

CMOS 4-Bit Microcontroller

TMP47C623F, TMP47C823F

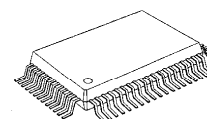
The TMP47C623/823 are high speed and high performance 4-bit single chip microcomputers based on the TLCS-470A series with a LCD driver, High Speed Event Counter and Pulse output circuit.

Part No.	ROM	RAM	Package	OTP Version
TMP47C623F	6144 × 8-bit	384 × 4-bit	P-QFP64-1420-1.00A	TMP47P823VF
TMP47C823F	8192 × 8-bit	512 × 4-bit		

Features

- ◆ 4-bit single chip microcomputer
- ◆ Instruction execution time:
 - 1.3 μ s (at 6 MHz), 244 μ s (at 32.8 kHz)
- ◆ 100 basic instructions
 - Table look-up instructions
- ◆ Subroutine nesting: 15 levels max.
- ◆ 6 interrupt sources (External: 2, Internal: 4)
 - All sources have independent latches each, and multiple interrupt control is available.
- ◆ I/O port (32 to 28 pins)
 - Input 2 ports 5 pins
 - I/O 7 ports 27 pins
- ◆ Two 12-bit Timer / Counters
 - Timer, event counter, and pulse width measurement mode
- ◆ 16-bit High Speed Event Counter
- ◆ Interval Timer (22 stages)
- ◆ Watchdog Timer
- ◆ Serial Interface with 8-bit buffer
 - Simultaneous transmission and reception capability.
 - External / internal colck, leading / trailing edge, and 4/8-bit mode
- ◆ LCD driver
 - LCD direct drive capability (max. 12-digit display at 1/4 duty LCD)
 - 1/4, 1/3 1/2 duties or static drive are programmably selectable.

P-QFP64-1420-1.00A



TMP47C623F
TMP47C823F
TMP47P823VF

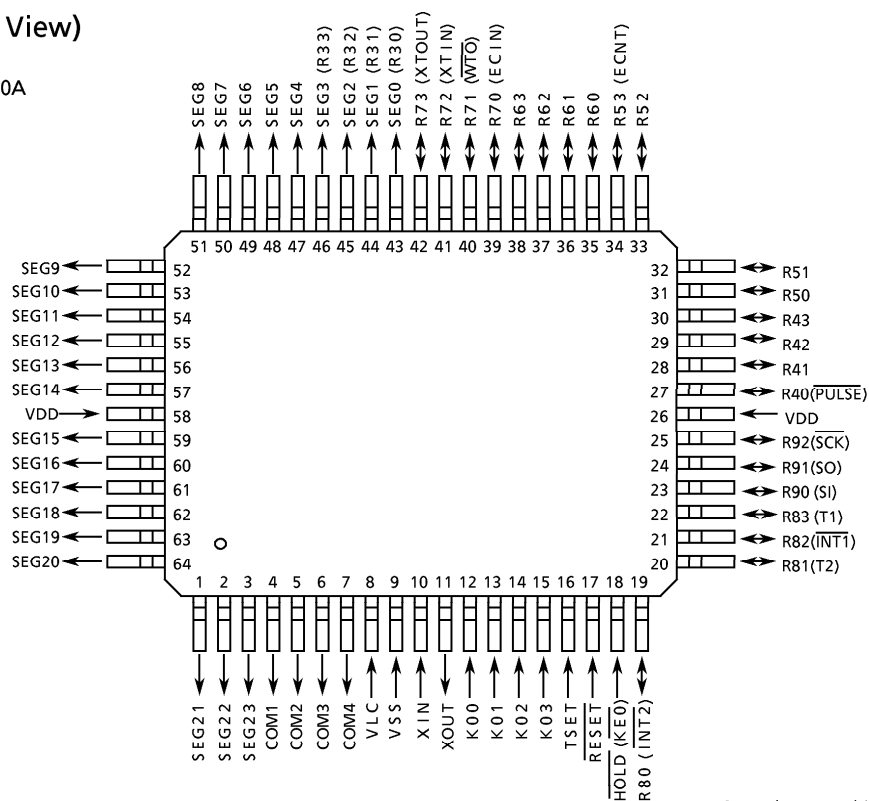
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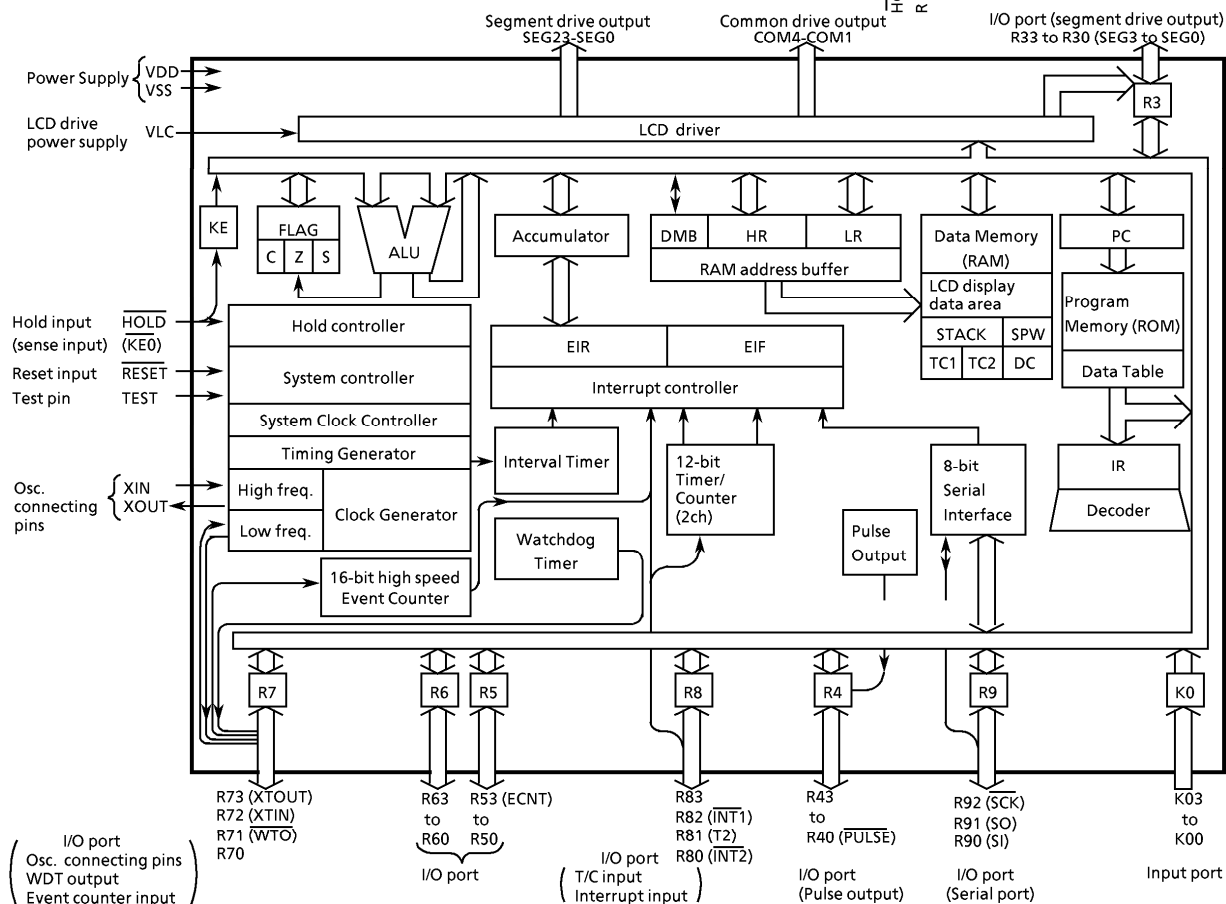
- ◆Pulse output
 - Pulse output frequency select
- ◆High current outputs
 - LED direct drive capability (typ.20 mA × 4 bits)
- ◆Dual-clock operation
 - High-speed / Low-power consumption operating mode
- ◆Hold function
 - Battery / Capacitor back-up
- ◆Real Time Emulator: BM47C823F0A

Pin Assignment (Top View)

P-QFP64-1420-1.00A



Block Diagram



Pin Function

Pin Name	Input/Output	Functions	
K03 to K00	Input	4-bit input port	
R33 to R30	I/O	4-bit I/O port with latch. When used as input port the latch must be set to "1".	LCD Segment drive output. When used as segment drive output the port R3 control register must be set to "1".
R43 to R41	I/O	4-bit I/O port with latch. When used as input port, pulse output, the latch must be set to "1".	
R40 (PULSE)	I/O (Output)		Pulse output
R53 (ECNT)	I/O	4-bit I/O port with latch. When used as input port, External interrupt input, the latch must be set to "1".	External interrupt input
R52 to R50			
R63 to R60			
R73 (XTOUT)	I/O (Output)	4-bit I/O port with latch.	Resonator connecting pins. For inputting external clock, XIN is used and XOUT is opened.
R72 (XTIN)	I/O (Input)		
R71 (WTO)	I/O (Output)	When used as input port, watchdog timer output or External pulse input pin, the latch must be set to "1".	Watchdog timer output
R70 (ECIN)	I/O		External pulse input pin
R83 (T1)	I/O	4-bit I/O port with latch.	Timer/Counter 1 external input
R82 (INT1)	I/O (Input)	When used as input port, external interrupt input pin, or Timer/Counter external input pin, the latch must be set to "1".	External interrupt 1 input
R81 (T2)			Timer/Counter 2 external input
R80 (INT2)			External interrupt 2 input
R92 (SCK)	I/O (I/O)	3-bit I/O port with latch.	Serial clock I/O
R91 (SO)	I/O (Output)	When used as input port, serial port the latch must be set to "1".	Serial data output
R90 (SI)	I/O (Input)		Serial data input
SEG23 to SEG0	Output	LCD Segment drive output	
COM4 to COM1		LCD Common drive output	
XIN	Input	Resonator connecting pins (high-frequency).	
XOUT	Output	For inputting external clock, XIN is used and XOUT is opened.	
RESET	Input	Reset signal input	
HOLD (KE0)	Input (Input)	Hold request/ release signal input	Sense input
TEST	Input	Test pin for out-going test. Be opened or fixed to low level.	
VDD	Power supply	+ 5 V	
VSS		0 V (GND)	
VLC		LCD drive power supply	

Operational Description

Concerning the TMP47C623/823 the configuration and functions of hardwares are described. As the description has been provided with priority on those parts differing from the TMP47C1260/1660 (TLC5-470A), technical data sheets for the TMP47C1260/1660 shall also be referred to.

