

CMOS 8-Bit microcomputer

TMP87CH48U/DF, TMP87CM48U/DF

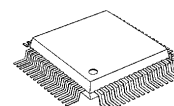
TMP87CH48/CM48 are a low power, high-speed and high-performance 8-bit single chip microcomputer, including large capacity ROM/RAM, input/output ports, a multiple timer counter, serial interfaces (UART, I²C bus, and SIO), four 12-bit PWM outputs, a 10-bit AD converter and two oscillators.

Product No.	ROM	RAM	Package	OTP
TMP87CH48U	16 Kbytes	512 bytes	P-LQFP64-1010-0.50	TMP87PH48U
TMP87CH48DF			P-QFP64-1414-0.80A	TMP87PH48DF
TMP87PM48U	32 Kbytes	1 Kbytes	P-LQFP64-1010-0.50	TMP87PM48U
TMP87PM48DF			P-QFP64-1414-0.80A	TMP87PM48DF

Features

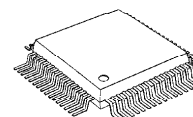
- ◆ 8-bit single chip microcomputer TLCS-870 series
- ◆ Minimum instruction execution time: 0.5 μ s (at 8 MHz), 122 μ s (at 32.768 kHz)
- ◆ 412 basic machine instructions: 129 types
- ◆ 15 interrupt sources (External: 6, Internal: 9)
 - All sources have independent latches each, and nested interrupt control is available.
 - Edge-selectable external interrupts with noise reject.
 - High-speed task switching by register bank changeover
- ◆ Input/output ports (56 pins)
 - High current output: 8 pins (Typ.20 mA), LED direct drive
- ◆ 16-bit timer counters: 2 channels
 - Timer, Event counter, PPG (Programmable Pulse Generator) output, Pulse width measurement, External trigger timer, Window modes

P-LQFP64-1010-0.50



TMP87CH48U
TMP87CM48U
TMP87PH48U
TMP87PM48U

P-QFP64-1414-0.80A



TMP87CH48DF
TMP87CM48DF
TMP87PH48DF
TMP87PM48DF

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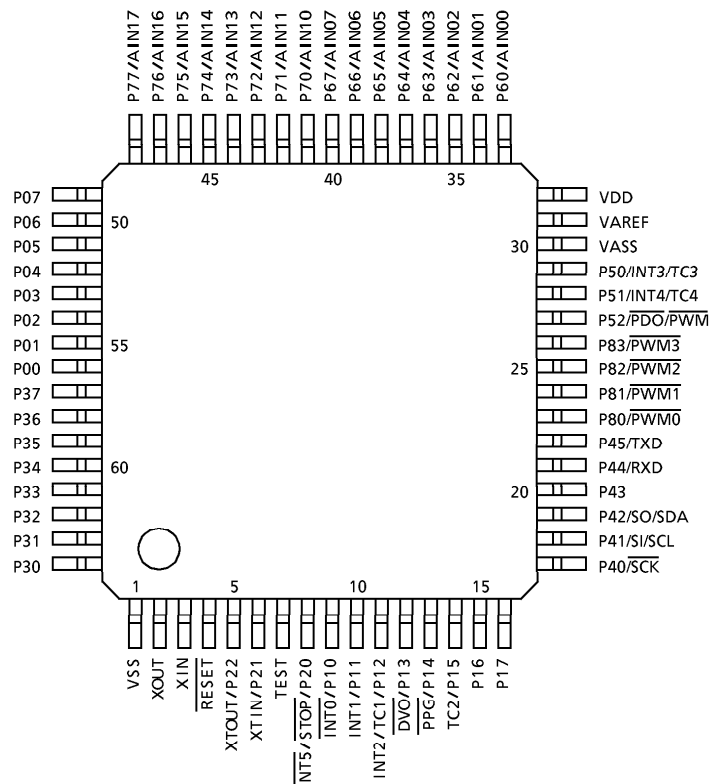
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- ◆ 8-bit timer counters: 2 channels
 - Timer, Event counter, Capture (Pulse width/duty measurement)
PWM (Changeable pulse width)
output, PDO (Programmable Divider Output)
- ◆ Time base timer (Interrupt frequency: 1 to 16384 Hz)
- ◆ Divider output functions (Frequency: 1 to 8 kHz)
- ◆ Watchdog timer
 - Interrupt/reset output (programmable)
- ◆ DA conversion (Changeable pulse width) output
 - 12-bit resolution: 4 channels
- ◆ UART: 1 channel (Parity/framing/overflow error detection)
- ◆ Serial bus interface (SBI-ver. B) 1 channel (I²C bus or clock synchronous SIO)
- ◆ 10-bit successive approximation type AD converter
 - Analog input: 16 channels
 - Conversion time: 24.5 μ s or 98 μ s (at 8 MHz)
- ◆ Clock oscillation circuit: Two circuits
 - Single/dual clock modes (Initial mode is always set to a single clock mode.)
- ◆ Low consumption power (Five modes)
 - STOP mode: Oscillation stop (Battery/capacitor back-up). Port output hold/high-impedance.
 - SLOW mode: Low consumption power operation by low-frequency clock
 - IDLE1 mode: CPU stops, and only peripheral hardware operates using high-frequency clock. Release by interrupts (CPU restarts).
 - IDLE2 mode: CPU stops, and only peripheral hardware operates using high or low-frequency clock). Release by interrupts.
 - SLEEP mode: CPU stops, and only peripheral hardware operates using low-frequency clock. Release by interrupts.
- ◆ Operation voltage: 2.7 to 5.5 V at 4.2 MHz/32.768 kHz, 4.5 to 5.5 V at 8 MHz/32.768 kHz
- ◆ Emulation pod: BM87CH48/CM48U0A

