

CMOS 8-bit Microcontroller

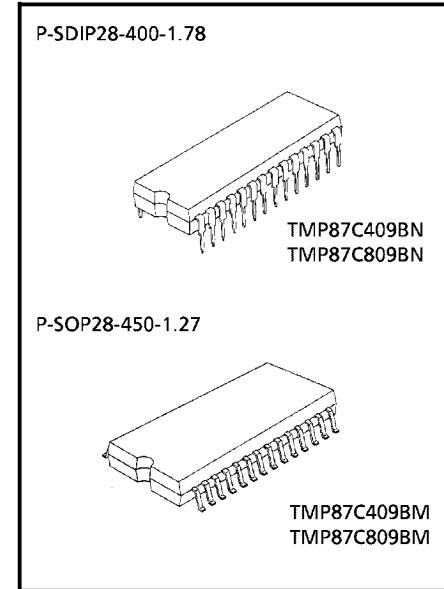
**TMP87C409BN, TMP87C409BM, TMP87C809BN, TMP87C809BM**

The TMP87C409B/809B are the high speed and high performance 8-bit single chip microcomputers. These MCU contain CPU core, ROM, RAM, input/output ports, three multi-function timer/counters, a 10-bit AD converter, on a chip. The TMP87C409B/809B provide high current output capability for LED direct drive.

Product No.	ROM	RAM	Package	OTP MCU
TMP87C409BN	4 K x 8 bits	256 x 8 bits	P-SDIP28-400-1.78	TMP87P809N
TMP87C409BM			P-SOP28-450-1.27	TMP87P809M
TMP87C809BN	8 K x 8 bits	256 x 8 bits	P-SDIP28-400-1.78	TMP87P809N
TMP87C809BM			P-SOP28-450-1.27	TMP87P809M

**Features**

- ◆ 8-bit single chip microcomputer TLCS-870 Series
- ◆ instruction execution time: 0.5  $\mu$ s (at 8 MHz)
- ◆ 412 basic instruction
  - Multiplication and Division (8 bits x 8 bits, 16 bits  $\div$  8 bits)
  - Bit manipulations  
(Set/Clear/Complement/Load/Store/Test/Exclusive or)
  - 16-bit data operations
  - 1-byte jump/subroutine-call (Short relative jump/Vector call)
- ◆ 11 interrupt sources (External: 4, Internal: 7)
  - All sources have independent latches each, and nested interrupt control is available.
  - 2 edge-selectable external interrupts with noise reject.
  - High-speed task switching by register bank changeover
- ◆ 3 Input/Output ports (22 pins)
  - High current output: 6 pins (Typ. 20 mA)
- ◆ 16-Bit Timer/Counter
  - Timer, Event counter modes



