

To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: <http://www.renesas.com>

April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (<http://www.renesas.com>)

Send any inquiries to <http://www.renesas.com/inquiry>.

Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.
2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
7. Renesas Electronics products are classified according to the following three quality grades: “Standard”, “High Quality”, and “Specific”. The recommended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as “Specific” without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as “Specific” or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is “Standard” unless otherwise expressly specified in a Renesas Electronics data sheets or data books, etc.
 - “Standard”: Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.
 - “High Quality”: Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.
 - “Specific”: Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.
8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

4 BIT SINGLE-CHIP MICROCONTROLLER

The μ PD17107(A1) is a tiny microcontroller consisting of 1K-byte (512×16 bits) ROM, 16×4 bit RAM, and 11 input/output ports.

The 17K architecture, which uses general registers to directly manipulate data memory, is employed for effective programming. Every instruction is 1 word long, consisting of 16 bits.

FEATURES

- Program memory (ROM) : 1K bytes (512×16 bits)
- Data memory (RAM) : 16×4 bits
- Input/output ports : 11 ports (including three N-ch open-drain outputs)
- Instruction execution time : $128 \mu\text{s}$ (at $f_{\text{CC}} = 62.5$ KHz) to $8 \mu\text{s}$ (at $f_{\text{CC}} = 1$ MHz)
- Stack level : 1
- A standby function (with the HALT and STOP modes)
- Data memory can retain data on low voltage (2.0 V at minimum).
- An RC oscillator^{Note} for the system clock: With a built-in capacitor (only a resistor is required to be connected.)
- Supply voltage: $V_{\text{DD}} = 2.5$ to 6.0 V (at $f_{\text{CC}} = 250$ kHz)
 $V_{\text{DD}} = 4.5$ to 6.0 V (at $f_{\text{CC}} = 1$ MHz)
- Operating ambient temperature: $T_{\text{A}} = -40$ to $+110$ °C

Note The capacitor for RC oscillator is contained in the μ PD17107(A1).

APPLICATIONS

Electronic units for automobiles, and suchlike

ORDERING INFORMATION

Part number	Package	Quality grade
μ PD17107CX(A1)-xxx	16-pin plastic DIP (300 mil)	Special
μ PD17107GS(A1)-xxx	16-pin plastic SOP (300 mil)	Special

Remark xxx : ROM code number

Please refer to "Quality grade on NEC Semiconductor Devices" (Document number IEI-1209) published by NEC Corporation to know the specification of quality grade on the devices and its recommended applications.

Each device has a different capacity of a built-in capacitor for system clock oscillation of the μ PD17107(A1). This causes the frequency deviation within about 30% even though the connected resistors have the same value. Use the μ PD17103(A1) (ceramic based oscillation) when the deviation is a critical problem.

The information in this document is subject to change without notice.

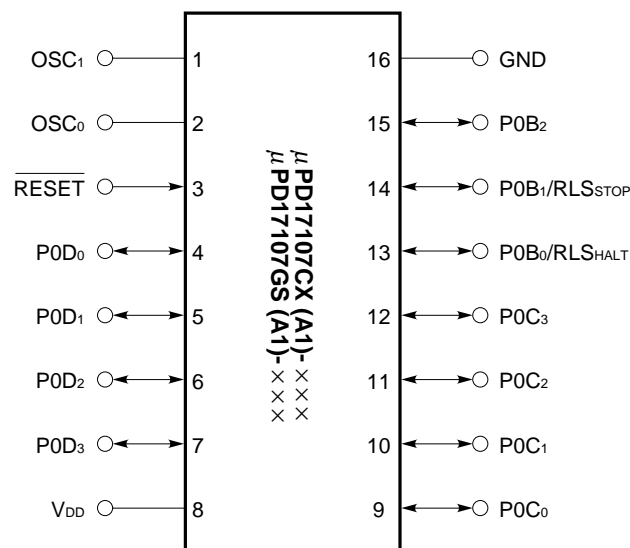
FUNCTIONS

Item	Function
ROM	1K byte (512 × 16 bits)
RAM	16 × 4 bits
Stack	1 level
Number of I/O ports	11 (N-ch open-drain output ports: 3)
System clock (f _{cc})	RC oscillation
Instruction execution time	128 μs (f _{cc} = 62.5 kHz) to 8 μs (f _{cc} = 1 MHz)
Standby function	HALT/STOP
Operating supply voltage	2.5 to 6.0 V (at f _{cc} = 62.5 kHz to 250 kHz) 4.5 to 6.0 V (at f _{cc} = 62.5 kHz to 1 MHz)
Package	16-pin plastic DIP (300 mil) 16-pin plastic SOP (300 mil)
One-time PROM	μPD17P107 (The quality grade is "Standard," not "A1." Operating ambient temperature: T _A = -40 to +85 °C)

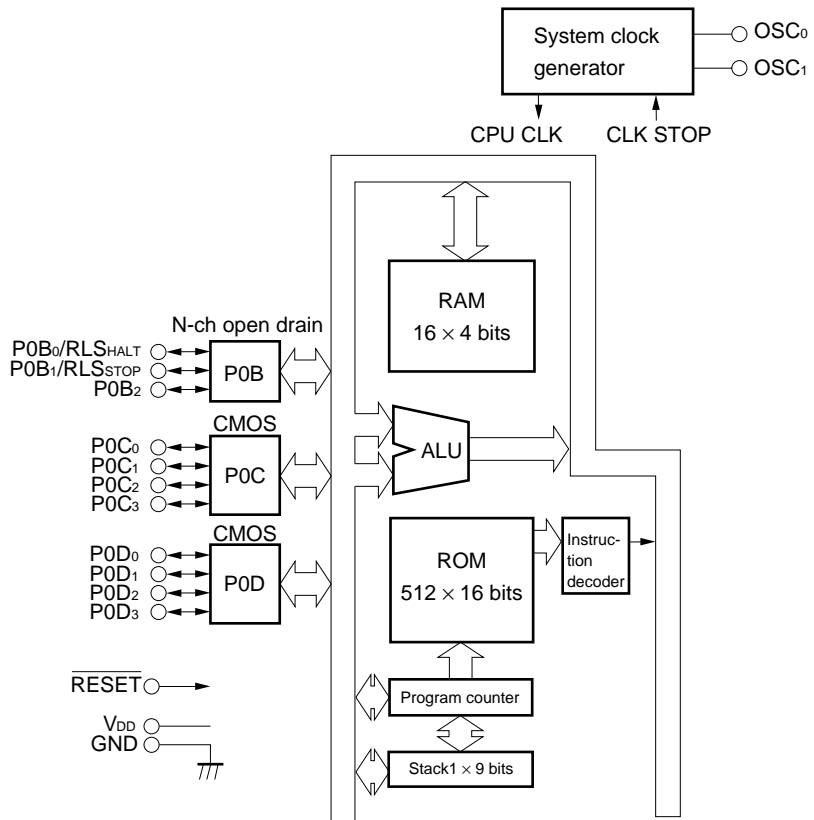
Caution Although a PROM product is highly compatible with a masked ROM product in respect of functions, they differ in internal ROM circuits and part of electrical characteristics. Before changing the PROM product to the masked ROM product in an application system, evaluate the system carefully using the masked ROM product.

