33	COM0	-780.0	-923.6
34	COM1	-780.0	-1038.6
35	COM2	-780.0	-1153.6
36	COM3	-780.0	-1268.6
37	COM4	-780.0	-1383.6
38	COM5	-780.0	-1501.1
39	COM6	-780.0	-1621.1
40	COM7	-780.0	-1741.1

Pad No.	Symbol	X	Y
41	COM8	-780.0	-1861.1
42	COM9	-780.0	-1981.1
43	COM10	-780.0	-2103.6
44	COM11	-780.0	-2228.6
45	COM12	-780.0	-2353.6
46	COM13	-780.0	-2478.6
47	COM14	-780.0	-2603.6
48	COM15	-780.0	-2731.1
49	VSS	-780.0	-2861.1
50	VDD2	-763.3	-3120.0
51	BZ1/VO	-633.2	-3120.0
52	BZ2	-483.2	-3120.0
53	VSS	-353.1	-3120.0
54	TEST	-237.9	-3120.0
55	$\overline{\text{RESET}}$	-127.9	-3120.0
56	P8.3	-17.9	-3120.0
57	P8.2	92.1	-3120.0
58	P8.1	202.1	-3120.0
59	P8.0	312.1	-3120.0
60	P0.3	422.1	-3120.0
61	P0.2	532.1	-3120.0
62	P0.1	642.1	-3120.0
63	P0.0	759.6	-3120.0
64	P4.3	780.0	-2861.1
65	P4.2	780.0	-2731.1
66	P4.1	780.0	-2603.6
67	P4.0	780.0	-2478.6
68	CLK	780.0	-2353.6
69	VDD	780.0	-2228.6
70	LXIN	780.0	-2103.6
71	LXOUT	780.0	-1981.1
72	P2.0	780.0	-1861.1
73	P2.1	780.0	-1741.1
74	P2.2	780.0	-1621.1
75	P2.3	780.0	-1501.1
76	P5.0	780.0	-1383.6
77	P5.1	780.0	-1268.6
78	P5.2	780.0	-1153.6
79	P5.3	780.0	-1041.1
80	P6.0	780.0	-931.1

Pad No.	Symbol	X	Y
81	P6.1	780.0	-821.1
82	P6.2	780.0	-711.1
83	P6.3	780.0	-601.1
84	P7.0	780.0	-491.1
85	P7.1	780.0	-381.1
86	P7.2	780.0	-271.1
87	P7.3	780.0	-161.1
88	SEG32	780.0	-53.6
89	SEG33	780.0	51.4
90	SEG34	780.0	156.4
91	SEG35	780.0	263.9
92	SEG36	780.0	373.9
93	SEG37	780.0	483.9
94	SEG38	780.0	593.9
95	SEG39	780.0	703.9
96	SEG40	780.0	816.4
97	SEG41	780.0	931.4
98	SEG42	780.0	1046.1
99	SEG43	780.0	1161.4
100	SEG44	780.0	1276.4
101	SEG45	780.0	1393.9
102	SEG46	780.0	1513.9
103	SEG47	780.0	1633.9
104	SEG48	780.0	1753.9
105	SEG49	780.0	1873.9
106	SEG50	780.0	1996.4
107	SEG51	780.0	2121.4
108	SEG52	780.0	2246.4
109	SEG53	780.0	2371.4
110	SEG54	780.0	2496.4
111	SEG55	780.0	2623.9
112	SEG56	780.0	2753.9
113	SEG57	715.0	3120.0
114	SEG58	605.0	3120.0
115	SEG59	495.0	3120.0
116	SEG60/P1.3	385.0	3120.0
117	SEG61/P1.2	275.0	3120.0
118	SEG62/P1.1	165.0	3120.0
119	SEG63/P1.0	55.0	3120.0
120	V2	-55.0	3120.0

Preliminary

Pad No.	Symbol	X	Y
121	V1	-165.0	3120.0
122	V4	-275.0	3120.0
123	V3	-385.0	3120.0
124	V5	-495.0	3120.0
125	VB	-605.0	3120.0
126	VA	-715.0	3120.0

