CMOS 8-Bit Microcontroller

# TMP86FS27FG

The TMP86FS27 is a high-speed, high-performance 8-bit microcomputer built around the TLCS-870/C Series core with built-in 60-Kbyte flash memory and it is pin compatible with its mask ROM version, the TMP86CM27/P27. Writing programs in the built-in flash memory enables this microcomputer to perform the same operations as the TMP86CM27/P27. The built-in flash memory can be rewritten on board (without removing it from the PCB) by a built-in boot program.

| Product No. | Flash Memory | RAM | Package |
|---|---|---|---|
| TMP86FS27FG | 60 Kbytes | 1 Kbytes | P-QFP80-1420-0.80M |

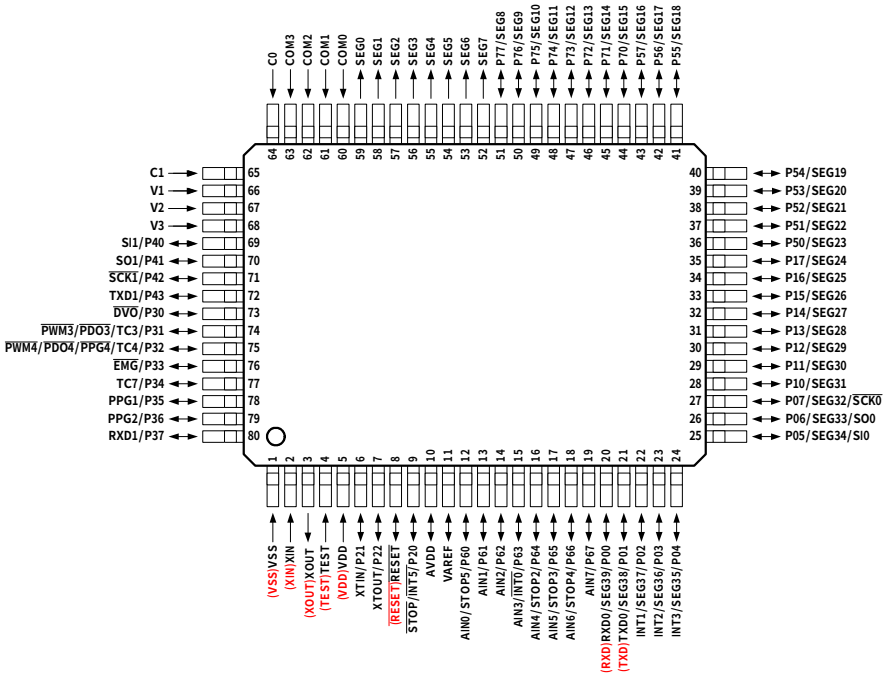
## Feautures

- 8-bit single chip microcomputer TLCS-870/C series
- Instruction execution time: 0.25 μs (at 16 MHz)
  122 μs (at 32.768 kHz)
- 132 types and 731 basic instructions
- 20 interrupt sources (External: 7, Internal: 13)
- Input/output ports (55 pins)
  - Large current output: 8pins (Typ.20mA), LED direct drive
- Watchdog timer
- Time base timer
- 10-bit timer counter: 1ch (2 output pins)
  - 2 ports output PPG (Programmed Pulse Generator)
  - 50% duty output mode
  - Variable duty output mode
  - External-triggered start and stop
  - Emargency stop pin
- Real time counter