P-LQFP64-1010-0.50
P-OFP64-1414-0.80A



The block diagram illustrates the internal architecture of the ATmega16 microcontroller. Key components include:

- Power and I/O Pins:** VDD, VSS, RESET, TEST, XIN, and XOUT.
- System Controller:** Includes a Standby controller, Timing generator (High/Low frequency), and Clock generator.
- ALU and Registers:** ALU, Flags (P, S, W), RBS, Stack pointer, Data memory (RAM), Register banks, Program counter, and Program memory (ROM).
- Interrupt Controller:** Manages interrupts from various sources.
- Timers and Counters:** Time base timer, Watchdog timer, 16-bit timer/counters (TC1, TC2), 8-bit timer/counters (TC3, TC4), and 8-bit serial interface (UART, I²C/SIO).
- AD Converter:** 10-bit AD converter connected to P2, P7, and VAREF.
- PWM:** 12-bit PWM module connected to P1.
- Input/Output Ports:** P2, P7, P6, P1, P5, P4, P8, P0, and P3.
- Pin Functions:** P22 to P20 (Input/output ports), P77 (AIN17) to P70 (AIN10) (Analog input), P67 (AIN7) to P60 (AIN0) (Analog input), P17 to P10 (Input/output ports), P52 to P50 (Input/output ports), P45 to P40 (Input/output ports), P80 (PWM0) to P83 (PWM3) (PWM output), P07 to P00 (Input/output ports), and P37 to P30 (Input/output ports).

Pin Function

Pin Name	Input/Output	Functions	
P07 to P00	I/O	8-bit programmable input/output port (tri-state). Each bit of these ports can be individually configured as an input or an output under software control. When used as an external interrupt input or a timer counter input, the latch must be set to input mode. When used as PPG output or a divider output, the output latch must be set to "1".	
P17, P16	I/O		
P15 (TC2)	I/O (Input)		Timer counter 2 input
P14 (PPG)	I/O (Output)		Programmable pulse generator output
P13 (DVO)			Divider output
P12 (INT2/TC1)	I/O (Input)		External interrupt input 2 or Timer counter 1 input
P11 (INT1)			External interrupt input 1
P10 (INT0)			External interrupt input 0
P22 (XTOUT)	I/O (Output)	3-bit input/output port. When used as an input port, an oscillator connecting pin, an external interrupt input or STOP mode release input of P20, the output latch must be set to "1".	Low-frequency oscillator connecting pins (32.768 kHz). For inputting external clock, XTIN is used and XTOUT is opened. External interrupt input 5 or STOP mode release signal input
P21 (XTIN)	I/O (Input)		
P20 (INT5/STOP)			
P37 to P30	I/O	8-bit input/output port (high current output). When used as an input port, the output latch must be set to "1".	
P45 (Tx/D)	I/O (Output)	8-bit input/output port. When used as an input port, a serial interface pin, the output latch must be set to "1".	UART serial data output (send)
P44 (Rx/D)	I/O (Input)		UART serial data output (receive)
P43	I/O		
P42 (SO/SDA)	I/O (Output, I/O)		SIO serial data output or I ² C bus data input/output
P41 (SI/SCL)	I/O (Input, I/O)		SIO serial data output or I ² C bus clock input/output
P40 (SCK)	I/O (I/O)		SIO serial clock input/output
P52 (PWM/PDO)	I/O (Output)	3-bit input/output port. When used as an input port, PWM output, high-speed PWM output, a programmable divider output, an external interrupt input or timer counter input, the output latch must be set to "1".	8-bit PWM output or 8-bit programmable divider output
P51 (INT4/TC4)	I/O (Input)		External interrupt input 4 or Timer counter 4 input
P50 (INT3/TC3)			External interrupt input 3 or Timer counter 3 input
P67 (AIN7) to P60 (AIN0)	I/O	8-bit programmable input/output port (tri-state). Each bit of these ports can be individually configured as an input or an output under software control. When used as an analog input, the latch must be set to an analog input mode by P6CR and P7CR.)	AD converter analog input
P77 (AIN17) to P70 (AIN10)			
P83 (PWM3) to P80 (PWM0)	I/O (Output)	4-bit programmable input/output port (tri-state). Each bit of the port can be individually configured as an input or an output under software control. An input or an output is determined by setting P8CR.	DA conversion (PWM) output (PWM3 to PWM0)
XIN, XOUT	Input, Output	Oscillator connecting pins for high frequency clock. For inputting external clock, XIN is used and XOUT is opened.	
RESET	I/O	Reset signal input or watchdog timer output/address-trap-reset output/system-clock-reset output.	
TEST	Input	Test pin for outgoing test. Be externally tied to low.	
VDD, VSS	Power Supply	+ 5 V, 0 V (GND)	
VAREF, VASS		AD conversion analog reference voltage, 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 (ROM), the data memory (RAM), and the reset circuit.