PIN CONFIGURATION (TOP VIEW)

16-pin plastic DIP
16-pin plastic SOP



BLOCK DIAGRAM



PIN FUNCTIONS

Pin functions

- Port pins

Pin	I/O	Function	Reset
P0B ₀ /RLS _{HALT}	I/O	For releasing the HALT mode	<ul style="list-style-type: none"> • Open-drain: High impedance (input mode) • With pull-up resistor selected: High level (input mode)
P0B ₁ /RLS _{STOP}		For releasing the STOP mode	
P0B ₂		<ul style="list-style-type: none"> • N-ch open-drain 3-bit I/O port (port 0B) • A built-in pull-up resistor can be connected with a mask option bit by bit. • This open-drain port has a withstand voltage of 9 V. 	
P0C ₀ -P0C ₃	I/O	CMOS (push-pull) 4-bit I/O port (port 0C)	High impedance (input mode)
P0D ₀ -P0D ₃	I/O	CMOS (push-pull) 4-bit I/O port (port 0D)	High impedance (input mode)

- Non-port pins

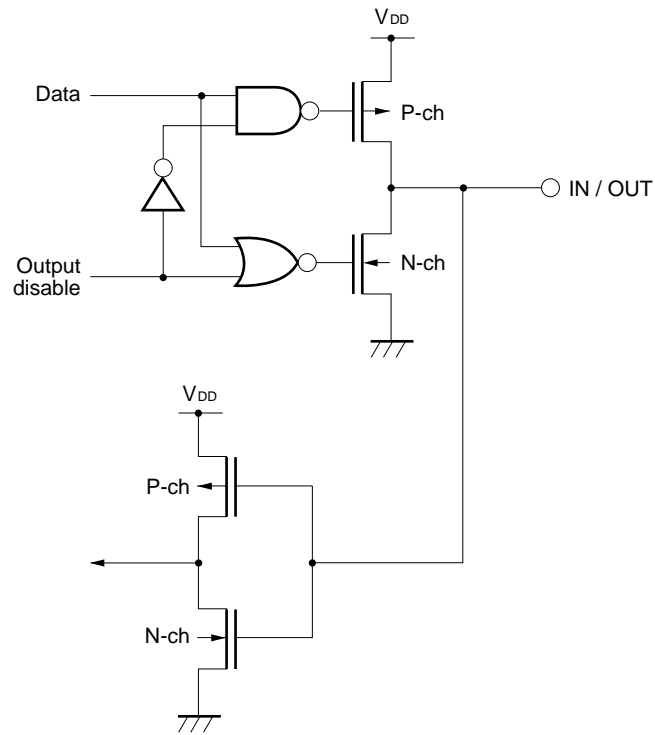
Pin	I/O	Function
$\overline{\text{RESET}}$	Input	<ul style="list-style-type: none"> • Reset input pin • A built-in pull-up resistor can be connected with a mask option.
V _{DD}	–	Positive power supply pin
GND	–	GND pin
OSC ₀ , OSC ₁	–	Pins to be connected to the resistor for system clock oscillation

I/O: Input/output

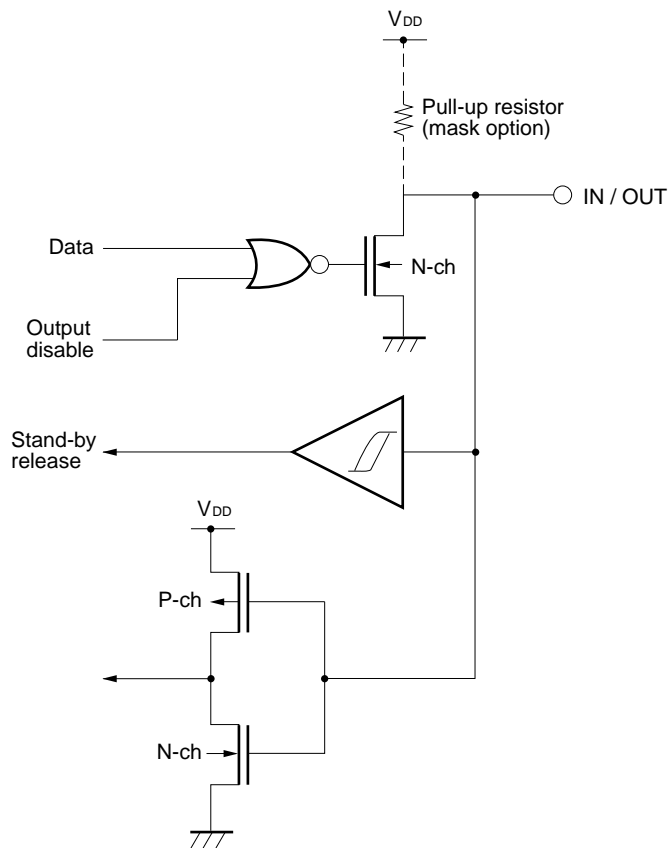
Equivalent input/output circuits

Below are simplified diagrams of the equivalent input/output circuits.

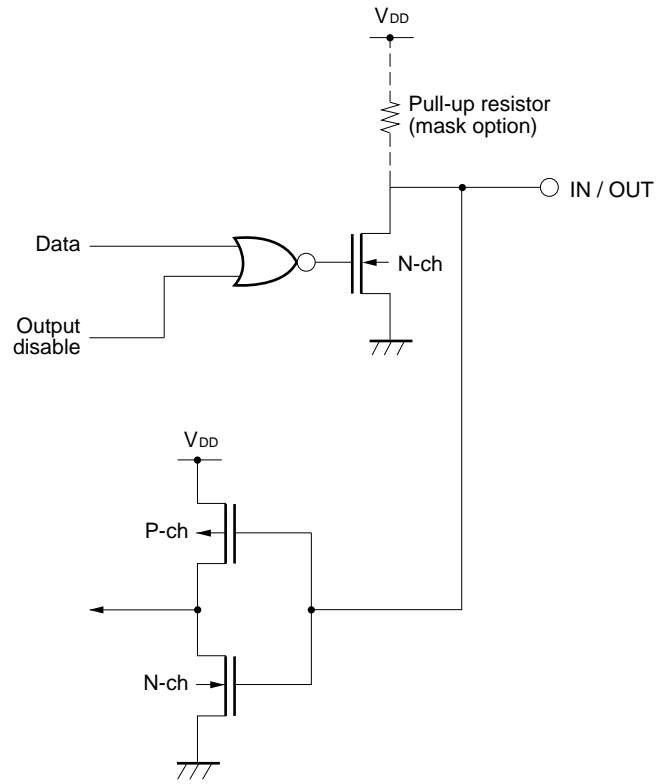
(1) P0C and P0D



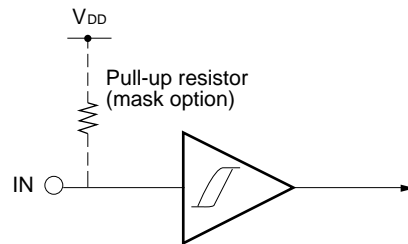
(2) P0B₀ and P0B₁



(3) P0B₂



(4) RESET



HANDLING UNUSED PINS

When connecting unused pins, the following conditions and handling are recommended:

Pin			Recommended conditions and handling	
			Internal	External
Port	Input mode	P0C, P0D	—	Connect each pin to V _{DD} or to ground through a resistor ^{Note} .
		P0B	Pull-up resistors that can be specified by the mask option are not incorporated.	
	Output mode	P0C, P0D (CMOS port)	—	Leave open.
		P0B (N-ch open-drain port)	Outputs low level without pull-up resistors that can be specified with the mask option.	
			Outputs high level with pull-up resistors that can be specified with the mask option.	

Note When a pin is pulled up (connected to V_{DD} through a resistor) or pulled down (connected to ground through a resistor) outside the chip, take the driving capacity and maximum current consumption of a port into consideration. When using high-resistance pull-up or pull-down resistors, apply appropriate countermeasures to ensure that noise is not attracted by the resistors. Although the optimum pull-up or pull-down resistor varies with the application circuit, in general a resistor of 10 to 100 kilohms is suitable.

Caution To fix the output level of a pin, it is recommended that the level be specified repeatedly within a loop in a program.

NOTES ON USE OF THE RESET PIN

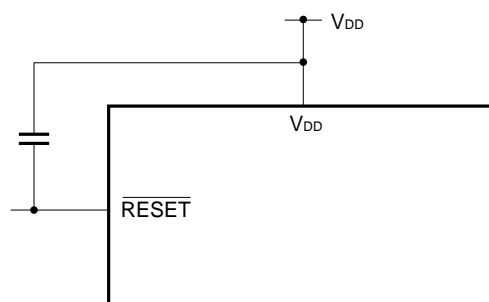
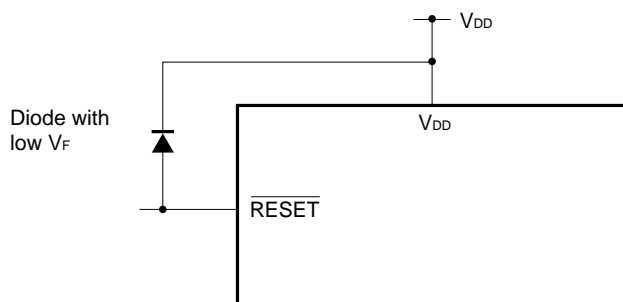
The RESET pin has the test mode selecting function for testing the internal operation of the μPD17107(A1) (IC test), besides the functions shown in "PIN FUNCTIONS."

Applying a voltage exceeding V_{DD} to the RESET pin causes the μPD17107(A1) to enter the test mode. When noise exceeding V_{DD} comes in during normal operation, the device is switched to the test mode.

For example, if the wiring from the RESET pin is too long, noise may be induced on the wiring, causing this mode switching.

When installing the wiring, lay the wiring in such a way that noise is suppressed as much as possible. If noise yet arises, use an external part to suppress it as shown below.

- Connect a diode with low V_F between the pin and V_{DD}.
- Connect a capacitor between the pin and V_{DD}.



CONTENTS

1. PROGRAM COUNTER (PC)	10
1.1 CONFIGURATION OF THE PROGRAM COUNTER (PC)	10
1.2 FUNCTIONS OF THE PROGRAM COUNTER (PC)	10
2. STACK	11
3. PROGRAM MEMORY (ROM)	12
4. DATA MEMORY (RAM)	13
4.1 CONFIGURATION OF THE DATA MEMORY (RAM)	13
4.1.1 Functions of the General Data Memory	13
4.1.2 Functions of the General Register	13
4.1.3 Functions of the Port Register	13
4.1.4 Functions of the System Register	14
5. ALU BLOCK	17
5.1 ALU BLOCK CONFIGURATION	17
5.2 FUNCTIONS OF THE ALU BLOCK	17
5.2.1 Functions of the ALU	17
5.2.2 Functions of Temporary Registers A and B	22
5.2.3 Functions of the Status Flip-Flop	22
5.2.4 Performing Operations in 4-Bit Binary	23
5.2.5 Performing Operations in BCD	23
5.2.6 Performing Operations in the ALU Block	24
5.3 ARITHMETIC OPERATIONS (ADDITION AND SUBTRACTION IN 4-BIT BINARY AND BCD) .	25
5.3.1 Addition and Subtraction When CMP = 0 and BCD = 0	25
5.3.2 Addition and Subtraction When CMP = 1 and BCD = 0	25
5.3.3 Addition and Subtraction When CMP = 0 and BCD = 1	26
5.3.4 Addition and Subtraction When CMP = 1 and BCD = 1	26
5.3.5 Warnings Concerning Use of Arithmetic Operations	27
5.4 LOGICAL OPERATIONS	27
5.5 BIT EVALUATIONS	28
5.5.1 TRUE (1) Bit Evaluation	28
5.5.2 FALSE (0) Bit Evaluation	29
5.6 COMPARISON EVALUATIONS	29
5.6.1 "Equal" Evaluation	30
5.6.2 "Not Equal" Evaluation	30
5.6.3 "Greater Than or Equal" Evaluation	31
5.6.4 "Less Than" Evaluation	31
5.7 ROTATIONS	32
5.7.1 Rotation to the Right	32
5.7.2 Rotation to the Left	33

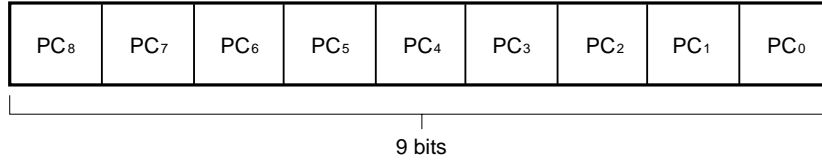
6. PORTS	34
6.1 PORT 0B (P0B ₀ /RLS _{HALT} , P0B ₁ /RLS _{STOP} , P0B ₂)	34
6.2 PORT 0C (P0C ₀ TO P0C ₃).....	34
6.3 PORT 0D (P0D ₀ TO P0D ₃).....	34
6.4 NOTES ON MANIPULATING PORT REGISTERS	36
7. STANDBY FUNCTIONS	37
7.1 HALT MODE	37
7.2 STOP MODE	37
7.3 SETTING AND RELEASING THE STANDBY MODES	37
7.4 HARDWARE STATUSES IN STANDBY MODE	38
7.5 TIMING FOR RELEASING THE STANDBY MODES	38
8. RESET FUNCTION	40
8.1 RESET FUNCTION	40
9. RESERVED WORDS USED IN ASSEMBLY LANGUAGE	41
9.1 MASK-OPTION PSEUDO INSTRUCTIONS	41
9.1.1 OPTION and ENDOP Pseudo Instructions	41
9.1.2 Mask-Option Definition Pseudo Instructions	41
9.2 RESERVED SYMBOLS	43
10. INSTRUCTION SET	44
10.1 INSTRUCTION SET LIST	44
10.2 INSTRUCTIONS	45
10.3 ASSEMBLER (AS17K) BUILT-IN MACRO INSTRUCTIONS.....	47
11. ELECTRICAL CHARACTERISTICS	48
12. CHARACTERISTIC CURVES (REFERENCE)	52
13. PACKAGE DRAWINGS	54
14. RECOMMENDED SOLDERING CONDITIONS	58
APPENDIX DEVELOPMENT TOOLS	59

