

## CMOS 8-Bit Microcontroller

## TMP88CS48AN, TMP88CS48AF

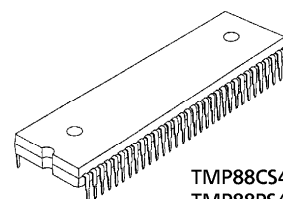
TMP88CS48A is high-speed and high-function 8-bit single-chip microcomputers whose built-in features include large-capacity RAM, multi-function timer/counter, and 10-bit AD converter, serial interface (UART/I<sup>2</sup>C bus). They are equipped with 3 phase brushless DC sensorless/sensor motor control, and AC motor inverter control.

Part No.	ROM	RAM	Package	OTP MCU
TMP88CS48AN	64 Kbytes	2 Kbytes	P-SDIP64-750-1.78	TMP88PS49N
TMP88CS48AF			P-QFP64-1420A-1.00A	TMP88PS49F

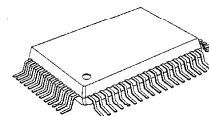
## Features

- ◆ 8-bit single-chip microcomputer TLCS-870/X series microcomputer
- ◆ Interrupt sources: 25 (6 external, 19 Internal)
- ◆ I/O ports: 56 pins
  - Large-current output: 8 pins (typ. 20 mA), LED direct drive
- ◆ 16-bit timer/counter: 2 channels
  - Timer, event counter, programmable pulse generator (PPG) output, pulse width measurement, external trigger timer, window mode
- ◆ 8-bit Timer/Counter: 3 channels
  - Timer, event counter, capture (pulse width/duty measurement), pulse width modulation (PWM) output, programmable divider output (PDO) mode
- ◆ Time base timer (interrupt frequency: 1 to 16384 Hz)
- ◆ Watchdog timer
- ◆ Divider output function (frequency: 1 to 8 kHz)
- ◆ Programmable motor driver (PMD): 1 channel
  - Rotor position: minimum resolution of 250 ns for detecting rotor position
  - Motor control timer, timer capture function
  - Overload protection function
    - DC overload protection function
    - AC overload protection function (Can halt counter in 3-phase PWM output circuit)
  - Protection circuit for malfunction (urgent halt)
  - Automatic direction change, automatic position detection start
- ◆ High-speed PWM output: 2 channel
  - Cycle: 32 kHz, 64 kHz, 128 kHz (at 8 MHz operation)
  - Resolution: 8-bit, 7-bit, 6-bit mode selectable

P-SDIP64-750-1.78

TMP88CS48AN  
TMP88PS49N

P-QFP64-1420A-1.00A

TMP88CS48AF  
TMP88PS49F

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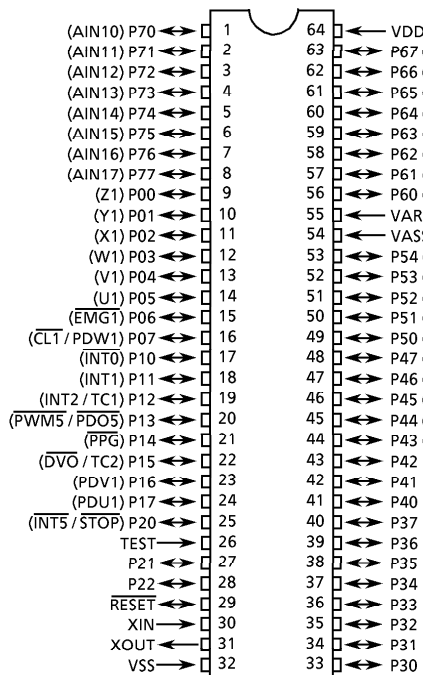