1. System Configuration

(1) Internal CPU Function

2.1 Program Counter (PC)

2.2 Program Memory (ROM) , and Data Table Bank Selector (DTB)

2.3 Data Memory (RAM)

The others are the same as those of the TMP47C1260/0660.

(2) Peripheral Hardware Function

- ① I/O Port
- ② Interval Timer
- ③ Timer/Counter
- ④ Watchdog Timer
- ⑤ High Speed Event/Counter
- ⑥ Pulse output
- ⑦ LCD Driver
- ⑧ Serial Interface

The description has been provide with priority on functions (①, ⑤, ⑥ and ⑦) added to and changed from the TMP47C1260/1660.

2. Internal CPU Function

2.1 Program Counter (PC)

The program counter is a 13-bit binary counter which indicates the address of the program memory storing the next instruction to be executed.

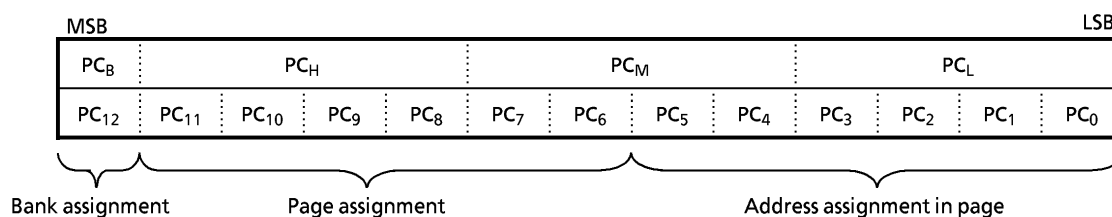


Figure 2-1. Configuration of program counter

The PC can directly address an 8192-byte address space.

2.2 Program Memory (ROM), and Data Table Bank Selector (DTB)

The TMP47C823 contains a program memory (masked ROM) of 8192 × 8 bit (addresses 0000 through 1FFF_H). The TMP47C623 contains a program memory (masked ROM) of 6144 × 8 bits (addresses 0000 through 17FF_H). The TMP47C623/823 don't have a data table bank selector (DTB).

The fixed data is read from the table look-up instructions is located in the program memory (address 1000 through 17FF for the TMP47C623, 1000 through 1FFF for the TMP47C823) and the fixed data can specify the data counter of a 12-bit register.

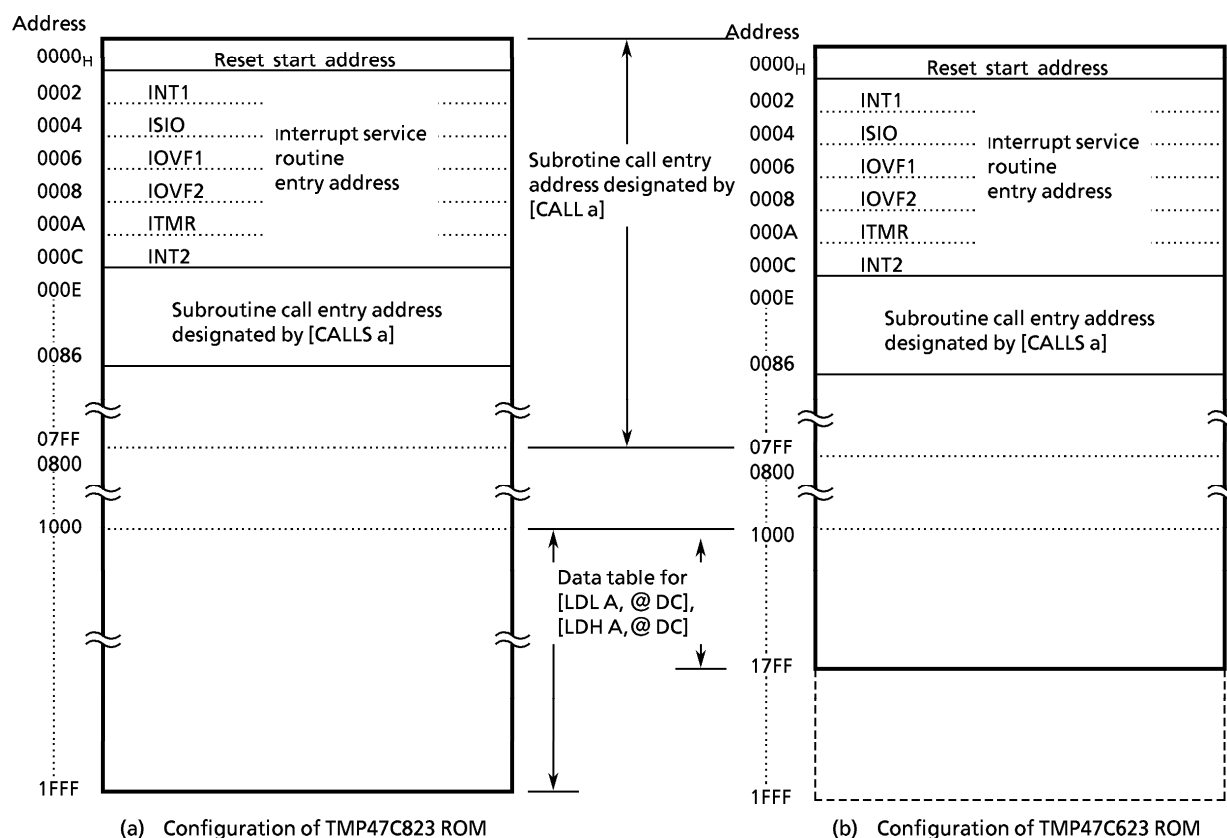


Figure 2-2. Program memory map

2.3 Data Memory Capacity

The TMP47C823 has two data memory banks (banks 0 and 1) of 256×4 bit.

The TMP47C623 has a data memory banks 0 of 256×4 bit and a data memory banks 1 of 128×4 bit.

A private stack (STK13) and stack pointer word (SPW13) for PC₁₃ have not been installed. When power-on is performed, the contents of the data memory become unpredictable, so that they must be initialized by the initialize routine.

When verifying the functions of the TMP47C623 with the TMP47P823V, addresses 80_H and later in DMB1 should not be accessed.