1. PROGRAM COUNTER (PC)

1.1 CONFIGURATION OF THE PROGRAM COUNTER (PC)

As shown in Fig. 1-1, the program counter is a 9-bit binary counter.

Fig. 1-1 Program Counter



1.2 FUNCTIONS OF THE PROGRAM COUNTER (PC)

The program counter specifies the address of a program memory (ROM) or a program.

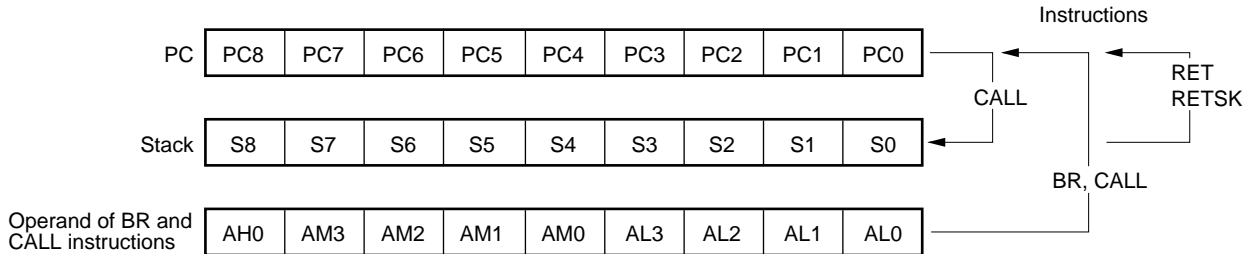
Usually, every time an instruction is executed, the program counter is incremented by one. When a branch instruction (BR), a subroutine call instruction (CALL), or a return instruction (RET) is executed, the address specified in the operand is loaded in the PC. Then the instruction in the address is executed. When a skip instruction is executed, the address of the instruction next to the skip instruction is specified irrespective of the contents of the skip instruction. If the skip conditions are satisfied, the instruction next to the skip instruction is regarded as a No Operation (NOP) instruction. So, the NOP instruction is executed and the address of the next instruction is specified.

2. STACK

Stack of the μPD17107(A1) is a register in which the return address of a program is saved when a subroutine call instruction is executed. One level of address stack is provided.

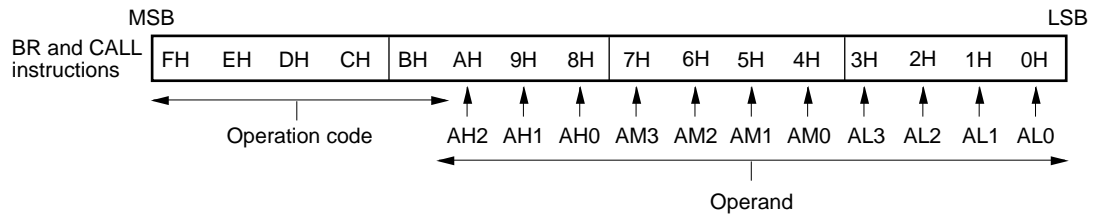
Fig. 2-1 shows the relationship between the PC, the stack, and the operand of BR and CALL instructions.

Fig. 2-1 Relationship between the PC, the Stack, and the Operand of BR and CALL Instructions



In Fig. 2-1, AHn, AMn, and ALn (0 ≤ n ≤ 3) indicate bit positions in a 16-bit instruction as follows:

Fig. 2-2 Configuration of a 16-Bit Instruction



When the assembler is not used and a BR or CALL instruction is used, AH2 and AH1 must be set to 0. Reset input clears all bits of the program counter to 0.

3. PROGRAM MEMORY (ROM)

Fig. 3-1 shows the program memory (ROM) configuration.

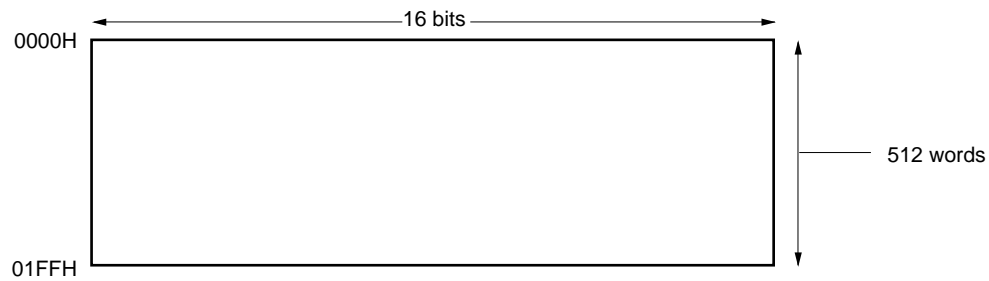
As shown in the figure, the program memory has 512 words by 16 bits.

The program memory has been addressed in units of 16 bits. The addresses 0000H to 01FFH are specified by the program counter (PC).

Every instruction is a 1 word long, consisting of 16 bits. One instruction can therefore be stored at one address in program memory.

Address 0000H is used as a reset start address.

Fig. 3-1 Program Memory Map



4. DATA MEMORY (RAM)

The data memory (RAM) stores data of arithmetic/logic and control operations. Data can be always written to or read from it by means of instructions.

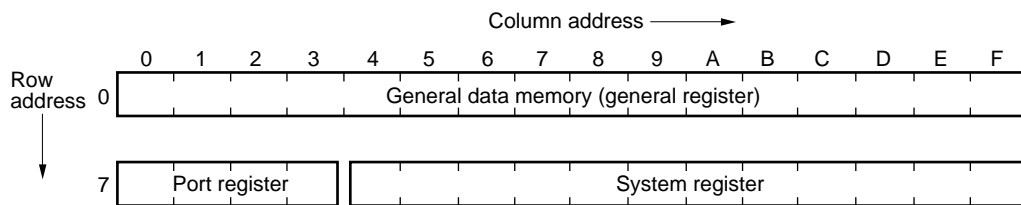
4.1 CONFIGURATION OF THE DATA MEMORY (RAM)

Fig. 4-1 shows the configuration of the data memory (RAM).