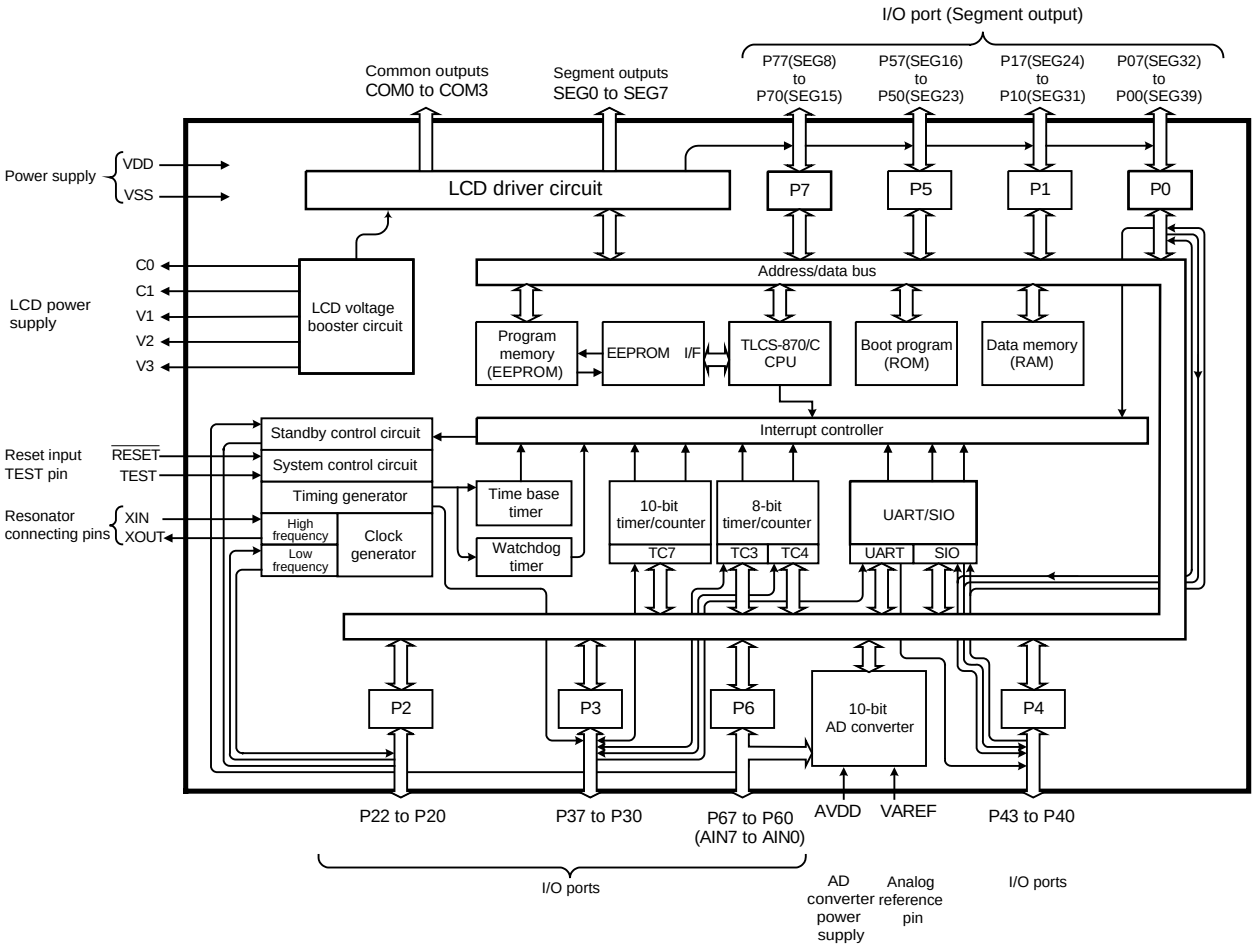
- 8-bit timer counter: 2 ch
  - Timer, PWM, PPG, PDO, Event counter modes
- 10-bit successive approximation type AD converter
  - Analog input: 8 ch
- Key-on wakeup: 4 ch
- Serial interface
  - 8-bit SIO: 1 ch
  - 8-bit UART: 1 ch
- Dual clock operation
  - Built-in voltage booster for LCD drier with displaymemory
  - LCD direct drive capability (MAX. 8 seg.× 4 com.)
  - 1/4, 1/3, 1/2 duties or static drive are programmably selectable
- Dual clock operation
  - Single/dual-clock mode
- Nine power saving operating modes
  - STOP mode: Oscillation stops. Battery/capacitor backup. Port output hold/high-impedance.
  - SLOW 1, 2 mode: Low power consumption operation using low-frequency clock (32.768 kHz)
  - IDLE 0 mode: CPU stops, and peripherals operate using high-frequency clock of time-base-timer. Release by INTTBT interrupt.
  - IDLE 1 mode: CPU stops, and peripherals operate using high-frequency clock. Release by interrupts.
  - IDLE 2 mode: CPU stops, and peripherals operate using high and low frequency clock. Release by interrupts.
  - SLEEP 0 mode: CPU stops, and peripherals operate using low-frequency clock of time-base-timer. Release by INTTBT interrupt.
  - SLEEP 1 mode: CPU stops, and peripherals operate using low-frequency clock. Release by interrupts.
  - SLEEP 2 mode: CPU stops, and peripherals operate using high and low frequency clock. Release by interrupts.
- Wide operating voltage: 4.5 to 5.5 V at 16 MHz/32.768 kHz
  2.7 to 5.5 V at 8 MHz/32.768 kHz