1.1 Memory Address Map

The TLCS-870 Series is capable of addressing 64 Kbytes of memory. Figure 1-1 shows the memory address maps of the TMP87CH48/CM48. In the TLCS-870 Series, the memory is organized 4 address spaces (ROM, RAM, SFR, and DBR). It uses a memory mapped I/O system, and all I/O registers are mapped in the SFR/DBR address spaces. There are 16 banks of general-purpose registers. The register banks are also assigned to the first 128 bytes of the RAM address space.

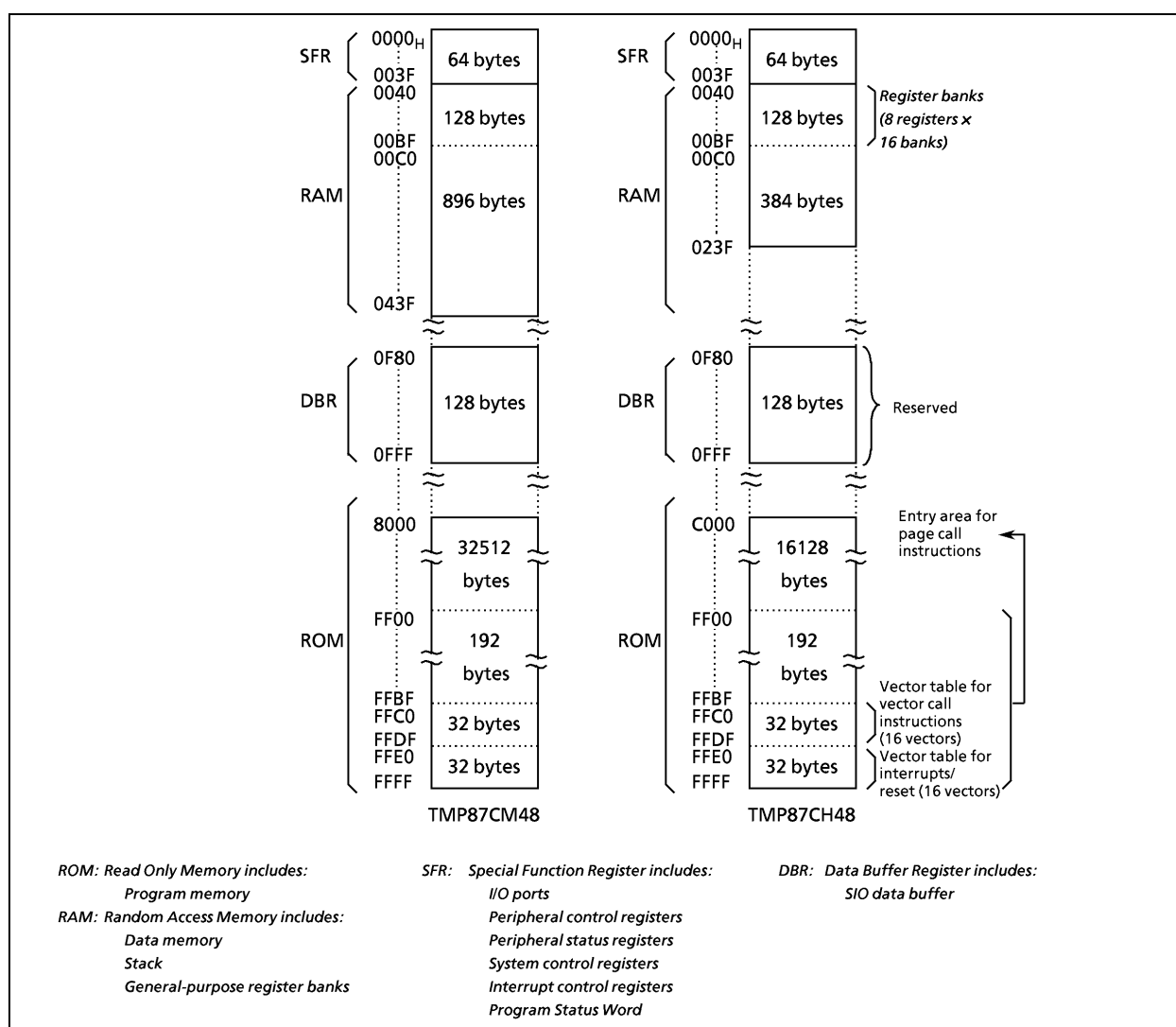


Figure 1-1. Memory Address Maps

Electrical Characteristics

(1) TMP87CH48

Absolute Maximum Ratings

(V_{SS} = 0 V)