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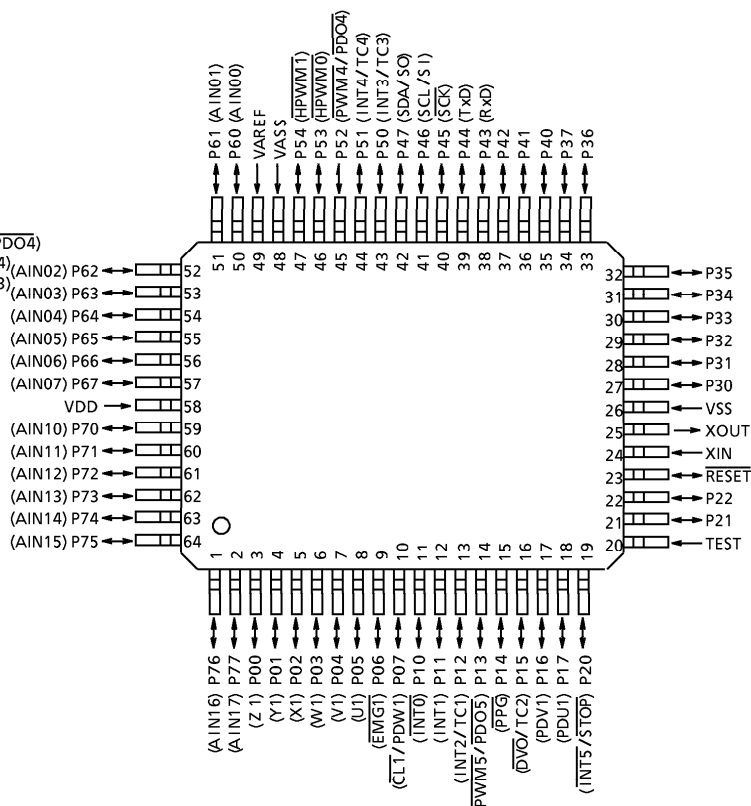
- ◆ Serial interface
  - 8-bit SIO/I<sup>2</sup>C bus
  - Universal asynchronous receiver transmitter (UART)
- ◆ 10-bit successive approximation type AD converter
  - Analog input: 16 channels
  - Conversion time: 46  $\mu$ s (at 16 MHz operation)
- ◆ Low power dissipation operation (2 modes)
  - STOP mode: Stops oscillation (battery or capacitor backup). Port output hold or high impedance selectable
  - IDLE mode: Stops CPU but continues operation of peripheral hardware. Released by interrupt (restarts CPU)
- ◆ Operating voltage: 4.5 to 5.5 V at 16 MHz operation
- ◆ Emulation pod: BM88CM49N0A

## Pin Assignments

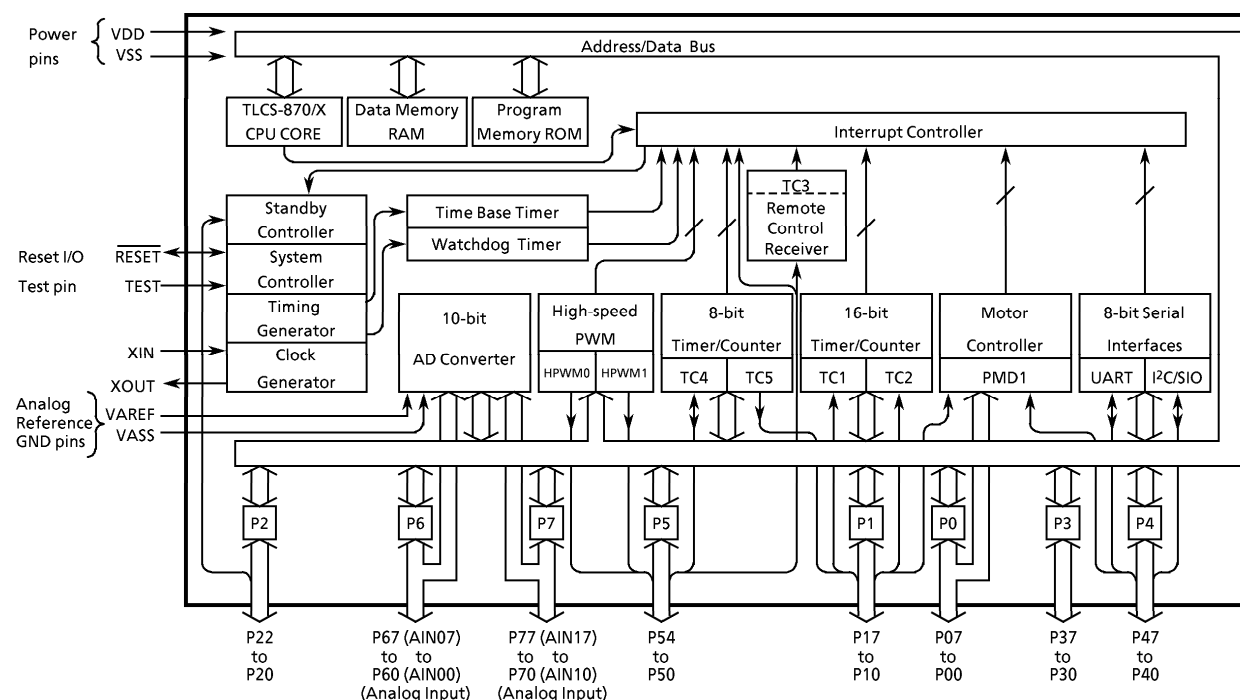
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P-QFP64-1420-1.00A