Note: The operating voltage, the operating temperature and the operating current are different between TMP86FS27 and TMP86CM27/P27.
About details, please refer to electrical characteristics of each products.

## Pin Assignments (Top view)



# Block Diagram



## Pin Function

The TMP86FS27 has MCU mode and serial PROM mode.

(1) MCU mode

In the MCU mode, the TMP86FS27 is a pin compatible with the TMP86CM27/P27 (Make sure to fix the TEST pin to low level).

(2) Serial PROM mode

The serial PROM mode is set by fixing TEST pin, P00 and P01 at "high" respectively when $\overline{\text{RESET}}$ pin is fixed "low".

After release of reset, the built-in BOOT ROM program is activated and the built-in flash memory is rewritten by serial I/F (UART).

| Pin Name (Serial PROM mode) | Input/ Output | Functions | Pin Name (MCU mode) |
|---|---|---|---|
| BOOT1/RXD | Input/Input | Fix "High" during reset. This pin is used as RXD pin after releasing reset. | P00 |
| BOOT2/TXD | Input/Output | Fix "High" during reset. This pin is used as TXD pin after releasing reset. | P01 |
| TEST | Input | Fix to "High". | |
| $\overline{\text{RESET}}$ | I/O | Reset signal input or an internal error reset output. | |
| VDD, AVDD | Power supply | 5 V | |
| VSS | | 0 V | |
| VAREF | | Leave open or apply reference voltage. | |
| P07 to P02, P17 to P10, P22 to P20, P37 to P30, P43 to P40, P57 to P50, P67 to P60, P77 to P70 | I/O | Open | |
| SEG7 to SEG0 | Output | 0 V output (Open) | |
| COM3 to COM0 | Output | 0 V output (Open) | |
| C0, C1, V1, V2, V3 | LCD power supply | Not use | |
| XIN | Input | Self oscillation with resonator (2 MHz, 4 MHz, 8 MHz, 16 MHz) | |
| XOUT | Output | | |

# Operation

This section describes the functions and basic operational blocks of TMP86FS27.

The TMP86FS27 has flash memory in place of the mask ROM which is included in the TMP86CM27/P27. The configuration and function are the same as the TMP86C847/H47.

## 1. Operating Mode

The TMP86FS27 has MCU mode and serial PROM mode.

### 1.1 MCU Mode

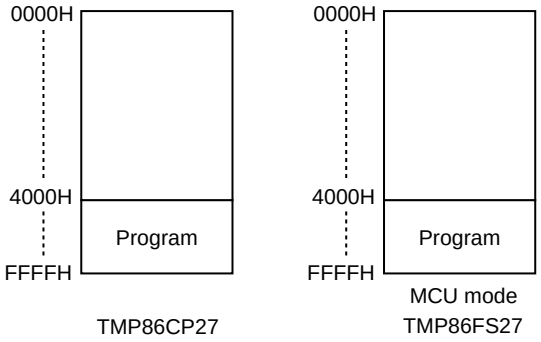
The MCU mode is set by fixing the TEST pin to the low level.

In the MCU mode, the operation is the same as the TMP86CM27/P27 (TEST pin cannot be used open because it has no built-in pull-down resistor).