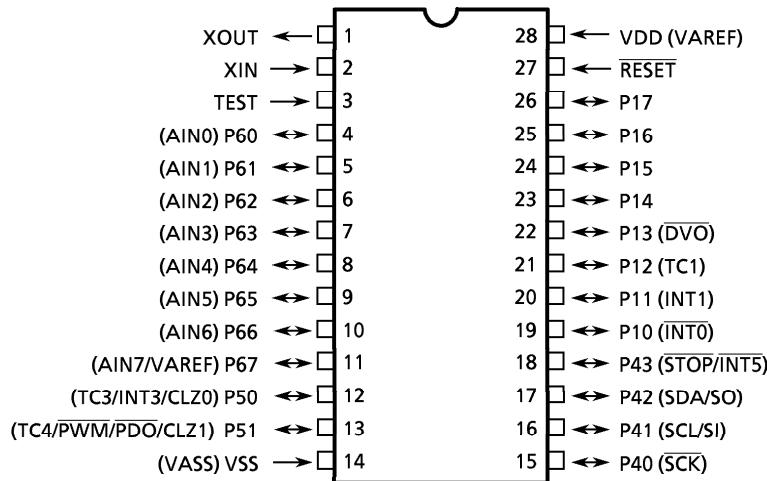
030619EBP2

- The information contained herein is subject to change without notice.
- The information contained herein is presented only as a guide for the applications of our products. No responsibility is assumed by TOSHIBA for any infringements of patents or other rights of the third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of TOSHIBA or others.
- TOSHIBA is continually working to improve the quality and reliability of its products. Nevertheless, semiconductor devices in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing TOSHIBA products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such TOSHIBA products could cause loss of human life, bodily injury or damage to property. In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the "Handling Guide for Semiconductor Devices," or "TOSHIBA Semiconductor Reliability Handbook" etc.
- The TOSHIBA products listed in this document are intended for usage in general electronics applications (computer, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). These TOSHIBA products are neither intended nor warranted for usage in equipment that requires extraordinarily high quality and/or reliability or a malfunction or failure of which may cause loss of human life or bodily injury ("Unintended Usage"). Unintended Usage include atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc.. Unintended Usage of TOSHIBA products listed in this document shall be made at the customer's own risk.
- The products described in this document are subject to the foreign exchange and foreign trade laws.
- TOSHIBA products should not be embedded to the downstream products which are prohibited to be produced and sold, under any law and regulations.
- For discussion of how the reliability of microcontrollers can be predicted, please refer to Section 1.3 of the chapter entitled Quality and Reliability Assurance/Handling Precautions.

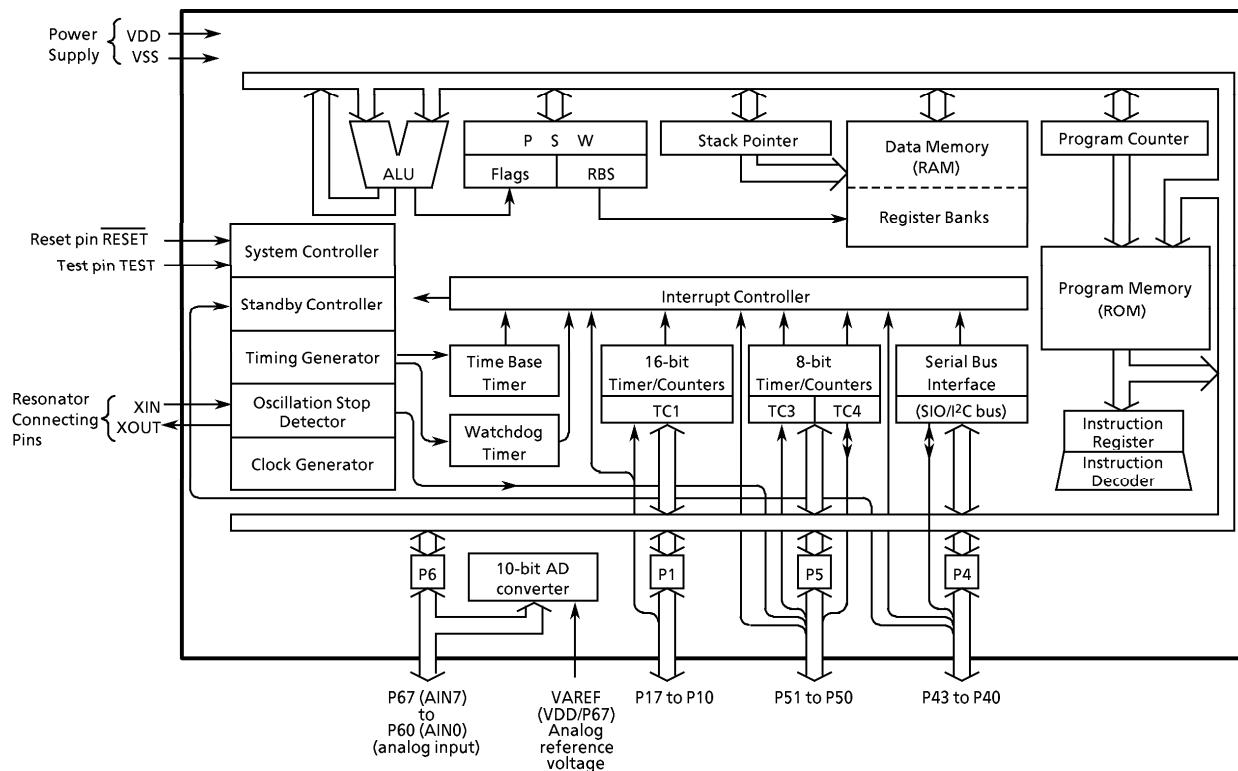
- ◆ Two 8-Bit Timer/Counters
  - Timer, Event counter, Capture (Pulse width/duty measurement), PWM output, Programmable divider output modes.
- ◆ Time Base Timer (Interrupt frequency: 1 Hz to 16 kHz)
- ◆ Divider output function (frequency: 1 kHz to 8 kHz)
- ◆ Watch dog Timer
- ◆ Serial bus Interface (SBI-ver. B)
  - I<sup>2</sup>C bus, 8-bit SIO modes.
- ◆ 10-bit successive approximate type AD converter
  - 8 analog inputs
- ◆ Two Oscillation Stop Detector outputs (High-impedance output)
- ◆ Two Power saving operating modes
  - STOP mode: Oscillation stops. Battery/Capacitor back-up.  
Port output hold/high-impedance.
  - IDLE mode: CPU stops, and Peripherals operate using high-frequency clock. Release by interrupts.
- ◆ Wide operating voltage: 2.2 to 5.5 V at 4.2 MHz/4.5 to 5.5 V at 8 MHz
- ◆ Emulation Pod: BM87C809N0A