Example: To clear RAM

```

LD      HL, #00H
SCLR1: CLR  DMB
SCLR2: ST   #0, @HL +
      B     SCLR2
      SET  DMB
SCLR3: ST   #0, @HL +
      B     SCLR3
      ADD  H, #1
      B     SCLR1
  
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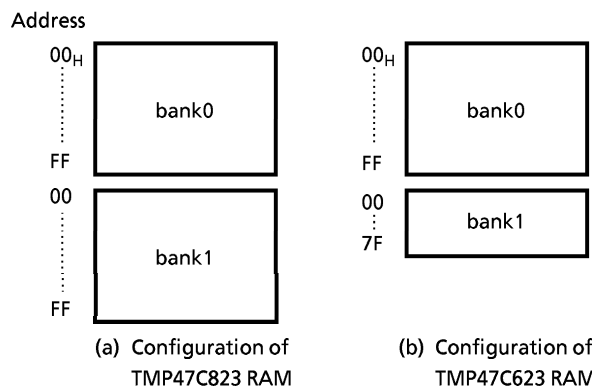


Figure 2-3. Data memory (RAM)

3. Peripheral Hardware Function

3.1 I/O Port

The TMP47C623/823 have 9 I/O port (32 pins) each as follows.

- ① K0 ; 4-bit input
- ② R3 ; 4-bit input / output (shared with segment output)
- ③ R4 ; 4-bit input / output (R40 pin is shared with pulse output)
- ④ R5 ; 4-bit input / output (R53 pin is shared with external interrupt input)
- ⑤ R6 ; 4-bit input / output
- ⑥ R7 ; 4-bit input / output (shared with the Low-frequency resonator connecting pin and the Watchdog timer output and high speed event counter input)
- ⑦ R8 ; 4-bit input / output (shared with external interrupt and timer/counter input)
- ⑧ R9 ; 3-bit input / output (shared with serial port)
- ⑨ KE ; 1-bit sense input (shared with hold request/release signal input)

The description has been provided with priority on ports (②③④⑥ and ⑧) changed from TMP47C1660. Further, TMP47C623/823 have not P1, P2 port, Therefore, the instruction [OUTB @ HL] and 5 bit to 8 bit data conversion table cannot be used.

Table 2-1 lists the port address assignments and the I/O instruction that can access the ports.

(1) port R3 (R33 to R30)

Port R3 is a 4-bit I/O port with latch shared by the segment output pin of LCD Driver. The port R3 control register (OP0E) determine whether this port is used for I/O port or segment output. The port R3 control register is initialized to "0" during reset and the Port R3 is I/O port. When used as an input port, the latch should be set to "1". The output latch of port R3 is initialized to "1" during reset.

Port R3 (Port address: OP03 / IP03)

3	2	1	0
R33 (SEG3)	R32 (SEG2)	R31 (SEG1)	R30 (SEG0)

Control of port R3/Segment output

(port address: OP0E) (Initial value: 0000)

3	2	1	0
R3CR3	R3CR2	R3CR1	R3CR0

R3CR	Selection of port R3/segment output
------	-------------------------------------

0: Port R3

1: Segment output

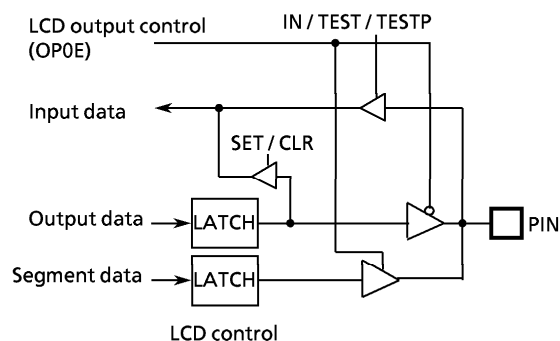


Figure 3-1. Port R3

Table 3-1. Port address assignments and available I/O instruction

Port Address (**)	Port		Input / output instruction					
	Input (IP**)	Output (OP**)	IN %p, A IN %p, @HL	OUT A, %p OUT @HL, %p	OUT #k, %p OUTB @HL	SET %p, b CLR %p, b	TEST %p, b TESTP %p, b	SET @L CLR @L TEST @L
00H	K0 input port	—	○	—	—	—	○	—
01	—	—	—	—	—	—	—	—
02	—	—	—	—	—	—	—	—
03	R3 input port	R3 output port (LCD OUTPUT)	○	○	—	○	○	○
04	R4 input port	R4 output port (PULSE OUTPUT)	○	○	—	○	○	○
05	R5 input port (Interrupt input)	R5 output port	○	○	—	○	○	○
06	R6 input port (HEC input)	R6 output port	○	○	—	○	○	○
07	R7 input port	R7 output port	○	○	—	○	○	○
08	R8 input port	R8 output port	○	○	—	○	○	○
09	R9 input port	R9 output port	○	○	—	○	○	○
0A	HEC Status (Note 2)	HEC1 Ta Setting register	—	○	—	—	—	—
0B	—	HEC2 Tb Setting resister	—	○	—	—	—	—
0C	HEC Low data input	—	○	—	—	—	—	—
0D	HEC High data input	Window gate pulse control	○	○	—	—	—	—
0E	Status input (Note 3)	R3 output control	○	○	—	—	—	—
0F	Serial receive buffer	Serial tansmit buffer	○	○	—	—	—	—
10H	HOLD pin status	Hold operating mode control	○	○	—	—	—	—
11	HOLD pin status	—	—	—	—	—	—	—
12	HOLD pin status	—	—	—	—	—	—	—
13	HOLD pin status	—	—	—	—	—	—	—
14	HOLD pin status	—	—	—	—	—	—	—
15	HOLD pin status	Watchdog timer control	—	○	—	—	—	—
16	HOLD pin status	System clock control	—	○	—	—	—	—
17	HOLD pin status	HEC Control	—	○	—	—	—	—
18	HOLD pin status	Pulse output control	—	○	—	—	—	—
19	HOLD pin status	Interval Timer interrupt control	—	○	—	—	—	—
1A	HOLD pin status	LCD driver control 1	—	○	—	—	—	—
1B	HOLD pin status	LCD driver control 2	—	○	—	—	—	—
1C	HOLD pin status	Timer/Counter 1 control	—	○	—	—	—	—
1D	HOLD pin status	Timer/Counter 2 control	—	○	—	—	—	—
1E	HOLD pin status	Serial Interface control 1	—	○	—	—	—	—
1F	HOLD pin status	Serial Interface control 2	—	○	—	—	—	—

Note 1: "—" means the reserved state. Unavailable for the user programs.

Note 2: To detect the overflow and status input of the high speed event counter (HEC).

Note 3: The status input of serial interface, clock generator, and HOLD (KE0) pin.

- (2) Port R4 (R43-R40), R5 (R53-R50), R7 (R73-R70)

The 4-bit I/O ports with a latch. When used as an input port, the latch should be set to "1". The latch is initialized to "1" during reset. R40 pin is shared by pulse output pin. To use this pin for the functional pin, the latch must be set to "1".

R53 pin is shared by pulse input pin. To use this pin for the functional pin, the latch must be set to "1". R70 pin is shared by high speed event counter pin. To use this pin for the functional pin, the latch must be set to "1".

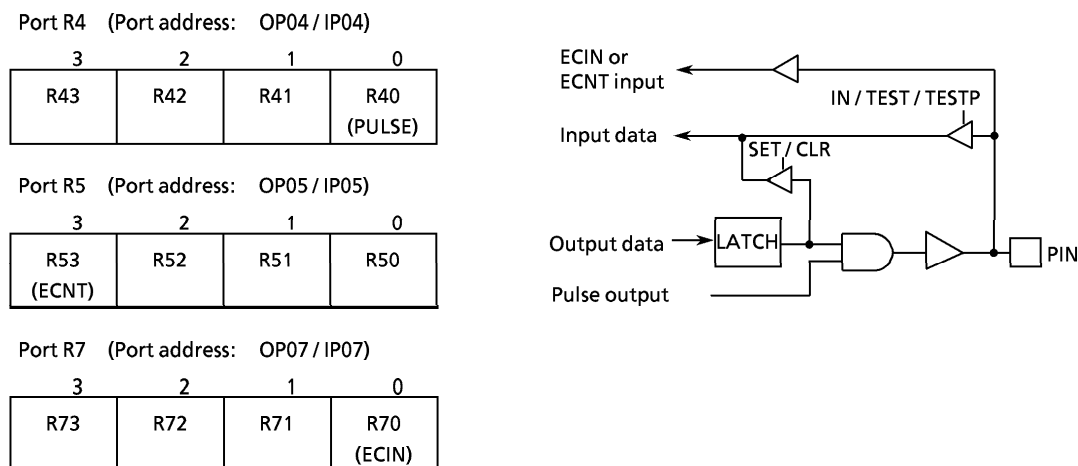


Figure 3-2. Port R4, R5, R7

3.2 High Speed Event/Counter (HEC)

The TMP47C623/823 have a 16-bit high-speed event counter (HEC) which can be used for ECIN pin input frequency measurement. HEC counts the edge (falling edge, falling edge/rising edge) of input pulses while the window gate pulse is at "H" level and interrupt requests (ECNT) are generated when the window gate pulse edge (falling edge, falling edge/rising edge).

The window gate pulse cycle is set by command.

The ECIN pin is also used as the R70 pin. When used as the ECIN pin, the R70 output latch is set to "1".

3.2.1 Configuration of HEC circuit

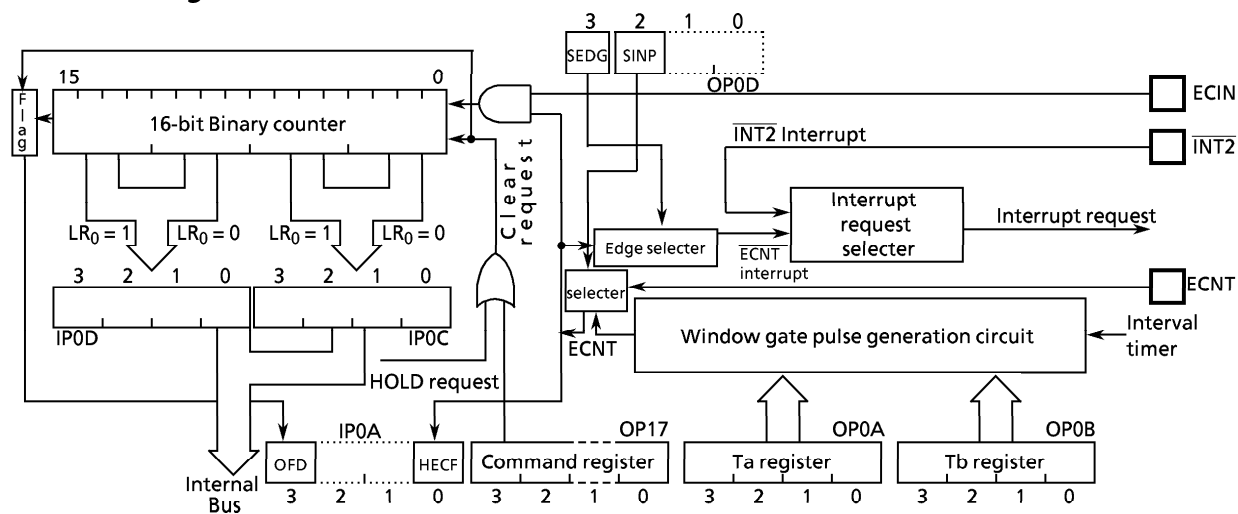


Figure 3-3. Configuration of high-speed event/counter

3.2.2 Control of HEC

HEC is controlled by the command register (OP17). External interrupt 2 is used as the interrupt source. The INT2 interrupt request is selected during reset, so ECNT interrupt is requested by command. Interrupt priority is the same as for external interrupt 2.

HEC control command register
(Port address: OP17)

3	2	1	0
EHEC	CHEC		SINT

(Initial value: 00*0)

EHEC	High Speed Event/Counter Function
------	-----------------------------------

0: Disable

1: Enable (Enable window gate pulse generation)

CHEC	Clear of High Speed Event/counter
------	-----------------------------------

0: Clear request (After Clear, CHEC is set to "1" automatically)

SINT	Select of Interrupt request
------	-----------------------------