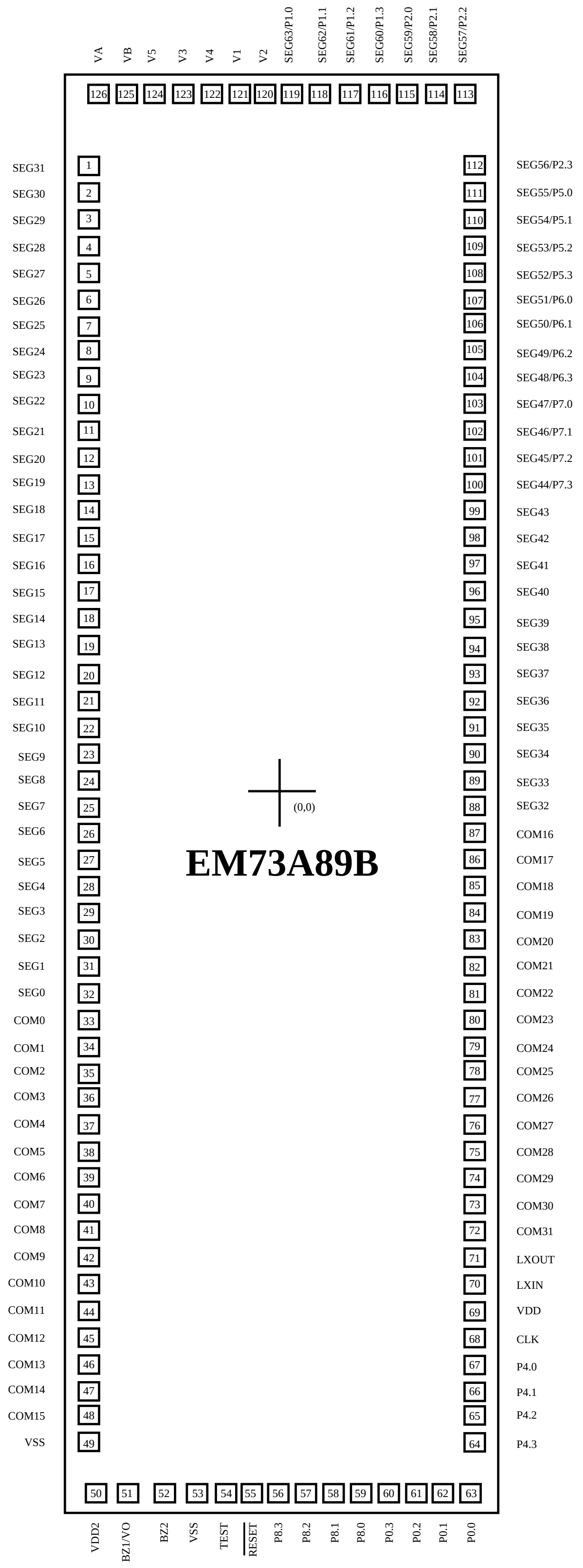
Unit : um

Chip size : 1810 x 6490um

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

Preliminary

PAD DIAGRAM (32 COMMONS)



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

Pad No.	Symbol	X	Y
1	SEG31	-780.0	2753.9
2	SEG30	-780.0	2623.9
3	SEG29	-780.0	2496.4
4	SEG28	-780.0	2371.4
5	SEG27	-780.0	2246.4
6	SEG26	-780.0	2121.4
7	SEG25	-780.0	1996.4
8	SEG24	-780.0	1873.9
9	SEG23	-780.0	1753.9
10	SEG22	-780.0	1633.9
11	SEG21	-780.0	1513.9
12	SEG20	-780.0	1393.9
13	SEG19	-780.0	1276.4
14	SEG18	-780.0	1161.4
15	SEG17	-780.0	1046.4
16	SEG16	-780.0	931.4
17	SEG15	-780.0	816.4
18	SEG14	-780.0	703.9
19	SEG13	-780.0	593.9
20	SEG12	-780.0	483.9
21	SEG11	-780.0	373.9
22	SEG10	-780.0	263.9
23	SEG9	-780.0	156.4
24	SEG8	-780.0	51.4
25	SEG7	-780.0	-53.6
26	SEG6	-780.0	-158.6
27	SEG5	-780.0	-263.6
28	SEG4	-780.0	-371.1
29	SEG3	-780.0	-481.1
30	SEG2	-780.0	-591.1
31	SEG1	-780.0	-701.1
32	SEG0	-780.0	-811.1
33	COM0	-780.0	-923.6
34	COM1	-780.0	-1038.6
35	COM2	-780.0	-1153.6
36	COM3	-780.0	-1268.6
37	COM4	-780.0	-1383.6
38	COM5	-780.0	-1501.1
39	COM6	-780.0	-1621.1
40	COM7	-780.0	-1741.1