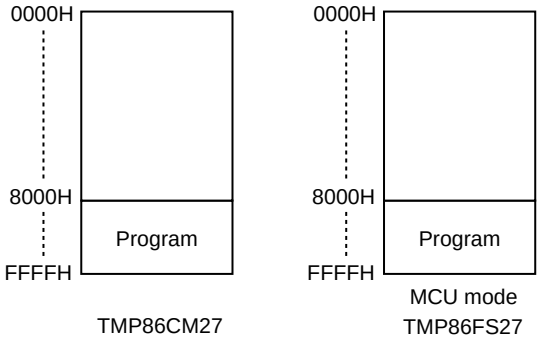
#### 1.1.1 Program memory

The TMP86FS27 has a 60-Kbyte built-in flash memory (addresses 1000H to FFFFH in the MCU mode).

When using TMP86FS27 for evaluation of TMP86CM27/P27, the program is written by the serial PROM mode.




(a) ROM Size = 48 Kbytes




(b) ROM Size = 32 Kbytes

Figure 1.1.1 Program Memory Area

Note: The area that is not in use should be set data to FFH.

### 1.1.2 Data Memory

TMP86FS27 has a built-in 1024-byte data memory (Static RAM).

### 1.1.3 Input/Output Circuitry

(1) Control pins

The control pins of the TMP86FS27 are the same as those of the TMP86CM27/P27.

(2) I/O ports

The I/O circuitries of TMP86FS27 I/O ports are the same as the those of TMP86CM27/P27.

# Electrical Characteristics

## Absolute Maximum Ratings ($V_{SS}$ = 0 V)

| Parameter | Symbol | Pins | Rating | Unit |
|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | −0.3 to 6.5 | V |
| Input voltage | $V_{IN}$ | | −0.3 to $V_{DD}$ + 0.3 | |
| Output voltage | $V_{OUT1}$ | | −0.3 to $V_{DD}$ + 0.3 | |
| Output current (Per 1 pin) | $I_{OUT1}$ | P0, P1, P3, P4, P6 ports | −1.8 | mA |
| | $I_{OUT2}$ | P0, P1, P2, P4, P5, P6, P7 ports | 3.2 | |
| | $I_{OUT3}$ | P3 port | 30 | |
| Output current (Total) | $\Sigma I_{OUT1}$ | P0, P1, P3, P4, P6 ports | −30 | |
| | $\Sigma I_{OUT2}$ | P0, P1, P2, P4, P5, P6, P7 ports | 60 | |
| | $\Sigma I_{OUT3}$ | P3 port | 80 | |
| Power dissipation [Topr = 70°C] | PD | | 250 | mW |
| Soldering temperature (time) | Tsld | | 260 (10 s) | °C |
| Storage temperature | Tstg | | −55 to 125 | |
| Operating temperature | Topr | | −40 to 70 | |

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 Condition

1) MCU mode ($V_{SS}$ = 0 V, Topr = −40 to 70ºC)

| Parameter | Symbol | Pins | Condition | | Min | Max | Unit |
|---|---|---|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | fc = 16 MHz | NORMAL1, 2 mode | 4.5 | 5.5 | V |
| | | | | IDLE0, 1, 2 mode | | | |
| | | | fc = 8 MHz | NORMAL1, 2 mode | 2.7 | | |
| | | | | IDLE0, 1, 2 mode | | | |
| | | | fs = 32.768 kHz | SLOW1, 2 mode | | | |
| | | | | SLEEP0, 1, 2 mode | | | |
| | | | STOP mode | | 2.0 | | |
| Input high level | $V_{IH1}$ | Except hysteresis input | $V_{DD} \geq 4.5$ V | | $V_{DD} \times 0.70$ | $V_{DD}$ | |
| | $V_{IH2}$ | Hysteresis input | | | $V_{DD} \times 0.75$ | | |
| | $V_{IH3}$ | | $V_{DD} < 4.5$ V | | $V_{DD} \times 0.90$ | | |
| Input low level | $V_{IL1}$ | Except hysteresis input | $V_{DD} \geq 4.5$ V | | 0 | $V_{DD} \times 0.30$ | |
| | $V_{IL2}$ | Hysteresis input | | | | $V_{DD} \times 0.25$ | |
| | $V_{IL3}$ | | $V_{DD} < 4.5$ V | | | $V_{DD} \times 0.10$ | |
| Clock frequency | fc | XIN, XOUT | $V_{DD}$ = 4.5 to 5.5 V | | 1.0 | 16.0 | MHz |
| | | | $V_{DD}$ = 2.7 to 5.5 V | | | 8.0 | |
| | fs | XTIN, XTOUT | | | 30.0 | 34.0 | kHz |