0: INT2 Interrupt request

1: ECNT Interrupt request (falling edge of window gate pulse)

Note: * ; Don't care

Figure 3-4. HEC control command register

3.2.3 HEC operation

HEC counts input frequency only during the intervals that the window gate pulse is at "H" level when EHEC (command register bit 3) is "1". The window gate pulse can be set to 256 different cycles using port addresses OP0A and OP0B.

(1) Select of window gate pulse input

The window gate pulse (ECNT) input can be set to the window gate pulse generation circuit or ECNT input (R53) using SINT (bit 2) of command register (OP0D).

The window gate pulse is selected the window gate pulse generation circuit during initial.

Window gate pulse control command register
(Port address: OP0D)

3	2	1	0
SEDG	SINP		

(Initial value: 00**)

SEDG	Select of edge
------	----------------

0: falling edge

1: falling edge / rising edge

SINP	Select of window gate pulse
------	-----------------------------

0: Window gate pulse generation circuit input

1: ECNT input

Figure 3-5. Window gate pulse control command register

(2) Window gate pulse setting

The window gate pulse (ECNT) consists of a count time (Ta) and non-count time (Tb), each of which can be set independently using OP0A and OP0B. Thus, one cycle is Ta + Tb. The Ta and Tb setting times are as follows.

$$(16 - n) \times 2^{13} / f_c \text{ [s]} \quad (n = 0 \text{ to } 15)$$

Table 3-2 shows the setting times when $f_c = 4.194304 \text{ MHz}$ ECNT can be generated at the next rise edge of interval timer output ($f_c/2^{13} \text{ [Hz]}$) by setting EHEC = 1.)

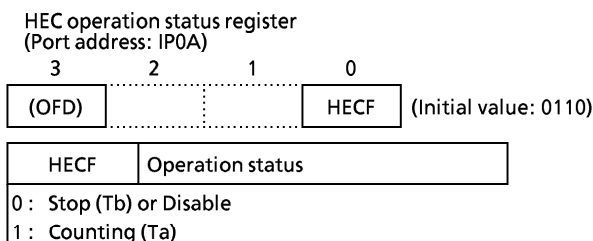


Figure 3-6. HEC operation status register

Example: Generating ECNT with a cycle of approximately 29 ms and a duty ratio of 3:2.

OUT #07H, %OP0A ; Set Ta to 17.58 ms
 OUT #0AH, %OP0B ; Set Tb to 11.72 msC
 LD A, #0FH
 OUT A, % OP17 ; Enables ECNT generation

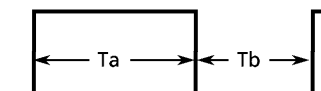


Table 3-2. Setting of Ta, Tb

Setting value	Setting time	Setting value	Setting time
0	31.25 ms	8	15.63 ms
1	29.30 ms	9	13.67 ms
2	27.34 ms	A	11.72 ms
3	25.39 ms	B	9.77 ms
4	23.44 ms	C	7.81 ms
5	21.48 ms	D	5.86 ms
6	19.53 ms	E	3.91 ms
7	17.58 ms	F	1.95 ms

(3) Count operation

Counting is enabled by setting EHEC to "1". Counting is stopped by clearing EHEC to "0" but the binary count values are held.

An INT2 interrupt is issued at the fall edge of the window gate pulse when SINT(command register bit 0) is set to "1". Normally, binary counter data are read, the counter cleared and the next count operation started by the interrupt service routine.

Select of window gate pulse edge can be set to edge (falling edge, falling edge/rising edge) using SEDG of command register (OP0D).

The binary counter is cleared with CHEC (command register bit2). EHEC and the binary counter are cleared during hold operation.

The window gate pulse (ECNT) status can be monitored using the status register. "1" is read out at "H" level (during counting). Figure 3-7 shows the HEC operation timing.

The detection of overflow (binary counter) can be monitored using the OFD (bit3) of command register (IP0A). The flag of OFD is held till the CHEC is cleared to "0".

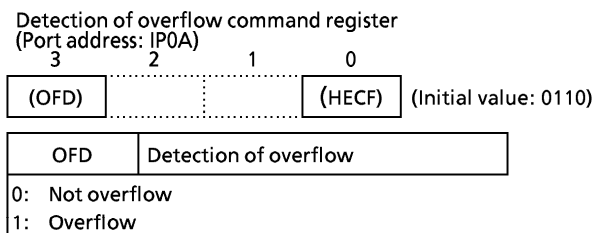


Figure 3-8. Detection of overflow command register

(4) Reading of count data

Binary counter data are read out by port addresses IP0C and IP0D. At that time, a total of 16 bits of data is read out by reading 4 bits at a time in accordance with the LR0 (L register bit 0) value. Table 3-3 shows the relationship between port address LR0 and count data.

Port address	LR ₀	Reading bit of HEC
IP0C	0	HEC3 to HEC0
	1	HEC7 to HEC4
IP0D	0	HEC11 to HEC8
	1	HEC15 to HEC12

Table 3-3. The relation ship between port address LR0 or count data

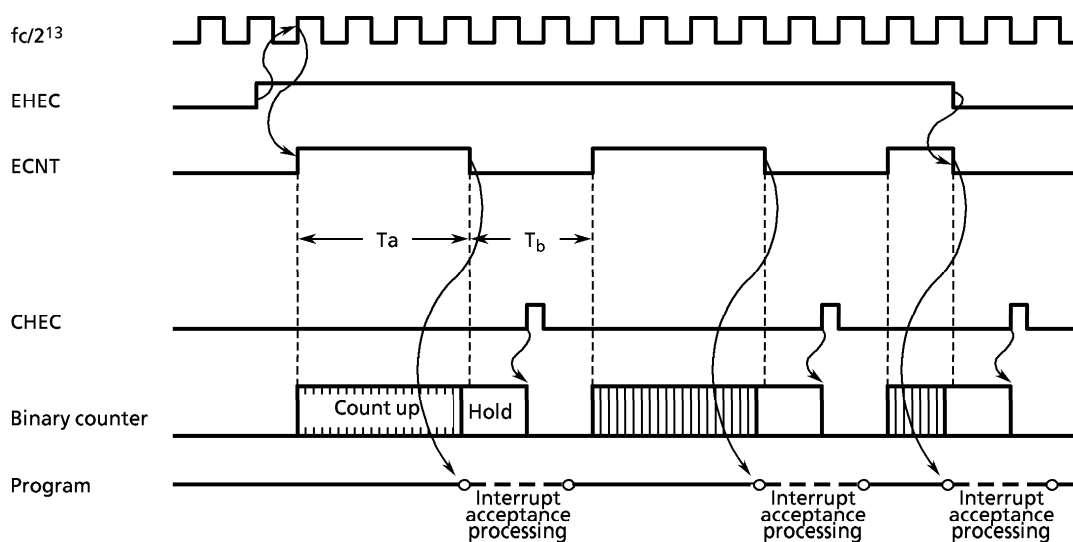


Figure 3-7. HEC operation timing

3.3 Pulse output circuit

The TMP47C623/823 has a built-in one-channel pulse output to use in driving, for example, a buzzer. Eight different pulse output frequencies can be selected by command. Pulses are output from the PULSE pin. The PULSE pin is also used as the R40 pin. When used as the PULSE pin, the R40 output latch is set to "1".

3.3.1 Control of pulse output circuit

The pulse output circuit is controlled by the command register (OP18). Pulses are output by setting EPULS to "1". Pulse output is disabled (by clearing OP18 to "0") during hold operation.

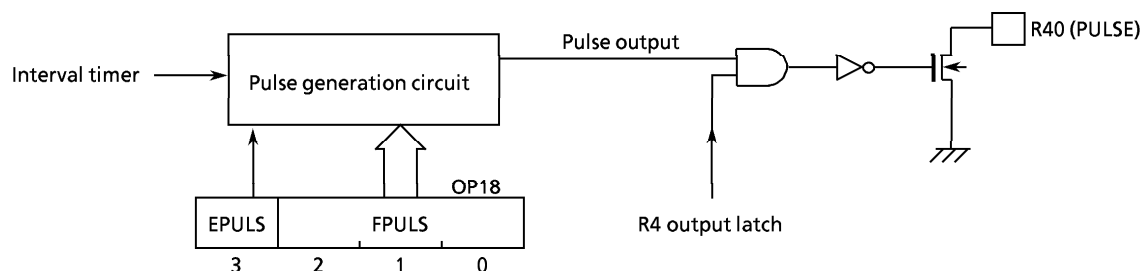


Figure 3-9. Pulse output circuit

Pulse output control command register
(Port address: OP18)

3	2	1	0
EPULS	FPULS		

EPULS	Pulse output control
-------	----------------------

0: Disable
1: Enable

FPULS	Pulse output frequency select
-------	-------------------------------

Example: At $f_c = 4.19 \text{ MHz}$

000:	$f_c / (2^9 \times 8) \text{ [Hz]}$	1.024 [kHz]
001:	$f_c / (2^9 \times 7)$	1.170
010:	$f_c / (2^9 \times 6)$	1.365
011:	$f_c / (2^9 \times 5)$	1.638
100:	$f_c / (2^9 \times 4)$	2.048
101:	$f_c / (2^9 \times 3)$	2.731
110:	$f_c / (2^9 \times 2)$	4.096
111:	$f_c / (2^9 \times 1)$	8.192

Note: f_c : High-frequency clock

Figure 3-10. Pulse output command register

3.4 LCD Driver

The TMP47C623/823 have the circuit that directly drives the liquid crystal display (LCD) and its control circuit.

The TMP47C623/823 have the following connecting pins with LCD.

- ① Segment output port 24 pins (SEG23 to SEG4)
- ② Segment output port (R3 I/O port) 4 pins (SEG3 to SEG0)
- ③ Common output port 4 pins (COM4 to COM1)

In addition, VLC pin is provided as the drive power pin.

The devices that can be directly driven is selectable from LCD of the following drive methods.

- ① 1 / 4 Duty (1 / 3 Bias) LCD Max. 96 Segment (12 digits x 8 segments)
- ② 1 / 3 Duty (1 / 3 Bias) LCD Max. 72 Segment (9 digits x 8 segments)
- ③ 1 / 3 Duty (1 / 2 Bias) LCD Max. 72 Segment (9 digits x 8 segments)
- ④ 1 / 2 Duty (1 / 2 Bias) LCD Max. 48 Segment (6 digits x 8 segments)
- ⑤ Static LCD Max. 24 Segment (3 digits x 8 segments)

3.4.1 Configuration of LCD driver

Figure 2-8 shows the configuration of the LCD driver.

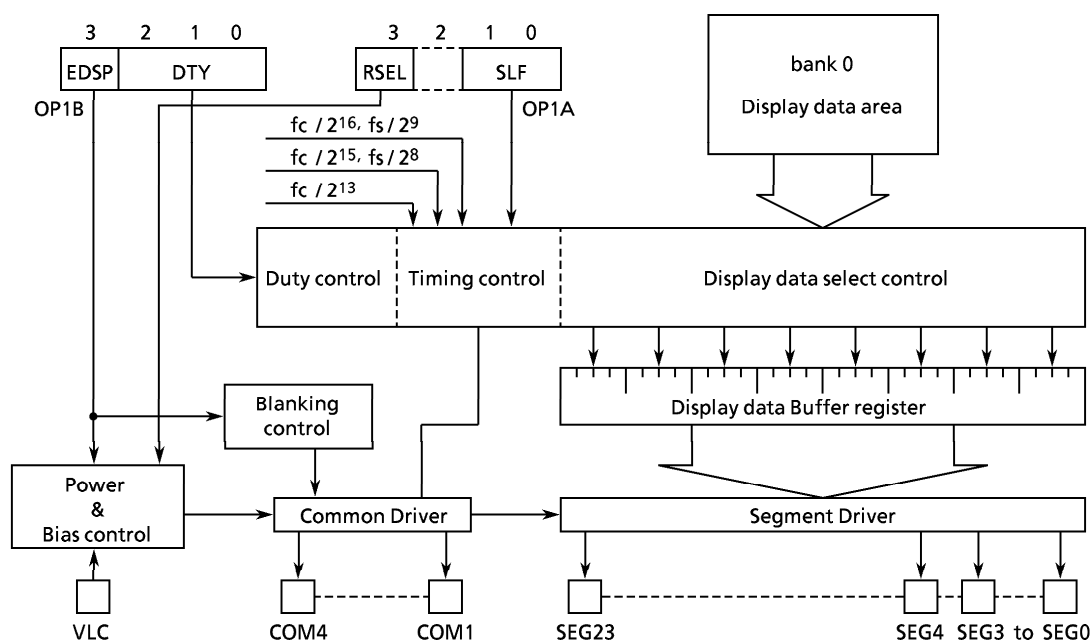


Figure 3-11. LCD driver

3.4.2 Control of LCD driver circuit

The LCD driver is controlled by the command register 1,2 (OP1A, OP1B). Further, when the command register 1 is accessed, the most significant bit of the command register 2 must be set to "0" (Blanking).