Pad No.	Symbol	X	Y
41	COM8	-780.0	-1861.1
42	COM9	-780.0	-1981.1
43	COM10	-780.0	-2103.6
44	COM11	-780.0	-2228.6
45	COM12	-780.0	-2353.6
46	COM13	-780.0	-2478.6
47	COM14	-780.0	-2603.6
48	COM15	-780.0	-2731.1
49	VSS	-780.0	-2861.1
50	VDD2	-763.3	-3120.0
51	BZ1/VO	-633.2	-3120.0
52	BZ2	-483.2	-3120.0
53	VSS	-353.1	-3120.0
54	TEST	-237.9	-3120.0
55	$\overline{\text{RESET}}$	-127.9	-3120.0
56	P8.3	-17.9	-3120.0
57	P8.2	92.1	-3120.0
58	P8.1	202.1	-3120.0
59	P8.0	312.1	-3120.0
60	P0.3	422.1	-3120.0
61	P0.2	532.1	-3120.0
62	P0.1	642.1	-3120.0
63	P0.0	759.6	-3120.0
64	P4.3	780.0	-2861.1
65	P4.2	780.0	-2731.1
66	P4.1	780.0	-2603.6
67	P4.0	780.0	-2478.6
68	CLK	780.0	-2353.6
69	VDD	780.0	-2228.6
70	LXIN	780.0	-2103.6
71	LXOUT	780.0	-1981.1
72	COM31	780.0	-1861.1
73	COM30	780.0	-1741.1
74	COM29	780.0	-1621.1
75	COM28	780.0	-1501.1
76	COM27	780.0	-1383.6
77	COM26	780.0	-1268.6
78	COM25	780.0	-1153.6
79	COM24	780.0	-1041.1
80	COM23	780.0	-931.1

Pad No.	Symbol	X	Y
81	COM22	780.0	-821.1
82	COM21	780.0	-711.1
83	COM20	780.0	-601.1
84	COM19	780.0	-491.1
85	COM18	780.0	-381.1
86	COM17	780.0	-271.1
87	COM16	780.0	-161.1
88	SEG32	780.0	-53.6
89	SEG33	780.0	51.4
90	SEG34	780.0	156.4
91	SEG35	780.0	263.9
92	SEG36	780.0	373.9
93	SEG37	780.0	483.9
94	SEG38	780.0	593.9
95	SEG39	780.0	703.9
96	SEG40	780.0	816.4
97	SEG41	780.0	931.4
98	SEG42	780.0	1046.1
99	SEG43	780.0	1161.4
100	SEG44/P7.3	780.0	1276.4
101	SEG45/P7.2	780.0	1393.9
102	SEG46/P7.1	780.0	1513.9
103	SEG47/P7.0	780.0	1633.9
104	SEG48/P6.3	780.0	1753.9
105	SEG49/P6.2	780.0	1873.9
106	SEG50/P6.1	780.0	1996.4
107	SEG51/P6.0	780.0	2121.4
108	SEG52/P5.3	780.0	2246.4
109	SEG53/P5.2	780.0	2371.4
110	SEG54/P5.1	780.0	2496.4
111	SEG55/P5.0	780.0	2623.9
112	SEG56/P2.3	780.0	2753.9
113	SEG57/P2.2	715.0	3120.0
114	SEG58/P2.1	605.0	3120.0
115	SEG59/P2.0	495.0	3120.0
116	SEG60/P1.3	385.0	3120.0
117	SEG61/P1.2	275.0	3120.0
118	SEG62/P1.1	165.0	3120.0
119	SEG63/P1.0	55.0	3120.0
120	V2	-55.0	3120.0

Pad No.	Symbol	X	Y
121	V1	-165.0	3120.0
122	V4	-275.0	3120.0
123	V3	-385.0	3120.0
124	V5	-495.0	3120.0
125	VB	-605.0	3120.0
126	VA	-715.0	3120.0