DC Characteristics ($V_{SS}$ = 0 V, Topr = –40 to 70°C)

| Parameter | Symbol | Pins | Condition | | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Hysteresis voltage | $V_{HS}$ | Hysteresis input | | | – | 0.9 | – | V |
| Input current | $I_{IN1}$ | TEST | $V_{DD}$ = 5.5 V, $V_{IN}$ = 5.5/0 V | | – | – | ±2 | μA |
| | $I_{IN2}$ | Sink open drain, tri-state | | | | | | |
| | $I_{IN3}$ | $\overline{RESET}$, $\overline{STOP}$ | | | | | | |
| Input resistance | $R_{IN1}$ | TEST pull down | | | – | 70 | – | kΩ |
| | $R_{IN2}$ | $\overline{RESET}$ pull up | | | 100 | 200 | 450 | |
| High frequency feedback resistor | $R_{fx1}$ | XIN-XOUT | | | – | 1.2 | – | MΩ |
| Low frequency feedback resistor | $R_{fxt}$ | XTIN-XTOUT | | | – | 6 | – | |
| Output leakage current | $I_{LO1}$ | Sink open drain | $V_{DD}$ = 5.5 V, $V_{OUT}$ = 5.5 V | | – | – | 2 | μA |
| | $I_{LO2}$ | Tri-state | $V_{DD}$ = 5.5 V, $V_{OUT}$ = 5.5/0 V | | – | – | ±2 | |
| Output high voltage | $V_{OH1}$ | Tri-state | $V_{DD}$ = 4.5 V, $I_{OH}$ = –0.7 mA | | 4.1 | – | – | V |
| Output low voltage | $V_{OL}$ | Except XOUT and P3 ports | $V_{DD}$ = 4.5 V, $I_{OL}$ = 1.6 mA | | – | – | 0.4 | |
| Output low current | $I_{OL}$ | Except XOUT and P3 ports | $V_{DD}$ = 4.5 V, $V_{OL}$ = 0.4 V | | – | 1.6 | – | mA |
| | $I_{OL2}$ | P3 (High current port) | $V_{DD}$ = 4.5 V, $V_{OL}$ = 1.0 V | | | 20 | | |
| Supply current in NORMAL 1, 2 mode | $I_{DD}$ | | $V_{DD}$ = 5.5 V<br>$V_{IN}$ = 5.3 V/0.2 V<br>fc = 16 MHz<br>fs = 32.768 kHz | | – | 13 | 20 | mA |
| Supply current in IDLE1, 2 mode | | | | | – | 8 | 15 | |
| Supply current in IDLE0 mode | | | | | – | 6 | 12.5 | |
| Supply current in SLOW1 mode | | | $V_{DD}$ = 3.0 V<br>$V_{IN}$ = 2.8 V/0.2 V<br>fs = 32.768 kHz | When a program operates on flash memory | – | 1200 | 2400 | μA |
| | | | | When a program operates on RAM | – | 12 | 23 | |
| Supply current in SLEEP1 mode | | | | | – | 8 | 20 | |
| Supply current in SLEEP0 mode | | | | | – | 6 | 17 | |
| Supply current in STOP mode | | | $V_{DD}$ = 5.0 V<br>$V_{IN}$ = 5.3 V/0.2 V | | – | 0.5 | 10 | |

Note 1: Typical values show those at Topr = 25°C, $V_{DD}$ = 5 V.