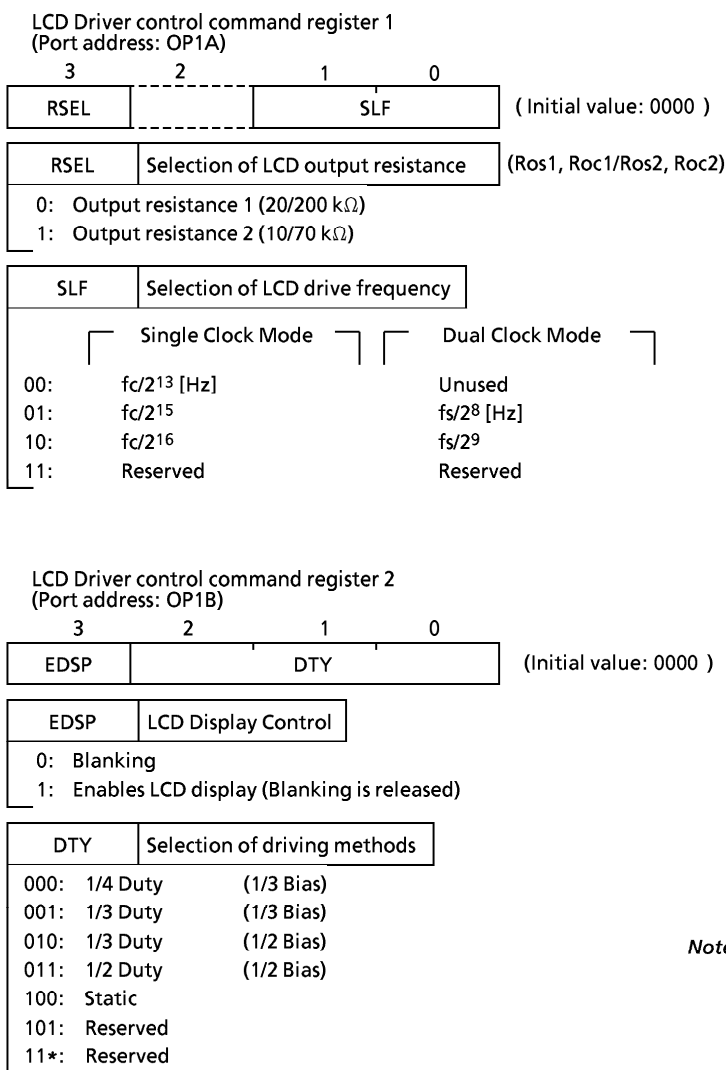


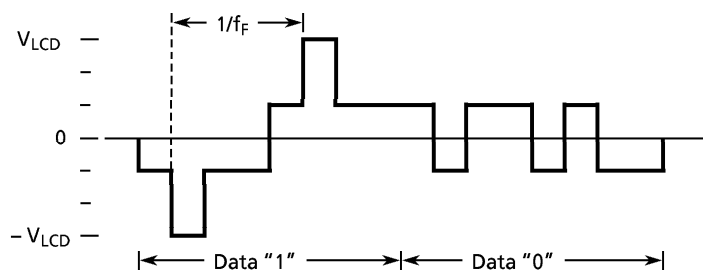
Figure 3-12. LCD driver control Command Register

(1) Driving methods of LCD driver

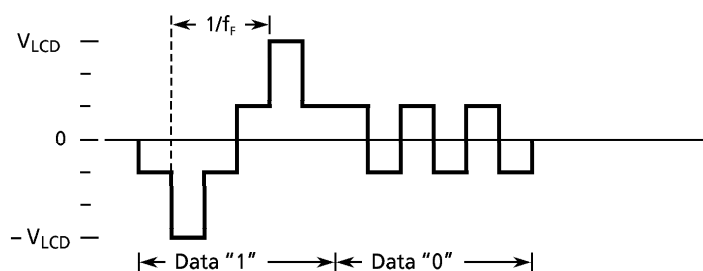
Driving methods of LCD is selected 5 kind of DTY (bit 2 to 0 of command register 2). The drive method is initialized according to LCD used in the initial program.

Example of LCD and their drive waveform are shown in Figure 3-13.

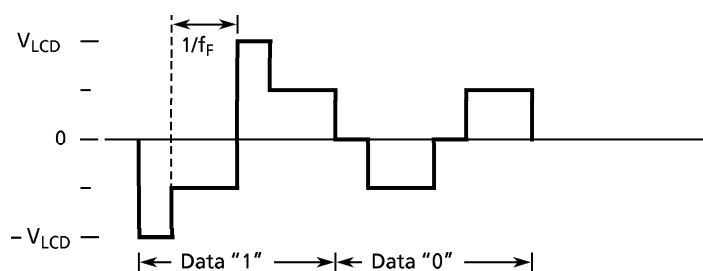
① 1/4 Duty (1/3 Bias)



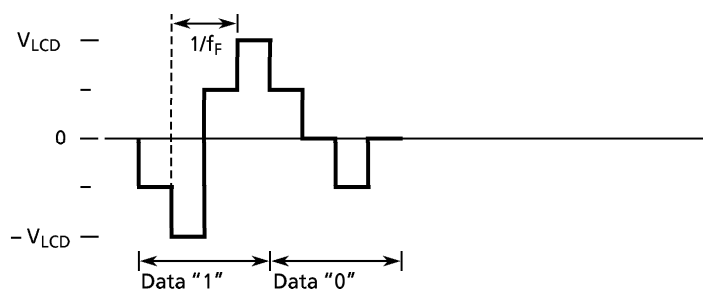
② 1/3 Duty (1/3 Bias)



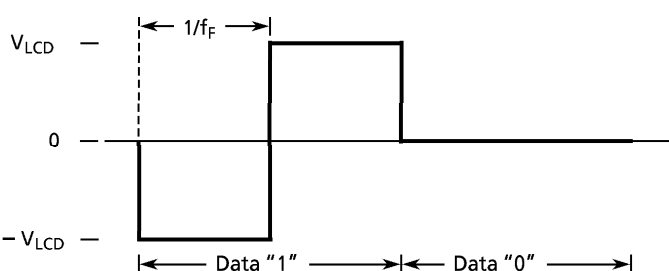
③ 1/3 Duty (1/2 Bias)



④ 1/2 Duty (1/2 Bias)



⑤ Static



Note: f_F ; FRAME FREQUENCY
 V_{LCD} ; LCD drive voltage
 $(=V_{DD}-V_{LC})$

Figure 3-13. LCD drive waveform (COM-SEG pins)

(2) Frame frequency

Frame frequency (f_F) is set according to the drive method and base frequency as shown in the following Table 3-4.

The base frequency is selected by SLF (the lower 2 bits of the command register) according to the reference clock frequency and f_s .

Table 3-4. Setting of LCD frame frequency

a. At the single clock mode

SLF	Base Frequency [Hz]	Frame Frequency [Hz]			
		1/4 Duty	1/3 Duty	1/2 Duty	Static
10	$\frac{f_c}{2^{16}}$	$\frac{f_c}{2^{16}}$	$\frac{4}{3} \cdot \frac{f_c}{2^{16}}$	$\frac{4}{2} \cdot \frac{f_c}{2^{16}}$	$\frac{f_c}{2^{16}}$
	$f_c = 4 \text{ MHz}$	61	81	122	61
01	$\frac{f_c}{2^{15}}$	$\frac{f_c}{2^{15}}$	$\frac{4}{3} \cdot \frac{f_c}{2^{15}}$	$\frac{4}{2} \cdot \frac{f_c}{2^{15}}$	$\frac{f_c}{2^{15}}$
	$f_c = 4 \text{ MHz}$	122	163	244	122
00	$\frac{f_c}{2^{13}}$	$\frac{f_c}{2^{13}}$	$\frac{4}{3} \cdot \frac{f_c}{2^{13}}$	$\frac{4}{2} \cdot \frac{f_c}{2^{13}}$	$\frac{f_c}{2^{13}}$
	$f_c = 1 \text{ MHz}$	122	163	244	122

Note: f_c ; High-frequency clock [Hz]

b. At the dual clock mode

SLF	Base Frequency [Hz]	Frame Frequency [Hz]			
		1/4 Duty	1/3 Duty	1/2 Duty	Static
10	$\frac{f_s}{2^9}$	$\frac{f_s}{2^9}$	$\frac{4}{3} \cdot \frac{f_s}{2^9}$	$\frac{4}{2} \cdot \frac{f_s}{2^9}$	$\frac{f_s}{2^9}$
	$f_s = 32 \text{ kHz}$	61	83	125	61
01	$\frac{f_s}{2^8}$	$\frac{f_s}{2^8}$	$\frac{4}{3} \cdot \frac{f_s}{2^8}$	$\frac{4}{2} \cdot \frac{f_s}{2^8}$	$\frac{f_s}{2^8}$
	$f_s = 32 \text{ kHz}$	125	167	250	125

Note: f_s ; Low-frequency clock [Hz]

(3) LCD drive voltage

The LCD drive voltage (V_{LCD}) is given by the difference in potential (V_{DD} to V_{LC}) between pins VDD and VLC. Therefore, when the CPU operating voltage and LCD drive voltage are the same, the VLC pin is connected to the VSS pin.

The LCDs light only when the difference in potential between the segment output and common output is $\pm V_{LCD}$, and turn off at all other times.

During reset, the power switch of the LCD driver is turned off automatically, shutting off the VLC voltage.

Both the segment output and common output become V_{DD} level at this time and the LCDs turn off.

The power switch is turned on to supply VLC voltage to the LCD driver by setting EDSP (bit 3 of the command register 2) to "1". After that, the power switch will not turn off even during blanking (setting EDSP to "0") and the VLC voltage continues to flow.

The power switch is turned off during hold operation low power consumption by turning off the LCD. When hold operation is released the status in effect immediately before the hold operation is reinstated.

(4) LDC output resistance

Selection of LCD output resistance can be selected by command register (OP1A).

The LDC output resistance is selected by RSEL (MSB of command register) according to LCD used.

The LDC output resistance is selected 20/200 k Ω (RSEL) during initial.

Table 3-5. Selection of LCD output resistance

RSEL	Output low resistance		Output high resistance	
	Segment R _{OS1}	Common R _{OC1}	Segment R _{OS2}	Common R _{OC2}
0	20 k Ω		200 k Ω	
1	10 k Ω		70 k Ω	

Note: The output resistance shows Typ. values (T_{opr} = 25°C, VDD = 5 V)

3.4.3 LCD display operation

(1) Display data setting

Display data are stored to the display data area (Max 32 words) in the data memory (bank0).

The display data stored to the display data area (address 20-3F_H) are read automatically and sent to the LCD driver by the hardware.

The LCD driver generates the segment signals and common signals in accordance with the display data and drive method. Therefore, display patterns can be changed by only overwriting the contents of the display data area with a program. The table look up instruction is mainly used for this overwriting.

Figure 3-14 shows the correspondence between the display data area and the SEG/COM pins. The LCD light when the display data is "1" and turn off when "0".

The number of segment which can be driven differs depending on the LCD drive method therefore, the number of display data area bits used to store the data also differs. Consequently, data memory not used to store display data and data memory for which the addresses are not connected to LCD can be used to store ordinary user's processing data.

Address	bit 3	bit 2	bit 1	bit 0	
20 _H					SEG0
21					SEG1
22					SEG2
⋮	⋮	⋮	⋮	⋮	⋮
3E					SEG22
3F					SEG23
	COM4	COM3	COM2	COM1	

Table 3-6. Driving method and bit for display data

Driving methods	bit 3	bit 2	bit 1	bit 0
1/4 Duty	COM4	COM3	COM2	COM1
1/3 Duty	–	COM3	COM2	COM1
1/2 Duty	–	–	COM2	COM1
Static	–	–	–	COM1

Note: – ; This bit is not used for display data.

Figure 3-14. LCD display data area (Bank 0)

(2) Blanking

Blanking is applied by setting EDSP to "0" and turns off the LCD by outputting the non light operation level to the COM pin.

The SEG pin continuously outputs the signal level in accordance with the display data and drive method.

With static drive, no voltage is applied between the COM and SEG pins when the LCD is turned off by data (display data cleared to "0"), but the COM pin output becomes constant at the $V_{LCD}/2$ level when turning off the LCD by blanking, so the COM and SEG pins are then driven by $V_{LCD}/2$.

3.4.4 Control method of LCD driver

(1) Initial Setting

Flow chart of initial setting are as shown in Figure 3-15.

Example: When operating the TMP47C623/823 with 1/4 duty LCD using a from frequency of $f_c/2^{16}$ [HZ] .