Unit : um

Chip size : 1810 x 6490um

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

ABSOLUTE MAXIMUM RATINGS

Items	Sym.	Ratings	Conditions
Supply Voltage	V_{DD}	-0.5V to 3.6V	
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°C
Operating Temperature	T_{OPR}	-30°C to 70°C	
Storage Temperature	T_{STG}	-55°C to 125°C	

RECOMMANDED OPERATING CONDITIONS

Items	Sym.	Ratings	Conditions
Supply Voltage	V_{DD}	2.2V to 3.6V	
Input Voltage	V_{IH}	0.90xV_{DD} to V_{DD}	
	V_{IL}	0V to 0.10xV_{DD}	
Operating Frequency	F_{C}	4.6MHz ~ 9.2MHz	CLK
	Fs	32KHz	LXIN,LXOUT

DC ELECTRICAL CHARACTERISTICS (V_{DD}=3±0.3V, V_{SS}=0V, T_{OPR}=25°C)

Parameters	Sym.	Min.	Typ.	Max.	Unit	Conditions
Supply current	I_{DD}	-	0.5	1.2	mA	V_{DD}=3.3V,DUAL mode,no load, Fc=4.6MHz ,Fs=32KHz
		-	35	45	μA	V_{DD}=3.3V,SLOW mode,Fs=32KHz, LCD on
		-	30	40	μA	V_{DD}=3.3V, IDLE mode, LCD on
		-	7	12	μA	V_{DD}=3.3V, IDLE mode, LCD off
		-	0.1	1	μA	V_{DD}=3.3V, STOP mode
Hysteresis voltage	V_{HYS+}	0.50V_{DD}	-	0.75V_{DD}	V	$\overline{\text{RESET}}$, P0, P8
	V_{HYS-}	0.20V_{DD}	-	0.40V_{DD}	V	
Input current	I_{IH}	-	-	±1	μA	P0, $\overline{\text{RESET}}$, V_{DD}=3.3V,V_{IH}=3.3/0V
		-	-	±1	μA	Open-drain, V_{DD}=3.3V,V_{IH}=3.3/0V
	I_{IL}	-	-250	-500	μA	Push-pull (normal current push-pull) V_{DD}=3.3V, V_{IL}=0.4V
		-	-20	-25	μA	Push-pull (low current push-pull) V_{DD}=3.3V, V_{IL}=0.4V
Output voltage	V_{OH}	2.4	-	-	V	Push-pull, (high current push-pull) V_{DD}=2.7V, I_{OH}=-0.9mA
		2.0	2.4	-	V	Push-pull, (normal current push-pull) V_{DD}=2.7V, I_{OH}=-40μA
	V_{OL}	-	0.15	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	KΩ	P0, V_{DD}=3.3V
		300	600	900	KΩ	$\overline{\text{RESET}}$, V_{DD}=3.3V

Output current of BZ1, BZ2	I_{OH}	30	-	-	mA	V_{DD}=3.0V, V_{BZ}=1.5V, mask option : small size
	I_{OL}	30	-	-	mA	
	I_{OH}	75	-	-	mA	V_{DD}=3.0V, V_{BZ}=1.5V, mask option : large size
	I_{OL}	75	-	-	mA	
Output current of VO		2	3	4	mA	V_{DD}=3.0V, vo=0.7V
LCD reference voltage	V_{REF}	0.765	0.85	0.935	V	V_{DD}=3.0V,no load,VREF=000
		0.81	0.90	0.99	V	V_{DD}=3.0V,no load,VREF=001
		0.855	0.95	1.045	V	V_{DD}=3.0V,no load,VREF=010
		0.9	1.00	1.1	V	V_{DD}=3.0V,no load,VREF=011
		0.945	1.05	1.155	V	V_{DD}=3.0V,no load,VREF=100

INSTRUCTION TABLE

(1) Data Transfer

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

(2) Rotate

Mnemonic	Object code (binary)	Operation description	Byte	Cycle	Flag		
					C	Z	S
RLCA	0101 0000	┌←CF←Acc←┐	1	1	C	Z	C'
RRCA	0101 0001	└→CF→Acc→┘	1	1	C	Z	C'