## Block Diagram



## Pin Function

Pin Name	I/O	Function	
P07 ( $\overline{\text{CL1}}/\text{PDW1}$ )	I/O (Input)	8-bit programmable I/O port (tri state) Input or output specifiable in units of bits.	Overload protection input 1/motor control circuit W1-phase position detection input
P06 ( $\overline{\text{EMG1}}$ )		When using pins for motor control circuit, set accordingly using P0CR, then MDCR to 1.	Motor control circuit malfunction detection input 1
P05 (U1)	I/O (Output)		Motor control circuit U1-/V1-/W1-phase output
P04 (V1)			
P03 (W1)			
P02 (X1)	I/O (Output)		Motor control circuit X1-/ Y1-/Z1-phase output
P01 (Y1)			
P00 (Z1)			
P17 (PDU1)	I/O (Input)	8-bit programmable I/O port (tri state) Input or output specifiable units of bits.	Motor control circuit U1-phase position detection input
P16 (PDV1)		When using pins for motor control circuit, timer/counter input, or external interrupt input, set them to input mode.	Motor control circuit V1-phase position detection input
P15 ( $\overline{\text{DVO}}/\text{TC2}$ )	I/O (Output/Input)	When using pins for PPG output, divider output, or PWM output/PDO output, set them to output mode.	Divider output or Timer/Counter 2 input
P14 (PPG)	I/O (Output)		Programmable pulse generator output
P13 ( $\overline{\text{PWM5}}/\text{PDO5}$ )			8-BIT PWM output 5 or 8-BIT programmable divider output 5
P12 ( $\overline{\text{INT2}}/\text{TC1}$ )	I/O (Input)		External interrupt input 2 or Timer/Counter 1 input
P11 ( $\overline{\text{INT1}}$ )			External interrupt input 1
P10 ( $\overline{\text{INT0}}$ )			External interrupt input 0
P22	I/O	3-bit I/O port	—
P21		When using pins for input port, external interrupt input, or STOP mode release input, set output latches to 1.	—
P20 ( $\overline{\text{INT5}}/\text{STOP}$ )	I/O (Input)		External interrupt input 5 or STOP mode release signal input
P37	I/O (Output)	8-bit I/O port (large-current output)	—
P36		When using pins for motor control circuit input, set output latches to 1, then MDCR2 to 1.	
P35			
P34			
P33			
P32			
P31			
P30			
P47 ( $\overline{\text{SDA}}/\text{SO}$ )	I/O (I/O/Output)	8-bit I/O port	I <sup>2</sup> C/SIO I/O
P46 ( $\overline{\text{SCL}}/\text{SI}$ )	I/O (I/O/Input)	When using pins for motor control circuit input, UART/I <sup>2</sup> C/SIO, set output latches to 1.	
P45 ( $\overline{\text{SCK}}$ )	I/O (I/O)		UART data input
P44 (Tx/D)	I/O (Input)		UART data output
P43 (Rx/D)	I/O (Output)		
P42	I/O		—
P41			
P40			
P54 (HPWM1)	I/O (Output)	5-bit input/output port with latch.	high-speed PWM output
P53 (HPWM0)		When using pins for input port, HPWM output, PWM output/PDO output, external interrupt input, or timer/counter input, set output latches to 1.	8-BIT PWM output 4 or, 8-bit programmable divider output 4
P52 ( $\overline{\text{PWM4}}/\text{PDO4}$ )	I/O (Input)		External interrupt 4 input or timer / counter 4 input
P51 ( $\overline{\text{INT4}}/\text{TC4}$ )			External interrupt 3 input or timer / counter 3 input
P50 ( $\overline{\text{INT3}}/\text{TC3}$ )			