```
LD    A, #0000B ; Sets the 1/4 duty drive
OUT   A, %OP1B
LD    A, #0010B ; Setting of base frequency
OUT   A, %OP1A
:
:           ; Setting of clear or initial value of
:           ; display area in the data memory
LD    A, #1000B ; Display enable
OUT   A, %OP1B
:
```

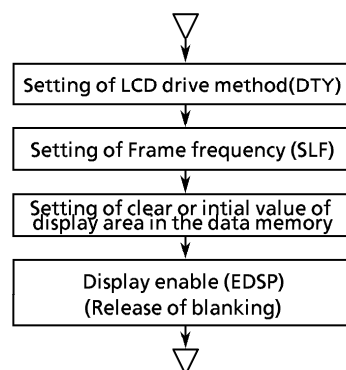


Figure 3-15. Initial setting of LCD driver

(2) Store of display data

Normally, display data are kept permanently in the program memory and are then stored to the display data area by the table look-up instruction.

This can be explained using numerical display with 1/4 duty LCD as an example. The COM and SEG connections to the LCD are the same as those shown in Figure 3-16 and the display data are as shown in Table 3-7. Programming example for displaying numerals corresponding to BCD data stored at address 10_H in the data memory is shown below.

```
LD    HL, #0FCH ; To set the DC
LD    A, 10H
ST    A, @HL+
ST    #DTBL / 16, @HL+
ST    #DTBL / 256, @HL+
LD    HL, #20H ; Store of display data
LDL   A, @DC
ST    A, @HL+
LDH   A, @DC+
ST    A, @HL+
:
DTBL: DATA 1101111B, 00000110B,
            11100011B, 10100111B,
            00110110B, 10110101B,
            11110101B, 00010111B,
            11110111B, 10110111B
```

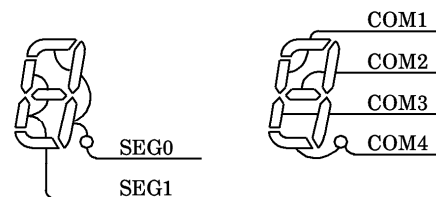


Figure 3-16. Example of COM and SEG connections

Table 3-7. Example of display data (1/4 Duty LCD)











Numeral	Display	Display data		Numeral	Display	Display data	
		Upper	Lower			Upper	Lower
0		1101	1111	5		1011	0101
1		0000	0110	6		1111	0101
2		1110	0011	7		0001	0111
3		1010	0111	8		1111	0111
4		0011	0110	9		1011	0111

Table 3-8 shows the same numerical display used in Table 3-7, but using 1/2 duty LCD. The connections of the COM and SEG pins to the LCD are the same as those shown in Figure 3-17.

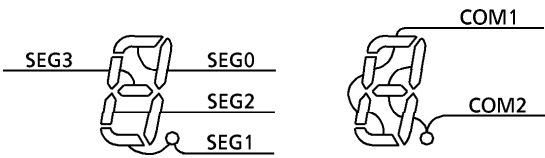


Figure 2-17 Example of COM and SEG connections

Table 3-8. Example of display data (1/2 Duty LCD)

Numeral	Display data				Numeral	Display data			
	Upper		Lower			Upper		Lower	
0	**01	**11	**01	**11	5	**11	**10	**01	**01
1	**00	**10	**00	**10	6	**11	**11	**01	**01
2	**10	**01	**01	**11	7	**01	**10	**00	**11
3	**10	**10	**01	**11	8	**11	**11	**01	**11
4	**11	**10	**00	**10	9	**11	**10	**01	**11

Note: * ; Don't care

(3) Example of drive output

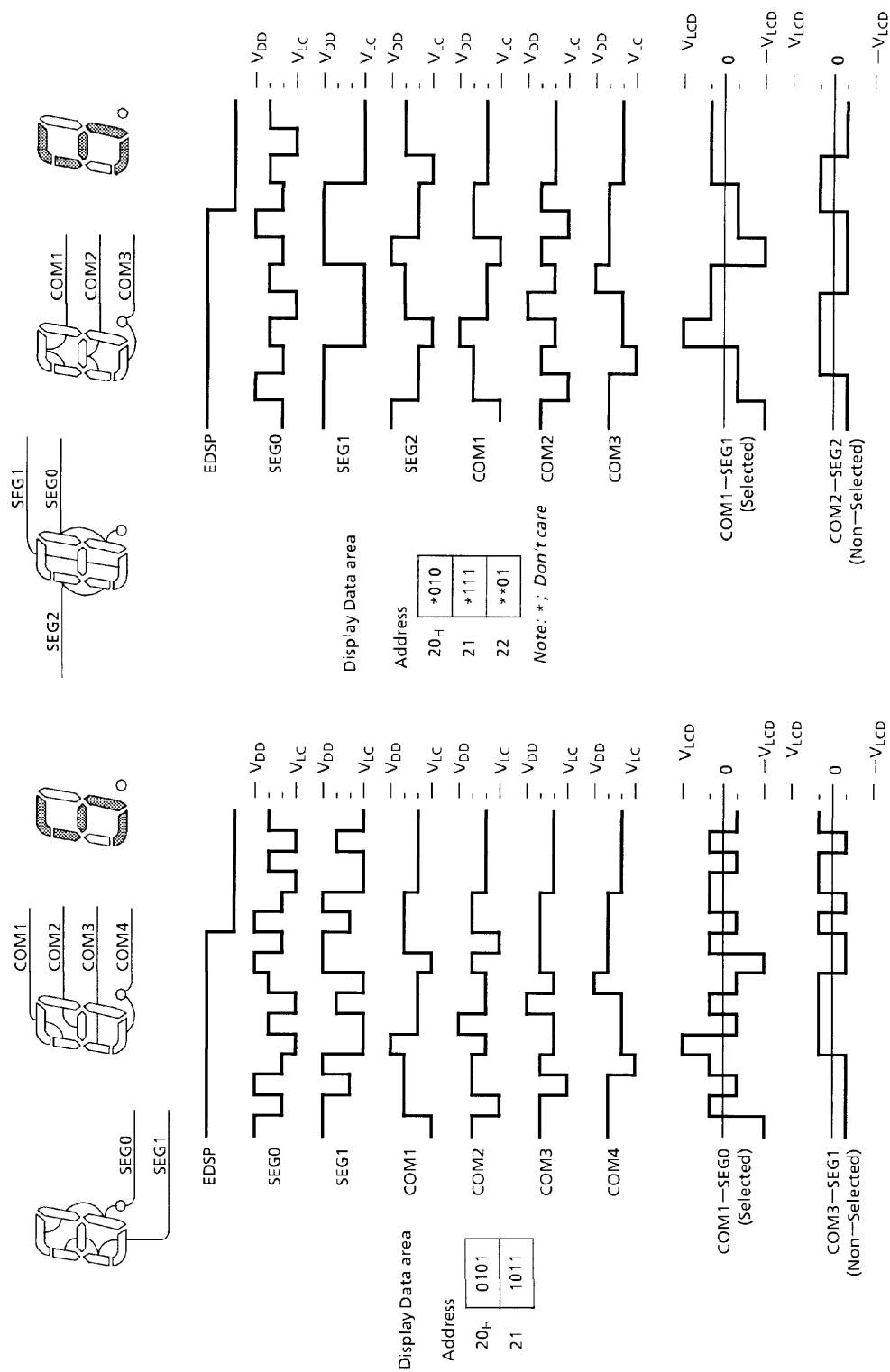


Figure 3-18. 1/4 duty (1/3 Bias) drive

Figure 3-19. 1/3 duty (1/3 Bias) drive

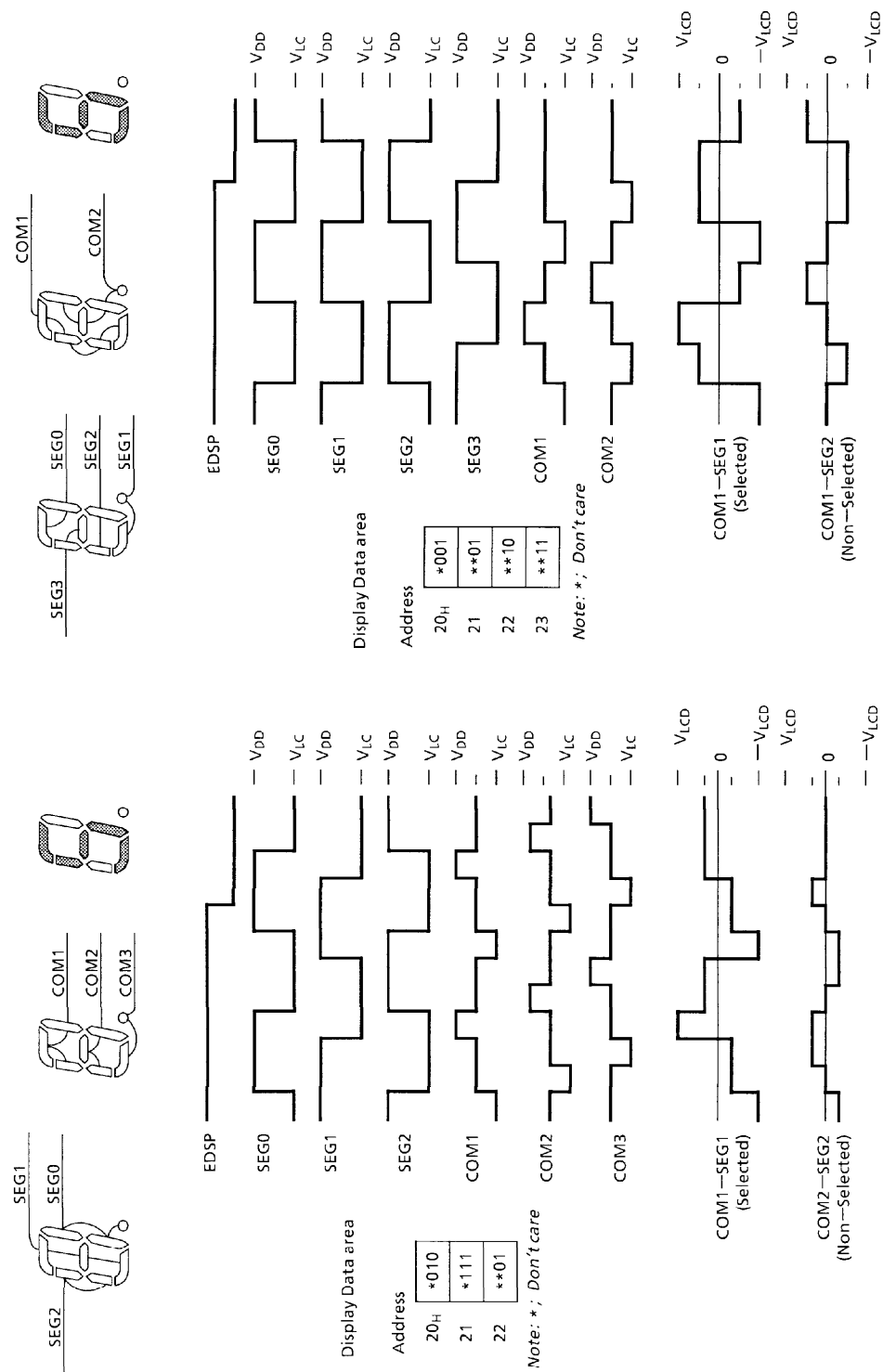


Figure 3-20. 1/3 duty (1/2 Bias) drive

Figure 3-21. 1/2 duty (1/2 Bias) drive

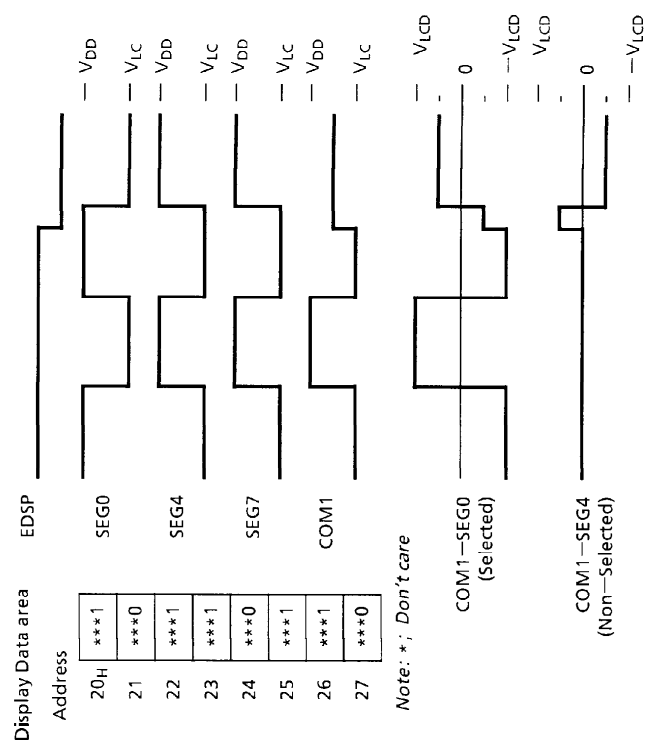
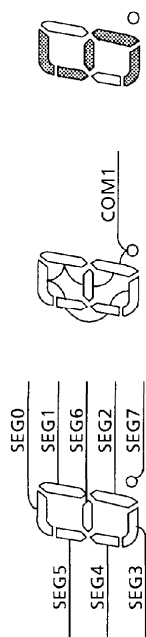


Figure 2-11. Static drive

Port Condition by RESET Operation

The transition of Port condition by RESET operation is shown as below.

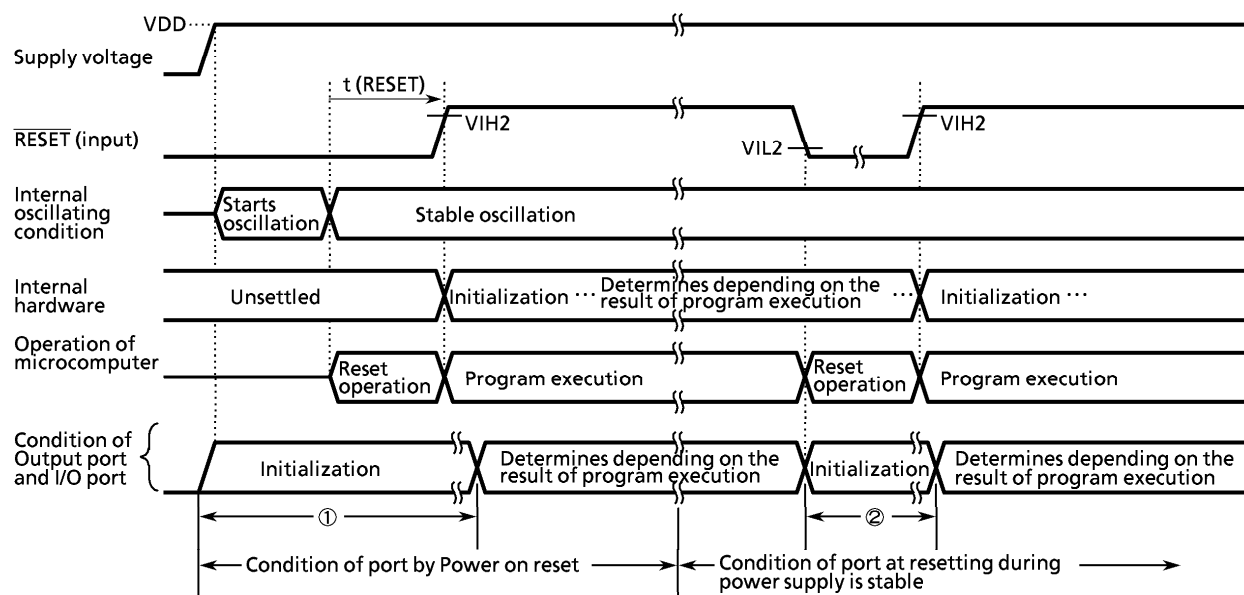


Figure 2-12. Port condition by Reset operation

Note 1: $t(\text{RESET}) > 24/f_c$

Note 2: V_{IL2} : Stands for low level input voltage of $\overline{\text{RESET}}$ pin.

V_{IH2} : Stands for high level input voltage of $\overline{\text{RESET}}$ pin.

Note 3: The term from power on reset to the time program is executed (above ①) and also the term starting from reset operation during power supply is stable to the program is executed (above ②), the port is on the initial condition. The initial condition of Port differs from I/O circuit by each port, refer to the section of "INPUT/OUTPUT CIRCUITRY". Thus, when using Port as an output pin, in the term of the above ① and ②, the voltage level on the signal that connects with the output pin of Port to the input pin of external application circuit should be determined by the external circuitry such as pull-up resistor and / or pull-down resistor.

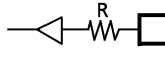
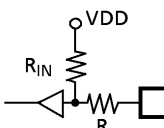
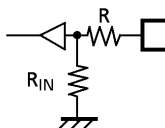
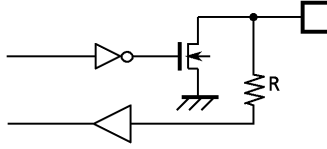
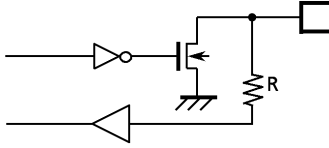
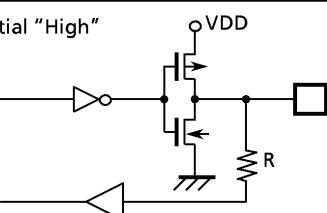
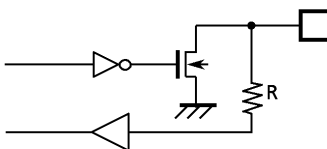
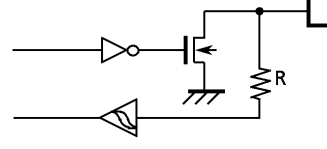