Parameter	Symbol	Conditions	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 _{OUT}		– 0.3 to V _{DD} + 0.3	V
Output current (Per 1 pin)	I _{OUT1}	Ports P0, P1, P2, P4, P5, P6, P7, P8	3.2	mA
	I _{OUT2}	Port P3	30	
Output current (Total)	Σ I _{OUT1}	Ports P0, P1, P2, P4, P5, P6, P7, P8	120	mA
	Σ I _{OUT2}	Port P3	120	
Power dissipation	PD		350	mW
Soldering temperature (Time)	T _{sld}		260 (10 s)	°C
Storage temperature	T _{stg}		– 55 to 125	°C
Operating temperature	T _{opr}		– 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_{SS} = 0 V, T_{opr} = – 40 to 85°C)

Parameter	Symbol	Pins	Conditions		Min	Max	Unit
Supply voltage	V _{DD}		fc = 8 MHz	NORMAL1/2 modes	4.5	5.5	V
				IDLE1/2 modes			
			fc = 4.2 MHz	NORMAL1/2 modes	2.7		
				IDLE1/2 modes			
			fs = 32.768 kHz	SLOW mode	2.0		
				SLEEP mode			
	STOP mode						
Input high voltage	V _{IH1}	Except hysteresis input	V _{DD} ≥ 4.5 V		V _{DD} × 0.70	V _{DD}	V
	V _{IH2}	Hysteresis input			V _{DD} × 0.75		
	V _{IH3}		V _{DD} < 4.5 V	V _{DD} × 0.90			
Input low voltage	V _{IL1}	Except hysteresis input	V _{DD} ≥ 4.5 V		0	V _{DD} × 0.30	V
	V _{IL2}	Hysteresis input				V _{DD} × 0.25	
	V _{IL3}		V _{DD} < 4.5 V	V _{DD} × 0.10			
Clock frequency	fc	XIN, XOUT	V _{DD} = 4.5 to 5.5 V		0.4	8.0	MHz
			V _{DD} = 2.7 to 5.5 V			4.2	
	fs	XTIN, XTOUT			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: The condition of clock frequency is in NORMAL1/2 modes and IDLE1/2 modes.

DC Characteristics

(V_{SS} = 0 V, Topr = -40 to 85°C)

Parameter	Symbol	Pins	Conditions	Min	Typ.	Max	Unit
Hysteresis voltage	V _{HS}	Hysteresis inputs	V _{DD} = 5.0 V	–	0.9	–	V
Input current	I _{IN1}	TEST	V _{DD} = 5.5 V V _{IN} = 5.5 V/0 V	–	–	± 2	μA
	I _{IN2}	Open drain ports, Tri-state ports					
	I _{IN3}	RESET, STOP					
Input resistance	R _{IN2}	RESET	V _{DD} = 5.0 V	100	220	450	kΩ
Output leakage current	I _{LO}	Sink open drain ports	V _{DD} = 5.5 V, V _{OUT} = 5.5 V	–	–	2	μA
		Tri-state ports	V _{DD} = 5.5 V, V _{OUT} = 5.5/0 V	–	–	± 2	
Output high voltage	V _{OH2}	Tri-state ports	V _{DD} = 4.5 V, I _{OH} = –0.7 mA	4.1	–	–	V
Output low voltage	V _{OL}	Except for XOUT and P3	V _{DD} = 4.5 V, I _{OL} = 1.6 mA	–	–	0.4	mA
Output Low current	I _{OL3}	P3	V _{DD} = 4.5 V, V _{OL} = 1.0 V	–	20	–	mA
Supply current in NORMAL 1, 2 modes	I _{DD}		V _{DD} = 5.5 V V _{IN} = 5.3 V/0.2 V f _c = 8 MHz f _s = 32.768 kHz	–	4.5	5.5	mA
Supply current in IDLE 1, 2 modes			V _{DD} = 3.0 V, V _{IN} = 2.8 V/0.2 V V _{IN} = 4.19 MHz f _s = 32.768 kHz	–	2.5	4.0	mA
Supply current in NORMAL 1, 2 modes				–	1.75	3.0	mA
Supply current in IDLE 1, 2 modes			V _{DD} = 3.0 V V _{IN} = 2.8 V/0.2 V f _s = 32.768 kHz	–	1.25	2.0	mA
Supply current in SLOW mode				–	20	30	μA
Supply current in SLEEP mode			V _{DD} = 5.5 V V _{IN} = 5.3 V/0.2 V	–	10	20	μA
Supply current in STOP mode				–	0.5	10	μA
Supply current in STOP mode				–	0.5	10	μA

Note 1: Typical values show those at Topr = 25°C

Note 2: Input Current I_{IN1}, I_{IN3}; The current through resistor is not included, when the input resistor (pull-up or pull-down) is contained.Note 3: I_{DD} except for I_{REF}.