## Pin Assignments (Top View)

P-SDIP28-400-1.78 / P-SOP28-450-1.27



## Block Diagram



## Pin Function

Pin Name	Input / Output	Function	
P17 to P14	I/O	8-bit programmable input/output ports (tri-state).	
P13 (DVO)	I/O (Output)	Each bit of the port can be individually configured as an input or an output under software control.	Divider output
P12 (TC1)			Timer/Counter 1 input
P11 (INT1)	I/O (Input)	When used as an external input or a timer counter input, the input mode is configured. When used as an divider output, the latch must be set to "1".	External interrupt input 1
P10 (INT0)			External interrupt input 0
P43 (STOP/INT5)	I/O (Input/Output)	4-bit input/output port with latch (high current output).	STOP mode release input/External interrupt 5 input
P42 (SDA/SO)	I/O (I/O/Output)	When used as an input port, an I <sup>2</sup> C input/output or an external interrupt input the latch must be set to "1".	I <sup>2</sup> C bus serial data input/output or SIO serial data output
P41 (SCL/SI)	I/O (I/O/Input)		I <sup>2</sup> C bus serial clock input/output or SIO serial data input
P40 (SCK)	I/O (I/O)		SIO serial clock input/output
P51 (TC4/PWM/PDO/CLZ1)	I/O (Input/Output/Output/Output)	2-bit programmable input/output ports (tri-state, high current output). Each bit of the port can be individually configured as an input or an output under software control. When used as a timer counter input or an external interrupt input the input mode is configured.	Timer/counter 4 input or 8-bit PWM output or 8-bit PDO output or oscillation stop detector output 1
P50 (TC3/INT3/CLZ0)	I/O (Input/Output/Output)	When used as a PWM/PDO output, the latch must be set to "1" and the output mode is configured. When used as a oscillation stop detector output, the output mode is configured.	Timer/counter 3 input or external interrupt input 3 or oscillation stop detector output 0
P67 (AIN7/VAREF)	I/O (Input/Output)	8-bit programmable input/output ports (tri-state). Each bit of the port can be individually configured as an input or an output under software control.	AD converter analog input or analog reference power supply
P66 (AIN6) to P60 (AIN0)	I/O (Input)	When used as an analog input or an analog reference power supply, the input mode is configured.	AD converter analog inputs
XIN, XOUT	Input, Output	Resonator connecting pins for high-frequency clock. For inputting external clock, XIN is used and XOUT is opend.	
RESET	Input	Reset signal input.	
TEST	Input	Test pint for out-going test. Be tied to low.	
VDD (VAREF)	Power Supply	+ 5 V	Analog reference power supply
VSS (VASS)		0 V (GND)	Analog reference GND

## Operational Description

### 1. CPU Core Functions

The CPU core consists of a CPU, a system clock controller, an interrupt controller, and a watchdog timer. This section provides a description of the CPU core, the program memory, the data memory, and the reset circuit.

#### 1.1 Memory Address Map

The TMP87C409B/809B are capable of addressing 64 Kbytes of memory. Figure 1-1 shows the memory address maps of the TMP87C409B/809B. In the TMP87C409B/809B the memory is organized 3 address spaces (ROM, RAM and SFR). It uses a memory mapped I/O system, and all I/O registers are mapped in the SFR address spaces. There are 16 banks of general-purpose registers. The register banks are also assigned to the RAM address space.