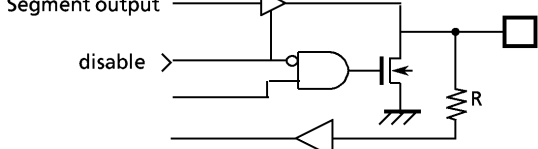
Input / Output Circuitry

(1) Control pins

The input / output circuitries of the TMP47C623/823 control pins are similar to those of the TMP47C1260/1660.

(2) I/O Ports

The input / output circuitries of the TMP47C623/823 I/O ports are shown as belows, any one of the circuitries can be chosen by a code (GA to GF) as a mask option.

Port	I/O	Input / Output Circuitry and Code			Remarks
K0	Input	GA, GD	GB, GE	GC, GF	Pull-up / pull-down resistor $R_{IN} = 70\text{ k}\Omega$ (typ.) $R = 1\text{ k}\Omega$ (typ.)
					
R4	I/O				Sink open drain output Initial "Hi-Z" High current $I_{OL} = 20\text{ mA}$ (typ.) $R = 1\text{ k}\Omega$ (typ.)
R5 R6	I/O	GA, GB, GC	GD, GE, GF		Sink open drain output or push-pull output $R = 1\text{ k}\Omega$ (typ.)
		Initial "Hi-Z" 	Initial "High" 		
R7	I/O				Sink open drain output Initial "Hi-Z" $R = 1\text{ k}\Omega$ (typ.)
R8 R9	I/O				Sink open drain output Initial "Hi-Z" Hysteresis input $R = 1\text{ k}\Omega$ (typ.)
R3	I/O				Sink open drain output or Segment output $R = 1\text{ k}\Omega$ (typ.)

Electrical Characteristics

Absolute Maximum Ratings

(V_{SS} = 0 V)

Parameter	Symbol	Pins	Ratings	Unit
Supply Voltage	V _{DD}		– 0.3 to 7	V
Supply Voltage (LCD drive)	V _{LC}		– 0.3 to V _{DD} + 0.3	V
Input Voltage	V _{IN}		– 0.3 to V _{DD} + 0.3	V
Output Voltage	V _{OUT1}	Except sink open drain pin, but include ports R7, R3	– 0.3 to V _{DD} + 0.3	V
	V _{OUT2}	Sink open drain pin, but include ports R7, R3	– 0.3 to 10	
Output Current (Per 1 pin)	I _{OUT1}	Except port R4	3.2	mA
	I _{OUT2}	Port R4	30	
Output Current (Total)	Σ I _{OUT}	Port R4	60	mA
Power Dissipation [T _{opr} = 50°C]	PD		600	mW
Soldering Temperature (time)	T _{sld}		260 (10 s)	°C
Storage Temperature	T _{stg}		– 55 to 125	°C
Operating Temperature	T _{opr}		– 40 to 70	°C

Note: The absolute maximum ratings are rated values which must not be exceeded during operation, even for an instant. Any one of the ratings must not be exceeded. If any absolute maximum rating is exceeded, a device may break down or its performance may be degraded, causing it to catch fire or explode resulting in injury to the user. Thus, when designing products which include this device, ensure that no absolute maximum rating value will ever be exceeded.

Recommended Operating Conditions

(V_{SS} = 0 V, T_{opr} = – 40 to 70°C)

Parameter	Symbol	Pins	Conditions	Min	Max	Unit
Supply Voltage	V _{DD}		In the Normal mode (fc = 4.2 MHz)	2.7	6.0	V
			In the Normal mode (fc = 5.0 MHz) Note3	2.9		
			In the Normal mode (fc = 6.0 MHz)	4.5		
			In the SLOW mode	2.7		
			In the HOLD mode	2.0		
Input High Voltage	V _{IH1}	Except Hysteresis Input	V _{DD} ≥ 4.5 V	V _{DD} × 0.7	V _{DD}	V
	V _{IH2}	Hysteresis Input		V _{DD} × 0.75		
	V _{IH3}		V _{DD} < 4.5 V	V _{DD} × 0.9		
Input Low Voltage	V _{IL1}	Except Hysteresis Input	V _{DD} ≥ 4.5 V	0	V _{DD} × 0.3	V
	V _{IL2}	Hysteresis Input			V _{DD} × 0.25	
	V _{IL3}		V _{DD} < 4.5 V		V _{DD} × 0.1	
Clock Frequency	fc	XIN, XOUT	High freq. V _{DD} ≥ 2.7 V	0.4	4.2	MHz
			High freq. V _{DD} ≥ 2.9 V Note 3		5.0	
			High freq. V _{DD} ≥ 4.5 V		6.0	
	fs	XTIN, XTOUT	Low freq.	30.0	34.0	kHz

Note 1: The recommended operating conditions for a device are operating conditions under which it can be guaranteed that the device will operate as specified. If the device is used under operating conditions other than the recommended operating conditions (supply voltage, operating temperature range, specified AC/DC values etc.), malfunction may occur. Thus, when designing products which include this device, ensure that the recommended operating conditions for the device are always adhered to.

Note 2: Input Voltage V_{IH3}, V_{IL3}: in the SLOW and HOLD mode.

Note 3: Operating Temperature – 30 to 50°C

DC Characteristics

(V_{SS} = 0 V, T_{opr} = – 40 to 70°C)

Parameter	Symbol	Pins	Conditions	Min	Typ.	Max	Unit
Hysteresis Voltage	V _{HS}	Hysteresis Input		—	0.7	—	V
Input Current	I _{IN1}	Port K0, TEST, $\overline{\text{RESET}}$, $\overline{\text{HOLD}}$	V _{DD} = 5.5 V, V _{IN} = 5.5 V / 0 V	—	—	± 2	μA