AD Conversion Characteristics

(V_{SS} = 0 V, V_{DD} = 2.7 to 5.5 V, Topr = -40 to 85°C)

Parameter	Symbol	Conditions	Min	Typ.	Max			Unit
					ADCDR1	ADCDR2		
						ACK = 0	ACK = 1	
Analog reference voltage	V _{AREF}	V _{AREF} – V _{ASS} ≥ 2.5 V	2.7	–	V _{DD}			V
	V _{ASS}		V _{SS}	–	1.5			
Analog input voltage	V _{AIN}		V _{ASS}	–	V _{AREF}			V
Analog supply current	I _{REF}	V _{AREF} = 5.5 V, V _{ASS} = 0.0 V	–	0.5	1.2			mA
Nonlinearity error		V _{DD} = 5.0, V _{SS} = 0.0 V V _{AREF} = 5.000 V V _{ASS} = 0.000 V	–	–	± 1	± 3	± 2	LSB
Zero point error		or V _{DD} = 2.7, V _{SS} = 0.0 V V _{AREF} = 2.700 V V _{ASS} = 0.000 V	–	–	± 1	± 3	± 2	
Full scale error			–	–	± 1	± 3	± 2	
Total error			–	–	± 2	± 6	± 4	

Note 1: ΔV_{AREF} = V_{AREF} – V_{ASS}ADCDR1: 8 bits – AD conversion result (1LSB = ΔV_{AREF}/256)ADCDR2: 10 bits – AD conversion result (1LSB = ΔV_{AREF}/1024)

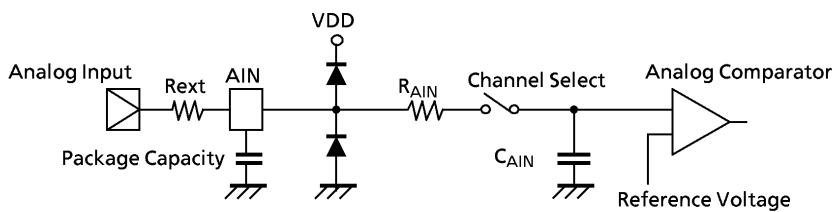
Note 2: Quantizing error is not contained in those errors.

AD Input Characteristics

(Topr = -40 to 85°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Input impedance (Resistance)	R_{AIN}	$V_{DD} = 5.0\text{ V}$, Conversion time $23\text{ }\mu\text{s}$ ($f_c = 8\text{ MHz}$)	–	5	–	$\text{k}\Omega$
		$V_{DD} = 2.7\text{ V}$, Conversion time $43.8\text{ }\mu\text{s}$ ($f_c = 4.2\text{ MHz}$)	–	20	–	
Input impedance (Capacity)	C_{AIN}	$V_{DD} = 5.0\text{ V}$, Conversion time $23\text{ }\mu\text{s}$ ($f_c = 8\text{ MHz}$)	–	7	–	pF
		$V_{DD} = 2.7\text{ V}$, Conversion time $43.8\text{ }\mu\text{s}$ ($f_c = 4.2\text{ MHz}$)	–	7	–	
Source impedance	R_{ext}	$V_{DD} = 5.0\text{ V}$, Conversion time $23\text{ }\mu\text{s}$ ($f_c = 8\text{ MHz}$)	–	–	5	$\text{k}\Omega$
		$V_{DD} = 2.7\text{ V}$, Conversion time $43.8\text{ }\mu\text{s}$ ($f_c = 4.2\text{ MHz}$)	–	–	5	

Note: Input current (Output leak current) error (Max $\pm 2\text{ }\mu\text{A}$) and quantizing error (Max $\pm 4\text{ LSB}$) for AD are contained.