The data memory is configured in units of four bits, or “one nibble,” and an address is assigned to each four bits of data. The high-order three bits are called the “row address,” and the low-order four bits are called the “column address.”

According to its functions, the data memory is divided into three blocks as shown below: General data memory, port register, and system register.

Fig. 4-1 Data Memory Map



4.1.1 Functions of the General Data Memory

The general data memory is a part of the data memory from which the system register (SYSREG) and port register are excluded. By executing a data memory manipulation instruction, a four-bit arithmetic operation and comparison, evaluation, and transfer between data on data memory and any immediate data can be executed with a single operation.

4.1.2 Functions of the General Register

The general register indicates any identical row address (16 nibbles) in the data memory specified in the register pointer (RP) in the system register. Since the μPD17107(A1) register pointer is always set to 0, the general data memory is also used as a general register. The general register can operate or transfer data to and from the data memory.

4.1.3 Functions of the Port Register

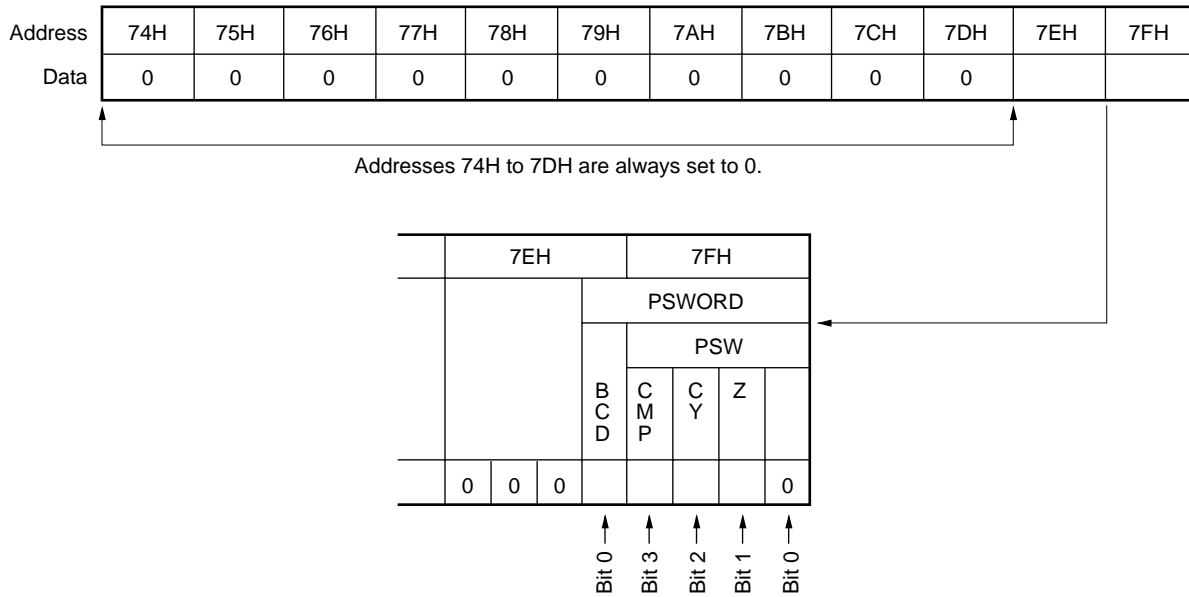
The port register is used to set output data or to read the input data of input/output ports.

Once data is written to the port register corresponding to a port, the port is set to output mode and outputs the data unless another data is rewritten (the output mode is maintained until the port register is reset). Whenever a read instruction is executed for a port register, the read data indicates the states of the pins, not the value of the port register, regardless of whether the pins are in the input or output mode.

4.1.4 Functions of the System Register

The system register controls the CPU. The program status word (PSWORD) is the only system register in the μPD17107(A1).

Fig. 4-2 System Register Map

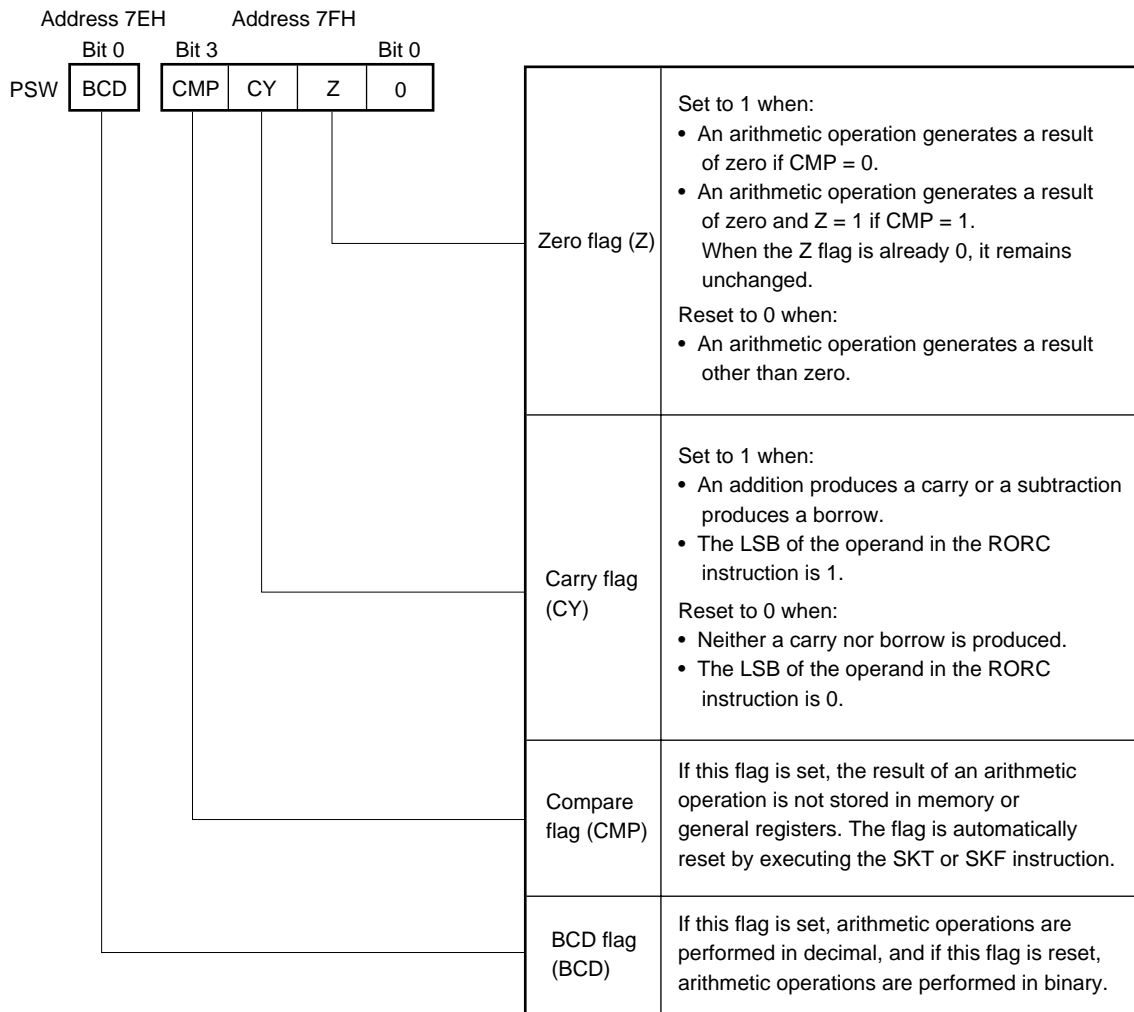


Bit 0 at address 7EH and all four bits at address 7FH (PSW) are assigned to the program status word.