Pin Name	Input/Output	Function	
P67 (AIN07) to P60 (AIN00)	I/O (Input)	8-bit programmable I/O port (tri state) Input or output specifiable in units of bits. When using pins for analog input, set to input mode using P6CR and ADCCR.	AD converter analog input
P77 (AIN17) to P70 (AIN10)	I/O (Input)	8-bit programmable I/O port (tri state) Input or output specifiable in units of bits. When using pins for analog input, set to input mode using P7CR and ADCCR.	AD converter analog input
XIN, XOUT	Input, Output	High-frequency oscillator connecting pins. For external clock input, input to XIN and leave XOUT open.	
RESET	I/O	Reset signal input, watchdog timer output, address trap reset output, system clock reset output	
TEST	Input	Shipment test pin, fix to "L" level.	
VDD, VSS	Power Supply	+ 5 V, 0 V (GND)	
VAREF, VASS		Analog reference voltage for AD conversion. Reference GND.	

## Operation

### 1. CPU Core Functions

The CPU core consists of the CPU, system clock control circuit, and interrupt control circuit. This chapter describes the CPU core, program memory, data memory and the reset circuit.

#### 1.1 Memory Address Map

The TMP88CS48A memory consists of four blocks: ROM, RAM, special function registers (SFR) and Data buffer registers (DBR). They are all mapped to a 1 Mbyte address space. Figure 1-1 shows the TMP88CS48A memory address map. There are 16 general-purpose registers mapped to the RAM address space.

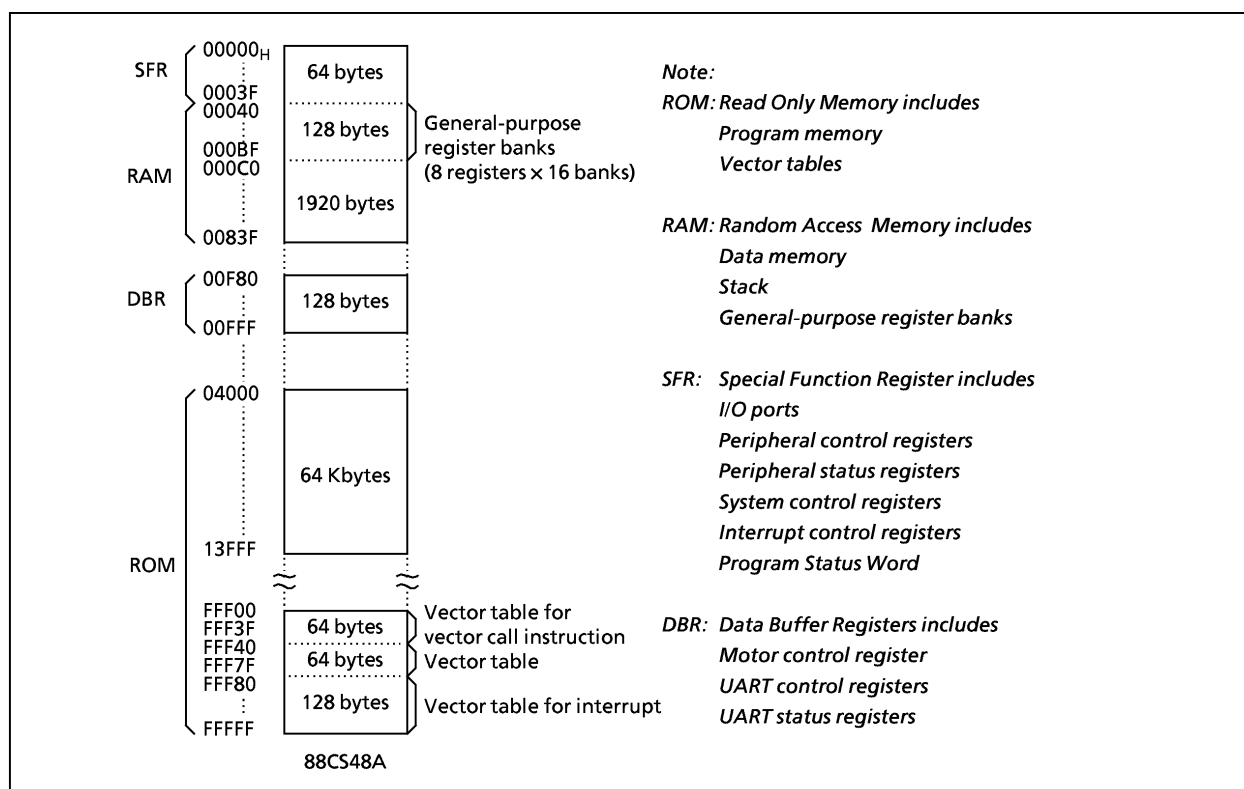


Figure 1-1. Memory Address Maps

## Electrical Characteristics

## Absolute Maximum Ratings

(V<sub>SS</sub> = 0 V)