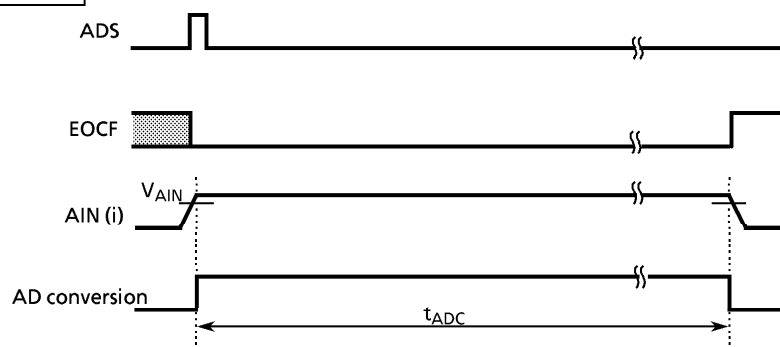
AD Pin Mode

AC Characteristics

 $(V_{SS} = 0\text{ V}, T_{opr} = -40\text{ to }85^{\circ}\text{C})$

Parameter	Symbol	Conditions	V _{DD}	Min	Typ.	Max	Unit
Machine cycle time	t _{cy}	In NORMAL 1, 2 mode	4.5 to	0.5	–	10	μs
		In IDLE 1, 2 mode	5.5 V				
		In SLOW mode	2.7 to	117.6	–	133.3	
		In SLEEP mode	5.5 V				
High level clock pulse width	t _{WCH}	For external clock operation (XIN input), f _c = 8 MHz	4.5 to 5.5 V	62.5	–	–	ns
Low level clock pulse width	t _{WCL}						
High level clock pulse width	t _{WSH}	For external clock operation (XTIN input), f _s = 32.768 kHz	2.7 to 5.5 V	14.7	–	–	μs
Low level clock pulse width	t _{WSL}						
AD conversion time	t _{ADC}	ADCCR bit 4 ; ACK = 0	–	–	49 tcy	–	ns
		ADCCR bit 4 ; ACK = 1	–	–	196 tcy	–	

Timing of AD Conversion

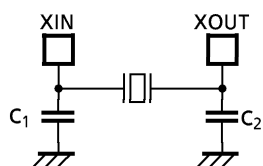


Note 1: During AD conversion, make the level of V_{AIN} stable.

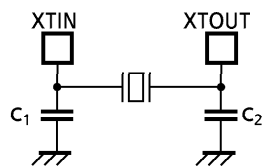
Note 2: $i = 17\text{ to }10, 07\text{ to }00$

Recommended Oscillating Conditions	(V _{SS} = 0 V, Topr = -40 to 85°C)
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Parameter	Oscillator	Oscillation Frequency	VDD	Recommended Oscillator	Recommended Constant	
					C ₁	C ₂
High-frequency oscillation	Ceramic resonator	8 MHz	4.5 to 5.5 V	KYOCERA KBR8.0M	30 pF	30 pF
		4 MHz	2.7 to 5.5 V	KYOCERA KBR4.0MS		
	Crystal oscillator	8 MHz	4.5 to 5.5 V	MURATA CSA4.00MG	20 pF	20 pF
		4 MHz	2.7 to 5.5 V	TOYOCOM 210B 8.0000		
Low-frequency oscillation	Crystal oscillator	8 MHz	4.5 to 5.5 V	TOYOCOM 204B 4.0000	15 pF	15 pF
		32.768 kHz	2.7 to 5.5 V	NDK MX-38T		



(1) High-frequency Oscillation



(2) Low-frequency Oscillation

Note 1: When it is used in high electrical field, an electrical shield of the package is recommended to retain normal operations.

Note 2: TOYAMA MURATA MFG. CO., LTD (JAPAN)

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>

Electrical Characteristics

(2) TMP87CM48

Absolute Maximum Ratings

(V_{SS} = 0 V)

Parameter	Symbol	Conditions	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 _{OUT}		– 0.3 to V _{DD} + 0.3	V
Output current (Per 1 pin)	I _{OUT1}	Ports P0, P1, P2, P4, P5, P6, P7, P8	3.2	mA
	I _{OUT2}	Port P3	30	
Output current (Total)	Σ I _{OUT1}	Ports P0, P1, P2, P4, P5, P6, P7, P8	120	mA
	Σ I _{OUT2}	Port P3	120	
Power dissipation	PD		350	mW
Soldering temperature (Time)	T _{sld}		260 (10 s)	°C
Storage temperature	T _{stg}		– 55 to 125	°C
Operating temperature	T _{opr}		– 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_{SS} = 0 V, T_{opr} = – 40 to 85°C)

Parameter	Symbol	Pins	Conditions		Min	Max	Unit
Supply voltage	V _{DD}		fc = 8 MHz	NORMAL1/2 modes	4.5	5.5	V
				IDLE1/2 modes			
			fc = 4.2 MHz	NORMAL1/2 modes	2.7		
				IDLE1/2 modes			
			fs = 32.768 kHz	SLOW mode	2.0		
				SLEEP mode			
	STOP mode						
Input high voltage	V _{IH1}	Except hysteresis input	V _{DD} ≥ 4.5 V		V _{DD} × 0.70	V _{DD}	V
	V _{IH2}	Hysteresis input			V _{DD} × 0.75		
	V _{IH3}				V _{DD} < 4.5 V		
Input low voltage	V _{IL1}	Except hysteresis input	V _{DD} ≥ 4.5 V		0	V _{DD} × 0.30	V
	V _{IL2}	Hysteresis input				V _{DD} × 0.25	
	V _{IL3}					V _{DD} < 4.5 V	
Clock frequency	fc	XIN, XOUT	V _{DD} = 4.5 to 5.5 V		0.4	8.0	MHz
			V _{DD} = 2.7 to 5.5 V			4.2	
	fs	XTIN, XTOUT			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: The condition of clock frequency is in NORMAL1/2 modes and IDLE1/2 modes.