The BCD flag is mapped in bit 0 at address 7EH, the CMP flag is mapped in bit 3 at address 7FH, the CY flag is mapped in bit 2, and the Z flag is mapped in bit 1 at address 7FH.

The high-order three bits at address 7EH and bit 0 at address 7FH are always set to 0.

Fig. 4-3 Configuration of the Program Status Word



Comparison instructions (SKE, SKNE, SKGE, or SKLT) do not change the state of the CY flag, but an arithmetic operation may affect the CY flag according to the result even if the CMP flag is set.

Each bit of the program status word is initialized to 0 when a reset signal is applied.

The Z flag in the program status word changes according to the set value of the CMP flag as listed in Table 4-1.

Table 4-1 Change in Z Flag

Conditions	CMP = 0	CMP = 1
When arithmetic operation results in 0	$Z \leftarrow 1$	Z flag does not change
When arithmetic operation results in a non-zero value	$Z \leftarrow 0$	$Z \leftarrow 0$

While CMP is 1, if an arithmetic operation results in 0H when the value of the Z flag is 1, the Z flag does not change. If an arithmetic operation results in other than 0H, the Z flag is reset to 0 and remains intact even when a second arithmetic operation results in 0H.

After the CMP and Z flags are set to 1, subtraction and comparison are performed several times. Then, if the Z flag still indicates 1, all of the comparison operations showed a match, resulting in 0. If the Z flag is 0 after the comparison operations, a mismatch occurred in at least one comparison operation.

Example of 12-bit data comparison

; Is the 12-bit data stored in M001, M002, and M003 equal to 456H?

CMP456:

```

SET2  CMP, Z
SUB   M001, #4 ; Stores the data in M001, M002, and M003.
SUB   M002, #5 ; Does not damaged the data.
SUB   M003, #6 ;
; CLR1 CMP
SKT1  Z        ; Resets CMP automatically when the bit test instruction is executed.
BR    DIFFER  ; ≠ 456H
BR    AGREE   ; = 456H
    
```

5. ALU BLOCK

The ALU is used for performing arithmetic operations, logical operations, bit evaluations, comparison evaluations, and rotations on 4-bit data.

5.1 ALU BLOCK CONFIGURATION

Fig. 5-1 shows the configuration of the ALU block.

As shown in Fig. 5-1, the ALU block consists of the main 4-bit data processor, temporary registers A and B, the status flip-flop for controlling the status of the ALU, and the decimal conversion circuit for use during arithmetic operations in BCD.

As shown in Fig. 5-1, the status flip-flop consists of the following flags: Zero flag flip-flop, carry flag flip-flop, compare flag flip-flop, and the BCD flag flip-flop.

Each flag in the status flip-flop corresponds directly to a flag in the program status word (PSWORD: addresses 7EH, 7FH) located in the system register. The flags in the program status word are the following: Zero flag (Z), carry flag (CY), compare flag (CMP), and the BCD flag (BCD).

5.2 FUNCTIONS OF THE ALU BLOCK

Arithmetic operations, logical operations, bit evaluations, comparison evaluations, and rotations are performed using the instructions in the ALU block. Table 5-1 lists each arithmetic/logical instruction, evaluation instruction, and rotation instruction.

By using the instructions listed in Table 5-1, 4-bit arithmetic/logical operations, evaluations and rotations can be performed in a single instruction. Arithmetic operations in BCD can also be performed on one place in a single instruction.

5.2.1 Functions of the ALU

The arithmetic operations consist of addition and subtraction. Arithmetic operations can be performed on the contents of the general register and data memory or on immediate data and the contents of data memory. Operations in binary are performed on four bits of data and operations in BCD are performed on one place.

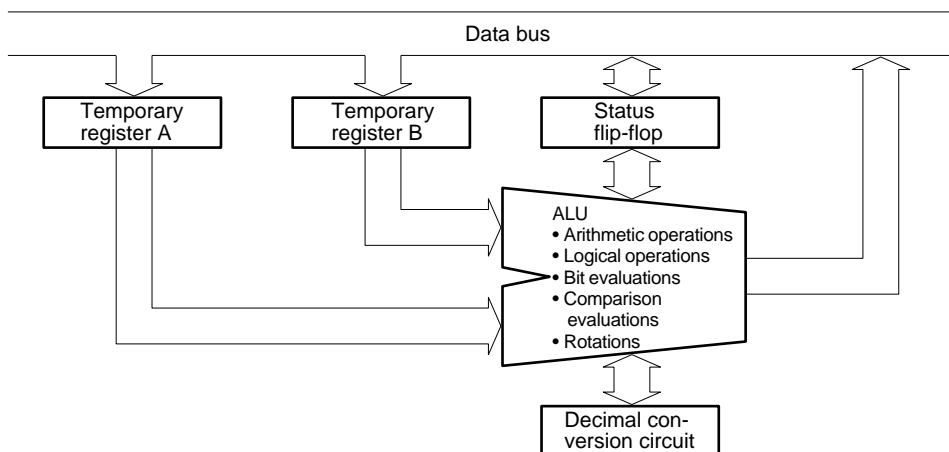
Logical operations include ANDing, ORing, and XORing. Their operands can be general register contents and data memory contents, or data memory contents and immediate data.

Bit evaluation is used to determine whether bits in 4-bit data in data memory are 0 or 1.

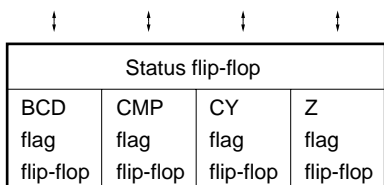
Comparison evaluation is used to compare contents of data memory with immediate data. It is used to determine whether one value is equal to or greater than the other, less than the other, or if both values are equal or not equal.

Rotation is used to shift 4-bit data in the general register one bit in the direction of its least significant bit (rotation to the right).

Fig. 5-1 Configuration of the ALU Block



Address	7EH	7FH			
Name	Program status word (PSWORD)				
Bit	b ₀	b ₃	b ₂	b ₁	b ₀
Flag	BCD	CMP	CY	Z	0



Function outline
Indicates when the result of an arithmetic operation is 0.
Stores the borrow or carry from an arithmetic operation.
Used to indicate whether to store the result of an arithmetic operation.
Used to indicate whether to perform BCD correction for arithmetic operations.