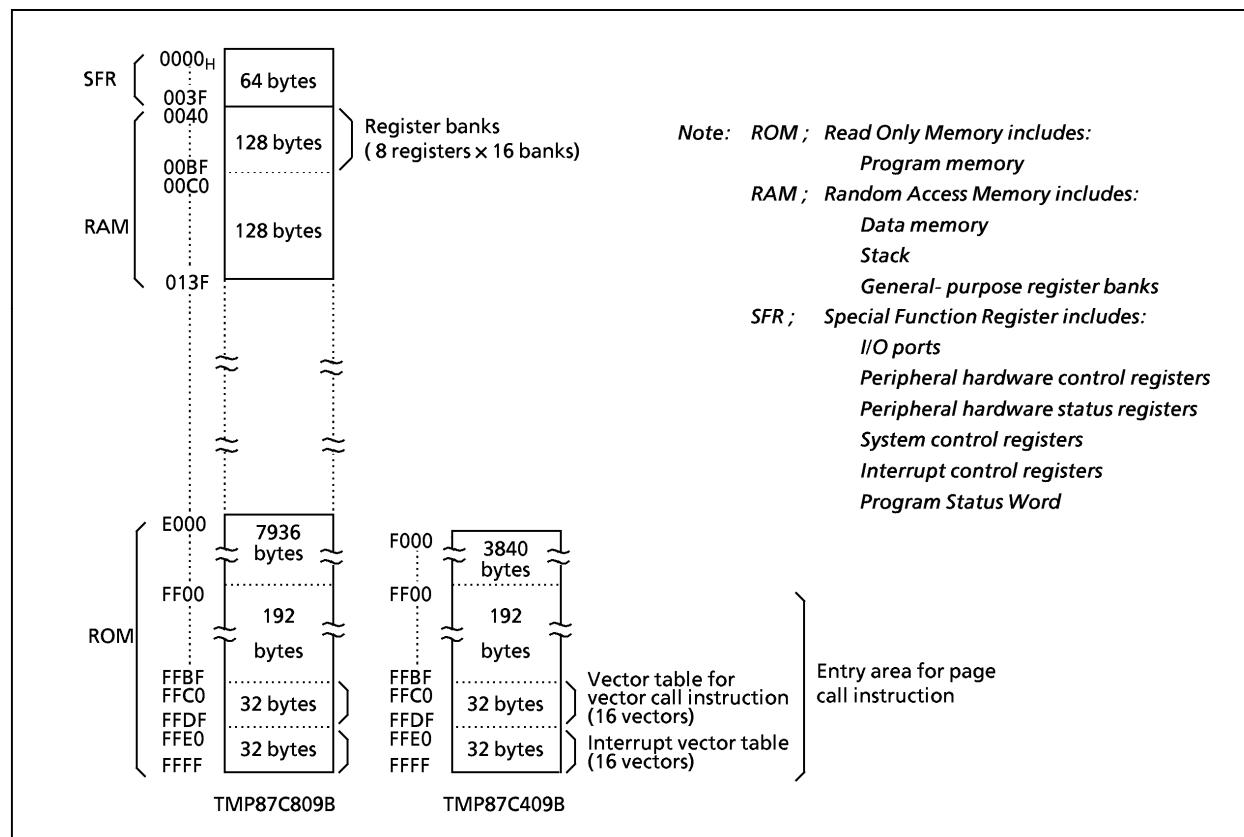


Figure 1-1. Memory address map

## Electrical Characteristics

Absolute Maximum Ratings		$(V_{SS} = 0 \text{ V})$			
Parameter	Symbol	Condition		Ratings	Unit
Supply Voltage	$V_{DD}$			– 0.3 to 6.5	V
Input Voltage	$V_{IN}$			– 0.3 to $V_{DD} + 0.3$	V
Output Voltage	$V_{OUT1}$	Ports P1, P5, P6, XOUT		– 0.3 to $V_{DD} + 0.3$	
	$V_{OUT2}$	Port P4		– 0.3 to 5.5	V
Output Current (Per 1 pin)	$I_{OL}$	$I_{OUT1}$	Ports P1, P6		3.2
		$I_{OUT2}$	Ports P4, P5		30
	IOH	$I_{OUT3}$	Ports P1, P5, P6		– 1.8
Output Current (Total)	$I_{OL}$	$\Sigma I_{OUT1}$	Ports P1, P6		30
		$\Sigma I_{OUT2}$	Ports P4, P5		80
	IOH	$\Sigma I_{OUT3}$	Ports P1, P5, P6		30
Power Dissipation [ $Topr = 70^\circ\text{C}$ ]		PD	SDIP	300	mW
			SOP	180	
Soldering Temperature (time)	$T_{sld}$				$260 (10 \text{ s})$ $^\circ\text{C}$
Storage Temperature	$T_{stg}$				– 55 to 125 $^\circ\text{C}$
Operating Temperature	$Topr$				– 30 to 70 $^\circ\text{C}$