Note 2: Input current ($I_{IN1}$, $I_{IN3}$); The current through pull-down or pull-up resistor is not included.

Note 3: $I_{DD}$ does not include $I_{REF}$ current.

Note 4: The supply currents of SLOW2 and SLEEP2 modes are equivalent to IDLE1, 2.

AD Conversion Characteristics ($V_{SS}$ = 0 V, 4.5 V ≤ $V_{DD}$ ≤ 5.5 V, Topr = –40 to 70°C)

| Parameter | Symbol | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Analog reference voltage | $V_{AREF}$ | | $A_{VDD}$ – 1.0 | – | $A_{VDD}$ | V |
| Power supply voltage of analog control circuit | $A_{VDD}$ | | $V_{DD}$ | | | |
| Analog reference voltage range (Note 4) | $\Delta V_{AREF}$ | | 3.5 | – | $V_{DD}$ | |
| Analog input voltage | $V_{AIN}$ | | $V_{SS}$ | – | $V_{AREF}$ | |
| Power supply current of analog reference voltage | $I_{REF}$ | $V_{DD}$ = $A_{VDD}$ = $V_{AREF}$ = 5.5 V<br>$V_{SS}$ = $A_{VSS}$ = 0.0 V | – | 0.6 | 1.0 | mA |
| Non linearity error | | $V_{DD}$ = $A_{VDD}$ = 5.0 V<br>$V_{SS}$ = $A_{VSS}$ = 0.0 V<br>$V_{AREF}$ = 5.0 V | – | – | ±2 | LSB |
| Zero point error | | | – | – | ±2 | |
| Full scale error | | | – | – | ±2 | |
| Total error (Note 1) | | | – | – | ±4 | |

($V_{SS}$ = 0 V, 2.7 V ≤ $V_{DD}$ < 4.5 V, Topr = –40 to 70°C)

| Parameter | Symbol | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Analog reference voltage | $V_{AREF}$ | | $A_{VDD}$ – 1.0 | – | $A_{VDD}$ | V |
| Power supply voltage of analog control circuit | $A_{VDD}$ | | $V_{DD}$ | | | |
| Analog reference voltage range (Note 4) | $\Delta V_{AREF}$ | | 2.5 | – | $V_{DD}$ | |
| Analog input voltage | $V_{AIN}$ | | $V_{SS}$ | – | $V_{AREF}$ | |
| Power supply current of analog reference voltage | $I_{REF}$ | $V_{DD}$ = $A_{VDD}$ = $V_{AREF}$ = 4.5V<br>$V_{SS}$ = $A_{VSS}$ = 0.0 V | – | 0.5 | 0.8 | mA |
| Non linearity error | | $V_{DD}$ = $A_{VDD}$ = 2.7 V<br>$V_{SS}$ = 0.0 V<br>$V_{AREF}$ = 2.7 V | – | – | ±2 | LSB |
| Zero point error | | | – | – | ±2 | |
| Full scale error | | | – | – | ±2 | |
| Total error (Note 1) | | | – | – | ±4 | |

Note 1: The total error includes all errors except a quantization error, and is defined as a maximum deviation from the ideal conversion line.

Note 2: Conversion time is different in recommended value by power supply voltage.

Note 3: Please use input voltage to AIN input pin in limit of $V_{AREF}$ – $V_{SS}$.
When voltage of range outside is input, conversion value becomes unsettled and gives affect to other channel conversion value.