[MEMO]

Table 5-1 List of ALU Instructions (1/2)

ALU function		Instruction	Operation	Explanation
Arithmetic operations	Addition	ADD r, m	$(r) \leftarrow (r) + (m)$	Adds contents of general register and data memory. Result is stored in general register.
		ADD m, #n4	$(m) \leftarrow (m) + n4$	Adds immediate data to contents of data memory. Result is stored in data memory.
		ADDC r, m	$(r) \leftarrow (r) + (m) + CY$	Adds contents of general register, data memory and carry flag. Result is stored in general register.
		ADDC m, #n4	$(m) \leftarrow (m) + n4 + CY$	Adds immediate data, contents of data memory and carry flag. Result is stored in data memory.
	Subtraction	SUB r, m	$(r) \leftarrow (r) - (m)$	Subtracts contents of data memory from contents of general register. Result is stored in general register.
		SUB m, #n4	$(m) \leftarrow (m) - n4$	Subtracts immediate data from data memory. Result is stored in data memory.
		SUBC r, m	$(r) \leftarrow (r) - (m) - CY$	Subtracts contents of data memory and carry flag from contents of general register. Result is stored in general register.
		SUBC m, #n4	$(m) \leftarrow (m) - n4 - CY$	Subtracts immediate data and carry flag from data memory. Result is stored in data memory.
Logical operations	Logical OR	OR r, m	$(r) \leftarrow (r) \vee (m)$	OR operation is performed on contents of general register and data memory. Result is stored in general register.
		OR m, #n4	$(m) \leftarrow (m) \vee n4$	OR operation is performed on immediate data and contents of data memory. Result is stored in data memory.
	Logical AND	AND r, m	$(r) \leftarrow (r) \wedge (m)$	AND operation is performed on contents of general register and data memory. Result is stored in general register.
		AND m, #n4	$(m) \leftarrow (m) \wedge n4$	AND operation is performed on immediate data and contents of data memory. Result is stored in data memory.
	Logical XOR	XOR r, m	$(r) \leftarrow (r) \nabla (m)$	XOR operation is performed on contents of general register and data memory. Result is stored in general register.
		XOR m, #n4	$(m) \leftarrow (m) \nabla n4$	XOR operation is performed on immediate data and contents of data memory. Result is stored in data memory.
Bit evaluation	True	SKT m, #n	$CMP \leftarrow 0$, if $(m) \wedge n = n$, then skip	Skips next instruction if all bits in data memory specified by n are TRUE (1). Result is not stored.
	False	SKF m, #n	$CMP \leftarrow 0$, if $(m) \wedge n = 0$, then skip	Skips next instruction if all bits in data memory specified by n are FALSE (0). Result is not stored.
Comparison evaluation	Equal	SKE m, #n4	$(m) - n4$, skip if zero	Skips next instruction if immediate data equals contents of data memory. Result is not stored.
	Not equal	SKNE m, #n4	$(m) - n4$, skip if not zero	Skips next instruction if immediate data is not equal to contents of data memory. Result is not stored.
	\geq	SKGE m, #n4	$(m) - n4$, skip if not borrow	Skips next instruction if contents of data memory is greater than or equal to immediate data. Result is not stored.
	$<$	SKLT m, #n4	$(m) - n4$, skip if borrow	Skips next instruction if contents of data memory is less than immediate data. Result is not stored.
Rotation	Rotate to the right	RORC r	$\rightarrow (CY) \rightarrow (r)_{b3} \rightarrow (r)_{b2} \rightarrow (r)_{b1} \rightarrow (r)_{b0}$	Rotate contents of the general register along with the CY flag to the right. Result is stored in general register.

Table 5-1 List of ALU Instructions (2/2)

ALU function	Operation depending on the program status word (PSWORD)																										
Arithmetic operation	<table border="1" data-bbox="477 359 1403 737"> <thead> <tr> <th data-bbox="477 359 626 436">Value in BCD flag</th> <th data-bbox="626 359 776 436">Value in CMP flag</th> <th data-bbox="776 359 967 436">Operation</th> <th data-bbox="967 359 1062 436">CY flag</th> <th data-bbox="1062 359 1403 436">Z flag</th> </tr> </thead> <tbody> <tr> <td data-bbox="477 436 626 514">0</td> <td data-bbox="626 436 776 514">0</td> <td data-bbox="776 436 967 514">Store result of binary operation</td> <td data-bbox="967 436 1062 737" rowspan="4">Set (1) when carry or borrow is generated, otherwise reset (0).</td> <td data-bbox="1062 436 1403 514">Set (1) when result of operation is 0000B, otherwise reset (0).</td> </tr> <tr> <td data-bbox="477 514 626 592">0</td> <td data-bbox="626 514 776 592">1</td> <td data-bbox="776 514 967 592">Do not store result of binary operation</td> <td data-bbox="1062 514 1403 592">Status maintained when result of operation is 0000B, otherwise reset (0).</td> </tr> <tr> <td data-bbox="477 592 626 669">1</td> <td data-bbox="626 592 776 669">0</td> <td data-bbox="776 592 967 669">Store result of decimal operation</td> <td data-bbox="1062 592 1403 669">Set (1) when result of operation is 0000B, otherwise reset (0).</td> </tr> <tr> <td data-bbox="477 669 626 737">1</td> <td data-bbox="626 669 776 737">1</td> <td data-bbox="776 669 967 737">Do not store result of decimal operation</td> <td data-bbox="1062 669 1403 737">Status maintained when result of operation is 0000B, otherwise reset (0).</td> </tr> </tbody> </table>					Value in BCD flag	Value in CMP flag	Operation	CY flag	Z flag	0	0	Store result of binary operation	Set (1) when carry or borrow is generated, otherwise reset (0).	Set (1) when result of operation is 0000B, otherwise reset (0).	0	1	Do not store result of binary operation	Status maintained when result of operation is 0000B, otherwise reset (0).	1	0	Store result of decimal operation	Set (1) when result of operation is 0000B, otherwise reset (0).	1	1	Do not store result of decimal operation	Status maintained when result of operation is 0000B, otherwise reset (0).
Value in BCD flag	Value in CMP flag	Operation	CY flag	Z flag																							
0	0	Store result of binary operation	Set (1) when carry or borrow is generated, otherwise reset (0).	Set (1) when result of operation is 0000B, otherwise reset (0).																							
0	1	Do not store result of binary operation		Status maintained when result of operation is 0000B, otherwise reset (0).																							
1	0	Store result of decimal operation		Set (1) when result of operation is 0000B, otherwise reset (0).																							
1	1	Do not store result of decimal operation		Status maintained when result of operation is 0000B, otherwise reset (0).																							
Logical operations	<table border="1" data-bbox="477 911 1403 995"> <tbody> <tr> <td data-bbox="477 911 626 995">Don't care (maintained)</td> <td data-bbox="626 911 776 995">Don't care (maintained)</td> <td data-bbox="776 911 967 995">No change</td> <td data-bbox="967 911 1062 995">Don't care (maintained)</td> <td data-bbox="1062 911 1403 995">Don't care (maintained)</td> </tr> </tbody> </table>					Don't care (maintained)	Don't care (maintained)	No change	Don't care (maintained)	Don't care (maintained)																	
Don't care (maintained)	Don't care (maintained)	No change	Don't care (maintained)	Don't care (maintained)																							
Bit evaluation	<table border="1" data-bbox="477 1346 1403 1430"> <tbody> <tr> <td data-bbox="477 1346 626 1430">Don't care (maintained)</td> <td data-bbox="626 1346 776 1430">Reset</td> <td data-bbox="776 1346 967 1430">No change</td> <td data-bbox="967 1346 1062 1430">Don't care (maintained)</td> <td data-bbox="1062 1346 1403 1430">Don't care (maintained)</td> </tr> </tbody> </table>					Don't care (maintained)	Reset	No change	Don't care (maintained)	Don't care (maintained)																	
Don't care (maintained)	Reset	No change	Don't care (maintained)	Don't care (maintained)																							
Comparison evaluation	<table border="1" data-bbox="477 1493 1403 1577"> <tbody> <tr> <td data-bbox="477 1493 626 1577">Don't care (maintained)</td> <td data-bbox="626 1493 776 1577">Don't care (maintained)</td> <td data-bbox="776 1493 967 1577">No change</td> <td data-bbox="967 1493 1062 1577">Don't care (maintained)</td> <td data-bbox="1062 1493 1403 1577">Don't care (maintained)</td> </tr> </tbody> </table>					Don't care (maintained)	Don't care (maintained)	No change	Don't care (maintained)	Don't care (maintained)																	
Don't care (maintained)	Don't care (maintained)	No change	Don't care (maintained)	Don't care (maintained)																							
Rotation	<table border="1" data-bbox="477 1772 1403 1835"> <tbody> <tr> <td data-bbox="477 1772 626 1835">Don't care (maintained)</td> <td data-bbox="626 1772 776 1835">Don't care (maintained)</td> <td data-bbox="776 1772 967 1835">No change</td> <td data-bbox="967 1772 1062 1835">Value in bit of the general register</td> <td data-bbox="1062 1772 1403 1835">Don't care (maintained)</td> </tr> </tbody> </table>					Don't care (maintained)	Don't care (maintained)	No change	Value in bit of the general register	Don't care (maintained)																	
Don't care (maintained)	Don't care (maintained)	No change	Value in bit of the general register	Don't care (maintained)																							