**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			$(V_{SS} = 0 \text{ V}, Topr = – 30 \text{ to } 70^\circ\text{C})$						
Parameter	Symbol	Pins	Conditions		Min	Max	Unit		
Supply Voltage	$V_{DD}$		$f_c = 8 \text{ MHz}$	NORMAL mode	4.5	5.5	V		
				IDLE mode					
			$f_c = 4.2 \text{ MHz}$	NORMAL mode	2.2				
				IDLE mode					
				STOP mode	2.0				
Input High Voltage	$V_{IH1}$	Except hysteresis input	$V_{DD} \geq 4.5 \text{ V}$		$V_{DD} \times 0.70$	$V_{DD}$	V		
	$V_{IH2}$	Hysteresis input			$V_{DD} \times 0.75$				
	$V_{IH3}$		$V_{DD} < 4.5 \text{ V}$		$V_{DD} \times 0.90$				
Input Low Voltage	$V_{IL1}$	Except hysteresis input	$V_{DD} \geq 4.5 \text{ V}$		$V_{DD} \times 0.30$	0	V		
	$V_{IL2}$	Hysteresis input			$V_{DD} \times 0.25$				
	$V_{IL3}$		$V_{DD} < 4.5 \text{ V}$		$V_{DD} \times 0.10$				
Clock Frequency	$f_c$	XIN, XOUT	$V_{DD} = 4.5 \text{ to } 5.5 \text{ V}$		1.0	8.0	MHz		
			$V_{DD} = 2.2 \text{ V to } 5.5 \text{ V}$			4.2			

**Note1:** 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.

**Note2:** Clock frequency  $f_c$ : Supply voltage range is specified in NORMAL mode and IDLE mode.

DC Characteristics			$(V_{SS} = 0 \text{ V}, \text{Topr} = -30 \text{ to } 70^\circ\text{C})$					
Parameter	Symbol	Pins	Conditions		Min	Typ.	Max	Unit
Hysteresis Voltage	$V_{HS}$	Hysteresis input			—	0.9	—	V
Input Current	$I_{IN1}$	TEST	$V_{DD} = 5.5 \text{ V}$ $V_{IN} = 5.5 \text{ V} / 0 \text{ V}$	—	—	$\pm 2$	$\mu\text{A}$	
	$I_{IN2}$	Tri-state ports						
	$I_{IN3}$	RESET, STOP						
Input Resistance	$R_{IN2}$	RESET			100	220	450	k $\Omega$
Output Leakage Current	$I_{LO}$	Tri-state ports	$V_{DD} = 5.5 \text{ V}, V_{OUT} = 5.5 \text{ V} / 0 \text{ V}$	— 2	—	2	$\mu\text{A}$	
Output High Voltage	$V_{OH2}$	Tri-state ports	$V_{DD} = 4.5 \text{ V}, I_{OH} = -0.7 \text{ mA}$	4.1	—	—	V	
Output Low Voltage	$V_{OL1}$	Except XOUT, P4 and P5	$V_{DD} = 4.5 \text{ V}, I_{OL} = 1.6 \text{ mA}$	—	—	0.4		
Output Low current	$I_{OL3}$	P4, P5	$V_{DD} = 4.5 \text{ V}, V_{OL} = 1.0 \text{ V}$	—	20	—	mA	
Supply Current in NORMAL mode	$I_{DD}$		$V_{DD} = 5.5 \text{ V}$ $f_c = 8 \text{ MHz}$ $V_{IN} = 5.3 \text{ V} / 0.2 \text{ V}$		8	14	mA	
Supply Current in IDLE mode			4		6			
Supply Current in NORAML mode			$V_{DD} = 3.0 \text{ V}$ $f_c = 4.2 \text{ MHz}$ $V_{IN} = 2.8 \text{ V} / 0.2 \text{ V}$		2.5	3.5	mA	
Supply Current in IDLE mode			1.5		2.0			
Supply Current in STOP mode			$V_{DD} = 5.5 \text{ V}$ $V_{IN} = 5.3 \text{ V} / 0.2 \text{ V}$		0.5	10	$\mu\text{A}$	
<p><i>Note 1: Typical values show those at <math>\text{Topr} = 25^\circ\text{C}, V_{DD} = 5 \text{ V}</math>.</i></p> <p><i>Note 2: Input Current <math>I_{IN1}, I_{IN3}</math>: The current through resistor is not included, when the input resistor (pull-up or pull-down) is contained.</i></p>								