(3) Arithmetic operation

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

INCL	0111 1110	LR←LR + 1	1	1	-	Z	C'
INCM	0101 1111	RAM[HL]←RAM[HL]+1	1	1	-	Z	C'
SUBA #k	0110 1110 0111 kkkk	Acc←k-Acc	2	2	-	Z	C
SBCAM	0111 0010	Acc←RAM[HLl - Acc - CF'	1	1	C	Z	C
SUBM #k	0110 1110 1111 kkkk	RAM[HL]←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←Acc&k	2	2	-	Z	Z'
ANDAM	0111 1011	Acc←Acc & RAM[HL]	1	1	-	Z	Z'
ANDM #k	0110 1110 1110 kkkk	RAM[HL]←RAM[HL]&k	2	2	-	Z	Z'
ORA #k	0110 1110 0100 kkkk	Acc←Acc¦ k	2	2	-	Z	Z'
ORAM	0111 1000	Acc ←Acc¦ RAM[HL]	1	1	-	Z	Z'
ORM #k	0110 1110 1100 kkkk	RAM[HL]←RAM[HL]¦ k	2	2	-	Z	Z'
XORAM	0111 1001	Acc←Acc^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↔RAM[x]	2	2	-	Z	1
EXAH	0110 0110	Acc↔HR	1	2	-	Z	1
EXAL	0110 0100	Acc↔LR	1	2	-	Z	1
EXAM	0101 1000	Acc↔RAM[HL]	1	1	-	Z	1
EXHL x	0100 1100 xxxx xx00	LR↔RAM[x], HR↔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←$PC_{12-6}.a_{5-0}$ elsenull	1	1	-	-	1
LBR a	1100 aaaa aaaa aaaa	If SF= 1 then PC←a else null	2	2	-	-	1
SLBR a	0101 0101 1100 aaaa aaaa aaaa (a:1000~1FFFh) 0101 0111 1100 aaaa aaaa aaaa (a:0000~0FFFh)	If SF=1 then PC←a else null	3	3	-	-	1

(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←CF', CF←0	1	1	0	-	*
TTCFS	0101 0010	SF←CF, CF←1	1	1	1	-	*
TZS	0101 1011	SF←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←IL & r	2	2	-	-	1
DICIL r	0110 0011 10rr rrrr	EIF←0,IL←IL&r	2	2	-	-	1
EICIL r	0110 0011 01rr rrrr	EIF←1,IL←IL&r	2	2	-	-	1
EXAE	0111 0101	MASK↔Acc	1	1	-	-	1
RTI	0100 1101	SP←SP+1,FLAG.PC ←STACK[SP],EIF ←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←$[DP]_L$	2	2	-	Z	1
LDADPM	0110 1010 1111 1101	Acc←$[DP]_M$	2	2	-	Z	1
LDADPH	0110 1010 1111 1110	Acc←$[DP]_H$	2	2	-	Z	1
LDASP	0110 1010 1111 1111	Acc←SP	2	2	-	Z	1
LDATAL	0110 1010 1111 0100	Acc←$[TA]_L$	2	2	-	Z	1
LDATAM	0110 1010 1111 0101	Acc←$[TA]_M$	2	2	-	Z	1
LDATAH	0110 1010 1111 0110	Acc←$[TA]_H$	2	2	-	Z	1
LDATBL	0110 1010 1111 1000	Acc←$[TB]_L$	2	2	-	Z	1
LDATBM	0110 1010 1111 1001	Acc←$[TB]_M$	2	2	-	Z	1
LDATBH	0110 1010 1111 1010	Acc←$[TB]_H$	2	2	-	Z	1
STADPL	0110 1001 1111 1100	$[DP]_L$←Acc	2	2	-	-	1
STADPM	0110 1001 1111 1101	$[DP]_M$←Acc	2	2	-	-	1
STADPH	0110 1001 1111 1110	$[DP]_H$←Acc	2	2	-	-	1
STASP	0110 1001 1111 1111	SP←Acc	2	2	-	-	1
STATAL	0110 1001 1111 0100	$[TA]_L$←Acc	2	2	-	-	1
STATAM	0110 1001 1111 0101	$[TA]_M$←Acc	2	2	-	-	1
STATAH	0110 1001 1111 0110	$[TA]_H$←Acc	2	2	-	-	1
STATBL	0110 1001 1111 1000	$[TB]_L$←Acc	2	2	-	-	1
STATBM	0110 1001 1111 1001	$[TB]_M$←Acc	2	2	-	-	1
STATBH	0110 1001 1111 1010	$[TB]_H$←Acc	2	2	-	-	1

**** 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