DC Characteristics

(V_{SS} = 0 V, T_{opr} = -40 to 85°C)

Parameter	Symbol	Pins	Conditions	Min	Typ.	Max	Unit
Hysteresis voltage	V _{HS}	Hysteresis inputs	V _{DD} = 5.0 V	–	0.9	–	V
Input current	I _{IN1}	TEST	V _{DD} = 5.5 V V _{IN} = 5.5 V/0 V	–	–	± 2	μA
	I _{IN2}	Open drain ports, Tri-state ports					
	I _{IN3}	RESET, STOP					
Input resistance	R _{IN2}	RESET	V _{DD} = 5.0 V	100	220	450	kΩ
Output leakage current	I _{LO}	Sink open drain ports	V _{DD} = 5.5 V, V _{OUT} = 5.5 V	–	–	2	μA
		Tri-state ports	V _{DD} = 5.5 V, V _{OUT} = 5.5/0 V	–	–	± 2	
Output high voltage	V _{OH2}	Tri-state ports	V _{DD} = 4.5 V, I _{OH} = -0.7 mA	4.1	–	–	V
Output low voltage	V _{OL}	Except for XOUT and P3	V _{DD} = 4.5 V, I _{OL} = 1.6 mA	–	–	0.4	mA
Output low current	I _{OL3}	P3	V _{DD} = 4.5 V, V _{OL} = 1.0 V	–	20	–	mA
Supply current in NORMAL 1, 2 modes	I _{DD}		V _{DD} = 5.5 V V _{IN} = 5.3 V/0.2 V f _c = 8 MHz f _s = 32.768 kHz	–	4.75	6.4	mA
Supply current in IDLE 1, 2 modes			V _{DD} = 3.0 V, V _{IN} = 2.8 V/0.2 V V _{IN} = 4.19 MHz f _s = 32.768 kHz	–	3.25	4.65	mA
Supply current in NORMAL 1, 2 modes				–	1.85	3.2	mA
Supply current in IDLE 1, 2 modes			V _{DD} = 3.0 V V _{IN} = 2.8 V/0.2 V f _s = 32.768 kHz	–	1.35	2.2	mA
Supply current in SLOW mode				–	20	30	μA
Supply current in SLEEP mode			V _{DD} = 5.5 V V _{IN} = 5.3 V/0.2 V	–	10	20	μA
Supply current in STOP mode				–	0.5	10	μA
Supply current in STOP mode				–	0.5	10	μA

Note 1: Typical values show those at T_{opr} = 25°CNote 2: Input Current I_{IN1}, I_{IN3}: The current through resistor is not included, when the input resistor (pull-up or pull-down) is contained.Note 3: I_{DD} except for I_{REF}.

AD Conversion Characteristics

(V_{SS} = 0 V, V_{DD} = 2.7 to 5.5 V, T_{opr} = -40 to 85°C)

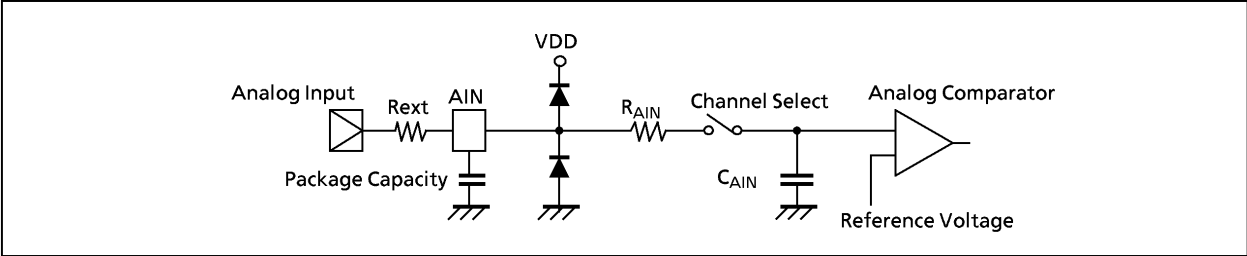
Parameter	Symbol	Conditions	Min	Typ.	Max			Unit
					ADCDR1	ADCDR2		
						ACK = 0	ACK = 1	
Analog reference voltage	V _{AREF}	V _{AREF} – V _{ASS} ≥ 2.5 V	2.7	–	V _{DD}			V
	V _{ASS}		V _{SS}	–	1.5			
Analog input voltage	V _{AIN}		V _{ASS}	–	V _{AREF}			V
Analog supply current	I _{REF}	V _{AREF} = 5.5 V, V _{ASS} = 0.0 V	–	0.5	1.2			mA
Nonlinearity error		V _{DD} = 5.0, V _{SS} = 0.0 V V _{AREF} = 5.000 V V _{ASS} = 0.000 V	–	–	± 1	± 3	± 2	LSB
Zero point error		or V _{DD} = 2.7, V _{SS} = 0.0 V V _{AREF} = 2.700 V V _{ASS} = 0.000 V	–	–	± 1	± 3	± 2	
Full scale error			–	–	± 1	± 3	± 2	
Total error			–	–	± 2	± 6	± 4	

Note 1: ΔV_{AREF} = V_{AREF} - V_{ASS}ADCDR1: 8 bits - AD conversion result (1LSB = ΔV_{AREF}/256)ADCDR2: 10 bits - AD conversion result (1LSB = ΔV_{AREF}/1024)

Note 2: Quantizing error is not contained in those errors.