AD Conversion Characteristics			$(V_{SS} = 0 \text{ V}, V_{DD} = 2.2 \text{ to } 5.5 \text{ V}, \text{Topr} = -30 \text{ to } 70^\circ\text{C})$				
Parameter	Symbol	Conditions	Min	Typ.	Max	Unit	
Analog Reference Voltage	$V_{AREF}$		2.2	—	$V_{DD}$	V	
	$V_{ASS}$		$V_{SS}$				
Analog Input Voltage range	$V_{AIN}$		$V_{ASS}$	—	$V_{AREF}$	V	
Analog Reference Current	$I_{REF}$	$V_{AREF} = 5.5 \text{ V}, V_{ASS}(V_{SS}) = 0.0 \text{ V}$	—	0.5	1.0	mA	
Nonlinearity Error		$V_{DD} = 5.0 \text{ V}$ $V_{AREF} = 5.000 \text{ V}$ $V_{ASS}(V_{SS}) = 0.000 \text{ V}$ or $V_{DD} = 2.2 \text{ V}$ $V_{AREF} = 2.200 \text{ V}$ $V_{ASS}(V_{SS}) = 0.000 \text{ V}$	—	—	$\pm 2$	LSB	
Zero Point Error			—	—	$\pm 2$		
Full Scale Error			—	—	$\pm 2$		
Total Error			—	—	$\pm 4$		

*Note: Quantizing error is not contained in those errors.*

## Oscillation Stop Detector Characteristics

(V<sub>SS</sub> = 0 V, Topr = -30 to 70°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Detection time	T <sub>CLZ</sub>	V <sub>DD</sub> = 2.2 V to 5.5 V (f <sub>c</sub> = 2 MHz to 4.2 MHz) V <sub>DD</sub> = 4.5 V to 5.5 (f <sub>c</sub> = 8 MHz)	2	20	400	μs

## AC Characteristics

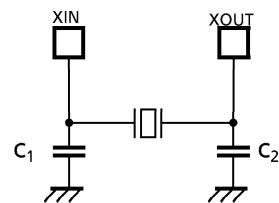
(V<sub>SS</sub> = 0 V, V<sub>DD</sub> = 4.5 to 5.5 V, Topr = -30 to 70°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Machine Cycle Time	t <sub>cy</sub>	In NORMAL mode	0.5	-	4	μs
		In IDLE mode				
High Level Clock Pulse Width	t <sub>WCH</sub>	For external clock operation	50	-	-	ns
Low Level Clock Pulse Width	t <sub>WCL</sub>	f <sub>c</sub> = 8 MHz				

## Recommended Oscillating Conditions

(V<sub>SS</sub> = 0 V, V<sub>DD</sub> = 2.2 to 5.5 V, Topr = -30 to 70°C)

Parameter	Oscillator	Oscillation Frequency	Recommended Oscillator	
High-frequency Oscillation	Ceramic Resonator	8 MHz (4.5 V to 5.5 V)	MURATA	CSTCC8M00G53-R0
			MURATA	CSTLS8M00G53-B0
		4 MHz (2.2 V to 5.5 V)	MURATA	CSTCR4M00G53-R0
			MURATA	CSTLS4M00G53-B0



(1) High-frequency Oscillation

*Note 1: When used in high electric field such as a picture tube, the package is recommended to be electrically shielded to maintain a regular operation.*

*Note 2: The product numbers and specifications of the resonators by Murata Manufacturing Co., Ltd. are subject to change. For up-to-date information, please refer to the following URL: <http://www.murata.co.jp/search/index.html>*