Parameter	Symbol	Pins	Ratings	Unit
Supply Voltage	V <sub>DD</sub>		– 0.3 to 6.5	V
Input Voltage	V <sub>IN</sub>		– 0.3 to V <sub>DD</sub> + 0.3	V
Output Voltage	V <sub>OUT1</sub>	Port P21, P22, $\overline{\text{RESET}}$ , Tri-state port	– 0.3 to V <sub>DD</sub> + 0.3	V
	V <sub>OUT2</sub>	Port P20, Sink open drain port	– 0.3 to 5.5	V
Output Current	I <sub>OUT1</sub>	Ports P1, P2, P4, P5, P6, P7	3.2	mA
	I <sub>OUT2</sub>	Port P0	20	
	I <sub>OUT3</sub>	Port P3	30	
Output Current	$\Sigma I_{\text{OUT1}}$	Ports P1, P2, P4, P5, P6, P7	120	mA
	$\Sigma I_{\text{OUT2}}$	Port P0	60	
	$\Sigma I_{\text{OUT3}}$	Port P3	120	
Power Dissipation [Topr = 70°C]	PD	TMP88CS48AN	600	mW
		TMP88CS48AF	350	
Soldering Temperature (time)	Tsld		260 (10 s)	°C
Storage Temperature	Tstg		– 55 to 125	°C
Operating Temperature	Topr		– 40 to 85	°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<sub>SS</sub> = 0 V, Topr = – 40 to 85°C)

Parameter	Symbol	Pins	Conditions	Min	Max	Unit
Supply Voltage	V <sub>DD</sub>		fc = 16 MHz	4.5	5.5	V
			NORMAL mode			
			IDLE mode			
Input High Voltage	V <sub>IH1</sub>	Except hysteresis input	V <sub>DD</sub> ≥ 4.5 V	V <sub>DD</sub> × 0.70	V <sub>DD</sub>	V
	V <sub>IH2</sub>	Hysteresis input		V <sub>DD</sub> × 0.75		
	V <sub>IH3</sub>		V <sub>DD</sub> < 4.5 V	V <sub>DD</sub> × 0.90		
Input Low Voltage	V <sub>IL1</sub>	Except hysteresis input	V <sub>DD</sub> ≥ 4.5 V	0	V <sub>DD</sub> × 0.30	V
	V <sub>IL2</sub>	Hysteresis input			V <sub>DD</sub> × 0.25	
	V <sub>IL3</sub>		V <sub>DD</sub> < 4.5 V		V <sub>DD</sub> × 0.10	
Clock Frequency	fc	XIN, XOUT	V <sub>DD</sub> = 4.5 to 5.5 V	8.0	16.0	MHz

*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: Clock frequency fc: The condition of supply voltage range is the value in NORMAL and IDLE modes.*

## DC Characteristics

(V<sub>SS</sub> = 0 V, T<sub>opr</sub> = – 40 to 85°C)

Parameter	Symbol	Pins	Conditions	Min	Typ.	Max	Unit
Hysteresis Voltage	V <sub>HS</sub>	Hysteresis inputs		–	0.9	–	V
Input Current	I <sub>IN1</sub>	TEST	V <sub>DD</sub> = 5.5 V V <sub>IN</sub> = 5.5 V/0 V	–	–	± 2	μA
	I <sub>IN2</sub>	Sink open drain, Tri-state ports					
	I <sub>IN3</sub>	RESET, STOP					
Input Resistor (*)	R <sub>IN</sub>	TEST with pull-down		20	70	170	kΩ
		RESET		90	220	510	
Output Leakage Current	I <sub>OL</sub>	Sink open drain, Tri-state ports	V <sub>DD</sub> = 5.5 V, V <sub>OUT</sub> = 5.5 V/0 V	–	–	± 2	μA
Output High Voltage	V <sub>OH</sub>	Tri-state ports	V <sub>DD</sub> = 4.5 V, I <sub>OH</sub> = – 0.7 mA	4.1	–	–	V
Output Low Current	I <sub>OL1</sub>	Except XOUT, Ports P0, P3.	V <sub>DD</sub> = 4.5 V, V <sub>OL</sub> = 0.4 V	–	1.6	–	mA
	I <sub>OL2</sub>	Port P0	V <sub>DD</sub> = 4.5 V, V <sub>OL</sub> = 1.0 V	6	10	–	
	I <sub>OL3</sub>	Port P3		12	20	–	
Supply Current in NORMAL Mode			V <sub>DD</sub> = 5.5 V V <sub>IN</sub> = 5.3 V/0.2 V	–	32	40	mA
Supply Current in IDLE Mode			f <sub>c</sub> = 16.0 MHz	–	24	30	mA
Supply Current in STOP Mode			V <sub>DD</sub> = 5.5 V V <sub>IN</sub> = 5.3 V/0.2 V	–	0.5	20	μA