AD Input Characteristics		(Topr = - 40 to 85°C)				
Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Input impedance (Resistance)	RAIN	VDD = 5.0 V, Conversion time 23 μs (fc = 8 MHz)	–	5	–	kΩ
		VDD = 2.7 V, Conversion time 43.8 μs (fc = 4.2 MHz)	–	20	–	
Input impedance (Capacity)	CAIN	VDD = 5.0 V, Conversion time 23 μs (fc = 8 MHz)	–	7	–	pF
		VDD = 2.7 V, Conversion time 43.8 μs (fc = 4.2 MHz)	–	7	–	
Source impedance	Rext	VDD = 5.0 V, Conversion time 23 μs (fc = 8 MHz)	–	–	5	kΩ
		VDD = 2.7 V, Conversion time 43.8 μs (fc = 4.2 MHz)	–	–	5	

Note: Input current (output leak current) error (Max ± 2 μA) and quantizing error (Max ± 4LSB) for AD are contained.



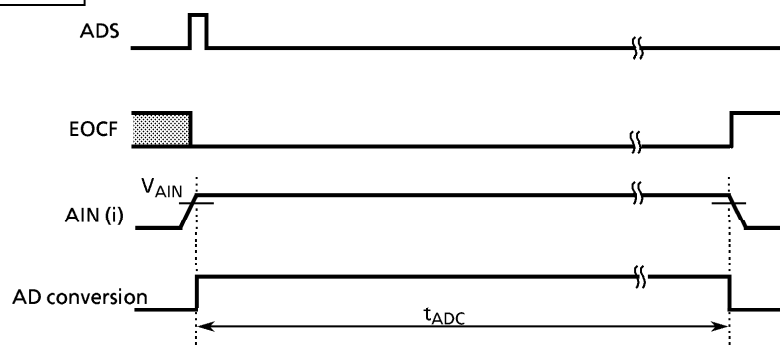
AD Pin Mode

AC Characteristics

 $(V_{SS} = 0\text{ V}, T_{opr} = -40\text{ to }85^{\circ}\text{C})$

Parameter	Symbol	Conditions	V _{DD}	Min	Typ.	Max	Unit
Machine cycle time	t _{cy}	In NORMAL 1, 2 mode	4.5 to	0.5	–	10	μs
		In IDLE 1, 2 mode	5.5 V				
		In SLOW mode	2.7 to	117.6	–	133.3	
		In SLEEP mode	5.5 V				
High level clock pulse width	t _{WCH}	For external clock operation (XIN input), f _c = 8 MHz	4.5 to 5.5 V	62.5	–	–	ns
Low level clock pulse width	t _{WCL}						
High level clock pulse width	t _{WSH}	For external clock operation (XTIN input), f _s = 32.768 kHz	2.7 to 5.5 V	14.7	–	–	μs
Low level clock pulse width	t _{WSL}						
AD conversion time	t _{ADC}	ADCCR bit 4; ACK = 0	–	–	49 t _{cy}	–	ns
		ADCCR bit 4; ACK = 1	–	–	196 t _{cy}	–	

Timing of AD Conversion

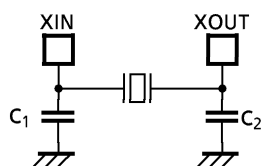


Note 1: During AD conversion, make the level of V_{AIN} stable.

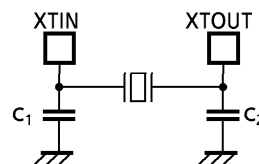
Note 2: $i = 17\text{ to }10, 07\text{ to }00$

Recommended Oscillating Conditions ($V_{SS} = 0\text{ V}$, $T_{opr} = -40\text{ to }85^{\circ}\text{C}$)

Parameter	Oscillator	Oscillation Frequency	VDD	Recommended Oscillator	Recommended Constant	
					C ₁	C ₂
High-frequency Oscillation	Ceramic Resonator	8 MHz	4.5 to 5.5 V	KYOCERA KBR8.0M	30 pF	30 pF
		4 MHz	2.7 to 5.5 V	KYOCERA KBR4.0MS MURATA CSA4.00MG		
	Crystal Oscillator	8 MHz	4.5 to 5.5 V	TOYOCOM 210B 8.0000	20 pF	20 pF
		4 MHz	2.7 to 5.5 V	TOYOCOM 204B 4.0000		
Low-frequency Oscillation	Crystal Oscillator	32.768 kHz	2.7 to 5.5 V	NDK MX-38T	15 pF	15 pF



(1) High-frequency Oscillation



(2) Low-frequency Oscillation

Note 1: When it is used in high electrical field, an electrical shield of the package is recommended to retain normal operations.

Note 2: TOYAMA MURATA MFG. CO., LTD (JAPAN)

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>