Note 4: Analog reference voltage range: $\Delta V_{AREF}$ = $V_{AREF}$ – $V_{SS}$

## AC Characteristics

($V_{SS}$ = 0 V, $V_{DD}$ = 4.5 to 5.5 V, Topr = –40 to 70°C)

| Parameter | Symbol | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Machine cycle time | tcy | NORMAL1, 2 mode | 0.25 | – | 4 | μs |
| | | IDLE0, 1, 2 mode | | | | |
| | | SLOW1, 2 mode | 117.6 | – | 133.3 | |
| | | SLEEP0, 1, 2 mode | | | | |
| High level clock pulse width | twcH | For external clock operation (XIN input), fc = 16 MHz | – | 31.25 | – | ns |
| Low level clock pulse width | twcL | | | | | |
| High level clock pulse width | twcH | For external clock operation (XTIN input), fs = 32.768 kHz | – | 15.26 | – | μs |
| Low level clock pulse width | twcL | | | | | |

($V_{SS}$ = 0 V, $V_{DD}$ = 2.7 to 4.5 V, Topr = –40 to 70°C)

| Parameter | Symbol | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Machine cycle time | tcy | NORMAL1, 2 mode | 0.5 | – | 4 | μs |
| | | IDLE0, 1, 2 mode | | | | |
| | | SLOW1, 2 mode | 117.6 | – | 133.3 | |
| | | SLEEP0, 1, 2 mode | | | | |
| High level clock pulse width | twcH | For external clock operation (XIN input), fc = 8 MHz | – | 62.5 | – | ns |
| Low level clock pulse width | twcL | | | | | |
| High level clock pulse width | twcH | For external clock operation (XTIN input), fs = 32.768 kHz | – | 15.26 | – | μs |
| Low level clock pulse width | twcL | | | | | |

## Flash Characteristics

($V_{SS}$ = 0 V, Topr = 25±5°C)

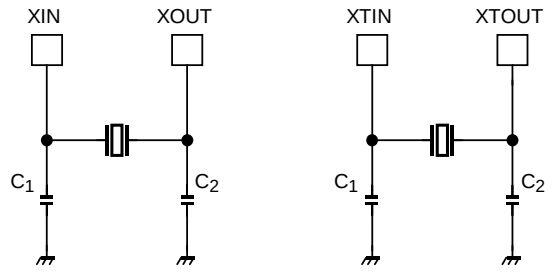
Recommended Operating Conditions (Serial PROM mode)

| Parameter | Symbol | Pins | Condition | Min | Max | Unit |
|---|---|---|---|---|---|---|
| Supply voltage | VDD | | fc = 2 MHz,4MHz, 8MHz, 16MHz | 4.5 | 5.5 | V |
| Clock frequency | Fc | XIN, XOUT | $V_{DD}$ = 4.5 V to 5.5 V | 2 | 16 | MHz |

Write/Retention Characteristics

| Parameter | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|
| Number of guaranteed writes to flash memory | $V_{SS}$ = 0 V, Topr = 25±5 °C | – | – | 10 | Times |
| Retention | $V_{SS}$ = 0 V, Topr =-40 to 70°C | – | – | 10 | Years |

## Recommended Oscillating Conditions




High-frequency oscillation Low-frequency oscillation

Note 1: A quartz resonator can be used for high-frequency oscillation only when VDD is 2.7 V or above. If VDD is below 2.7 V, use a ceramic resonator.

Note 2: To ensure stable oscillation, the resonator position, load capacitance, etc. must be appropriate. Because these factors are greatly affected by board patterns, please be sure to evaluate operation on the board on which the device will actually be mounted.

Note 3: For the resonators to be used with Toshiba microcontrollers, we recommend ceramic resonators manufactured by Murata Manufacturing Co., Ltd.
For details, please visit the website of Murata at the following URL:
http://www.murata.co.jp/search/index.html

## Handling Precaution

- The solderability test conditions for lead-free products (indicated by the suffix G in product name) are shown below.
  1. When using the Sn-63Pb solder bath
     Solder bath temperature = 230 °C
     Dipping time = 5 seconds
     Number of times = once
     R-type flux used
  2. When using the Sn-3.0Ag-0.5Cu solder bath
     Solder bath temperature = 245 °C
     Dipping time = 5 seconds
     Number of times = once
     R-type flux used

  The pass criteron of the above test is as follows:
  Solderability rate until forming ≥ 95 %
- When using the device (oscillator) in places exposed to high electric fields such as cathode-ray tubes, we recommend electrically shielding the package in order to maintain normal operating condition.