Note 1: Typical values show those at T<sub>opr</sub> = 25°C, V<sub>DD</sub> = 5 V.Note 2: Input Current I<sub>IN1</sub>, I<sub>IN3</sub>; The current through resistor is not included, when the input resistor (pull-up or pull-down) is contained.Note 3: I<sub>DD</sub> except I<sub>REF</sub>.

## AD Conversion Characteristics

(T<sub>opr</sub> = – 40 to 85°C)

Parameter	Symbol	Conditions	Min	Typ.	Max		Unit
					ADCDR1	ADCDR2	
						ACK = 1	
Analog Reference Voltage	V <sub>AREF</sub>	V <sub>AREF</sub> – V <sub>ASS</sub> ≥ 3.5 V	V <sub>DD</sub> – 1.0	—	V <sub>DD</sub>		V
	V <sub>ASS</sub>		V <sub>SS</sub>	—	1.0		
Analog Input Voltage	V <sub>AIN</sub>		V <sub>ASS</sub>	—	V <sub>AREF</sub>		V
Analog Supply Current	I <sub>REF</sub>	V <sub>AREF</sub> = 5.5 V, V <sub>ASS</sub> = 0.0 V	—	0.5	1.0		mA
Non-Linearity Error		V <sub>DD</sub> = 5.0 V, V <sub>SS</sub> = 0.0 V V <sub>AREF</sub> = 5.000 V V <sub>ASS</sub> = 0.000 V	—	—	± 1	± 2	LSB
Zero Point Error			—	—	± 1	± 2	
Full Scale Error			—	—	± 1	± 2	
Total Error			—	—	± 2	± 4	

Note 1: ADCDR1: 8-bit AD conversion result (1LSB = ΔV<sub>AREF</sub>/256)  
ADCDR2: 10-bit AD conversion result (1LSB = ΔV<sub>AREF</sub>/1024)

Note 2: Total error includes all errors except quantization error.



## AC Characteristics

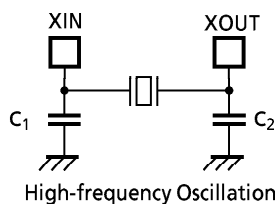
(V<sub>SS</sub> = 0 V, V<sub>DD</sub> = 4.5 to 5.5 V, T<sub>opr</sub> = – 40 to 85°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Machine Cycle Time	t <sub>cy</sub>	NORMAL mode	0.25	–	0.5	μs
		IDLE mode				
High Level Clock Pulse Width	t <sub>WCH</sub>	For external clock operation (XIN input)	31.25	–	62.5	ns
Low Level Clock Pulse Width	t <sub>WCL</sub>					

## Recommended Oscillating Conditions

(V<sub>SS</sub> = 0 V, V<sub>DD</sub> = 4.5 to 5.5 V, T<sub>opr</sub> = – 40 to 85°C)

Parameter	Oscillator	Oscillation Frequency	Recommended Oscillator	Recommended Constant	
				C <sub>1</sub>	C <sub>2</sub>
High-frequency Oscillation	Ceramic Resonator	16 MHz	MURATA CSA16.00MXZ	5 pF	5 pF
			MURATA CST16.00MXW	built-in 5 pF	built-in 5 pF



*Note: An electrical shield by metal shield on the surface of IC package should be recommendable in order to prevent the device from the high electric fieldstress applied from CRT (Cathode Ray Tube) for continuous reliable operation.*