	I _{IN2}	Open drain R port					
Input Low Current	I _{IL}	Push-pull R port	V _{DD} = 5.5 V, V _{IN} = 0.4 V	—	—	– 2	mA
Input Registance	R _{IN1}	Port K0 with pull-up/pull-down		30	70	150	kΩ
	R _{IN2}	$\overline{\text{RESET}}$		100	220	450	
Output Leakage Current	I _{LO}	Open drain port R	V _{DD} = 5.5 V, V _{OUT} = 5.5 V	—	—	2	μA
Output High Voltage	V _{OH}	Push-pull R port	V _{DD} = 4.5 V, I _{OH} = – 200 μA	2.4	—	—	V
Output Low Voltage	V _{OL}	Except XOUT	V _{DD} = 4.5 V, I _{OL} = 1.6 mA	—	—	0.4	V
Output Low Current	I _{OL}	Ports R4	V _{DD} = 4.5 V, V _{OL} = 1.0 V	15	20	—	mA
Segment Output Low Resistance	R _{OS1}	SEG pin	V _{DD} = 5 V, V _{DD} – V _{LC} = 3 V	—	10/20	—	kΩ
Common Output Low Resistance	R _{OC1}	COM pin					
Segment Output High Resistance	R _{OS2}	SEG pin		—	70 /200	—	kΩ
Common Output High Resistance	R _{OC2}	COM pin					
Segment / Common Output Resistance	V _{O2/3}	SEG / COM pin		3.8	4.0	4.2	V
	V _{O1/2}			3.3	3.5	3.7	
	V _{O1/3}			2.8	3.0	3.2	
Supply Current (in the Normal mode)	I _{DD}		V _{DD} = 5.5 V, V _{LC} = V _{SS} f _c = 4 MHz	—	3	6	mA
Supply Current (in the SLOW mode)	I _{DDs}		V _{DD} = 3.0 V, V _{LC} = V _{SS} f _s = 32.768 kHz	—	30	60	μA
Supply Current (in the HOLD mode)	I _{DDH}		V _{DD} = 5.5 V	—	0.5	10	μA

Note 1: Typ. values show those at T_{opr} = 25°C, V_{DD} = 5 V.Note 2: Input Current I_{IN1} ; The current through resistor is not included, when the input resistor (pull-up / pull-down) is contained.Note 3: Output Resistance R_{OS}, R_{OC} ; Shows on-resistance at the level switching.Note 4: V_{O2/3} ; Shows 2/3 level output voltage, when the 1/4 or 1/3 duty LCD is used.Note 5: V_{O1/2} ; Shows 1/2 level output voltage, when the 1/2 duty or static LCD is used.Note 6: V_{O1/3} ; Shows 1/3 level output voltage, when the 1/4 or 1/3 duty LCD is used.Note 7: Supply Current I_{DD}, I_{DDH} ; V_{IN} = 5.3 V / 0.2 V

The K0 port is open when the input resistor is contained.

The voltage applied to the R port is within the valid range.

Supply Current I_{DDs} ; V_{IN} = 2.8 V / 0.2 V. Only low frequency clock is only osillated (connecting XTIN, XTOUT).Note 8: When using LCD, it is necessary to consider values of R_{OS1/2} and R_{OC1/2}.

Note 9: Times for SEG / COM output resistance switching on:

R_{OS1}, R_{OC1}: 2/f_s (s)R_{OS2}, R_{OC2}: 1/(n · f_F)(1/n: duty, f_F: frame frequency)

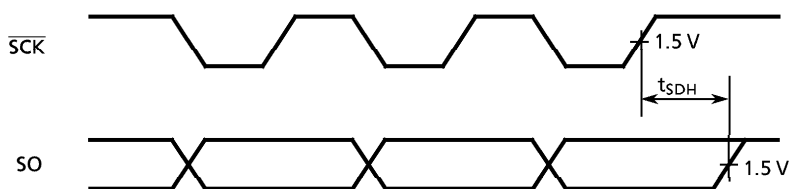
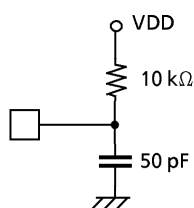
AC Characteristics

(V_{SS} = 0 V, T_{opr} = – 40 to 70°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Instruction Cycle Time	t _{cy}	in the Normal mode	1.3	—	20	μs
		in the SLOW mode	235	—	267	μs
High Level Clock Pulse Width	t _{WCH}	For external clock operation	80	—	—	ns
Low Level Clock Pulse Width	t _{WCL}					
Shift data Hold Time	t _{SDH}		0.5 t _{cy} – 0.3	—	—	μs
High Speed Timer / Counter input frequency	f _{HT}	ECIN input	—	—	fc	MHz

Note: Shift data Hold time:External circuit for \overline{SCK} pin and SO pin

Serial port (completion of transmission)



Recommended Oscillating Conditions

(V_{SS} = 0 V, T_{opr} = – 40 to 70°C)

(1) 6 MHz

Ceramic Resonator

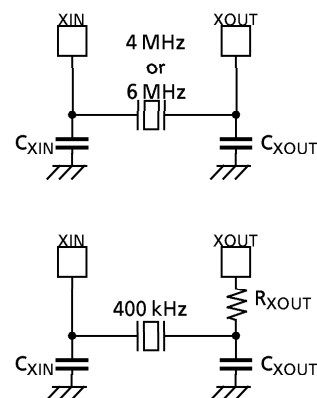
CSA6.00MGU (MURATA) C_{XIN} = C_{XOUT} = 30 pF
 KBR-6.00MS (KYOCERA) C_{XIN} = C_{XOUT} = 30 pF

(2) 4 MHz

Ceramic Resonator

CSA4.00MG (MURATA) C_{XIN} = C_{XOUT} = 30 pF
 KBR-4.00MS (KYOCERA) C_{XIN} = C_{XOUT} = 30 pF
 FCR-4.0M5 (TDK) C_{XIN} = C_{XOUT} = 33 pF

Crystal Oscillator

204B-6F 4.0000 (TOYOCOM) C_{XIN} = C_{XOUT} = 20 pF

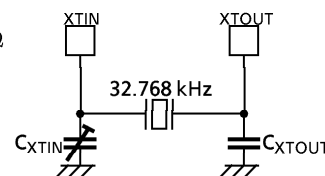
(3) 400 kHz

Ceramic Resonator

CSB400B (MURATA) C_{XIN} = C_{XOUT} = 220 pF, R_{XOUT} = 6.8 kΩ
 KBR-400B (KYOCERA) C_{XIN} = C_{XOUT} = 100 pF, R_{XOUT} = 10 kΩ

(4) 32.768 kHz (V_{SS} = 0 V, V_{DD} = 2.7 to 6.0 V, T_{opr} = – 30 to 70°C)

Crystal Oscillator

C_{XTIN}, C_{XTOUT} ; 10 to 33 pF

Note: In order to get the accurate oscillation frequency, the adjustment of capacitors must be required.

Typical Characteristics