5.2.2 Functions of Temporary Registers A and B

Temporary registers A and B are needed for processing of 4-bit data. These registers are used for temporary storage of the first and second data operands of an instruction.

5.2.3 Functions of the Status Flip-Flop

The status flip-flop is used for controlling operation of the ALU and for storing data which has been processed. Each flag in the status flip-flop corresponds directly to a flag in the program status word (PSWORD) located in the system register. This means that when a flag in the system register is manipulated it is the same as manipulating a flag in the status flip-flop. Each flag in the program status word is described below.

(1) Z flag

This flag is set (1) when the result of an arithmetic operation is 0000B, otherwise it is reset (0). However, as described below, depending on the status of the CMP flag, the conditions which cause this flag to be set (1) can be changed.

(i) When CMP = 0

Z flag is set (1) when the result of an arithmetic operation is 0000B, otherwise it is reset (0).

(ii) When CMP = 1

The previous state of the Z flag is maintained when the result of an arithmetic operation is 0000B, otherwise it is reset (0). Only affected by arithmetic operations.

(2) CY flag

This flag is set (1) when a carry or borrow is generated in the result of an arithmetic operation, otherwise it is reset (0).

When an arithmetic operation is being performed using a carry or borrow, the operation is performed using the CY flag as the least significant bit. When a rotation (RORC instruction) is performed, the contents of the CY flag becomes the most significant bit (bit b₃) of the general register and the least significant bit of the general register is stored in the CY flag.

Only affected by arithmetic operations and rotations.

(3) CMP flag

When the CMP flag is set (1), the result of an arithmetic operation is not stored in either the general register or data memory.

When the bit evaluation instruction is performed, the CMP flag is reset (0).

The CMP flag does not affect comparison evaluations, logical operations, or rotations.

(4) BCD flag

When the BCD flag is set (1), all arithmetic operations are performed in BCD. When the flag is reset (0), all operations are performed in 4-bit binary.

The BCD flag does not affect logical operations, bit evaluations, comparison evaluations, or rotations.

These flags can also be set through direct manipulation of the values in the program status word (PSWORD). When the flags in the program status word are manipulated, the corresponding flag in the status flip-flop is also manipulated.

5.2.4 Performing Operations in 4-Bit Binary

When the BCD flag is set to 0, arithmetic operations are performed in 4-bit binary.

5.2.5 Performing Operations in BCD

When the BCD flag is set to 1, arithmetic operations are performed in BCD. Table 5-2 shows the differences in the results of operations performed in 4-bit binary and in BCD. When the result of an addition in BCD is equal to or greater than 20, or the result of a subtraction in BCD is outside of the range -10 to +9, a value of 1010B (0AH) or higher is stored as the result (shaded area in Table 5-2).

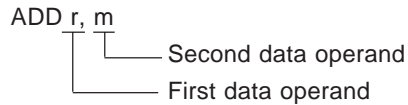
Table 5-2 Results of Arithmetic Operations Performed in 4-Bit Binary and BCD

Operation result	Addition in 4-bit binary		Addition in BCD		Operation result	Subtraction in 4-bit binary		Subtraction in BCD	
	CY	Operation result	CY	Operation result		CY	Operation result	CY	Operation result
0	0	0000	0	0000	0	0	0000	0	0000
1	0	0001	0	0001	1	0	0001	0	0001
2	0	0010	0	0010	2	0	0010	0	0010
3	0	0011	0	0011	3	0	0011	0	0011
4	0	0100	0	0100	4	0	0100	0	0100
5	0	0101	0	0101	5	0	0101	0	0101
6	0	0110	0	0110	6	0	0110	0	0110
7	0	0111	0	0111	7	0	0111	0	0111
8	0	1000	0	1000	8	0	1000	0	1000
9	0	1001	0	1001	9	0	1001	0	1001
10	0	1010	1	0000	10	0	1010	1	1100
11	0	1011	1	0001	11	0	1011	1	1101
12	0	1100	1	0010	12	0	1100	1	1110
13	0	1101	1	0011	13	0	1101	1	1111
14	0	1110	1	0100	14	0	1110	1	1100
15	0	1111	1	0101	15	0	1111	1	1101
16	1	0000	1	0110	-16	1	0000	1	1110
17	1	0001	1	0111	-15	1	0001	1	1111
18	1	0010	1	1000	-14	1	0010	1	1100
19	1	0011	1	1001	-13	1	0011	1	1101
20	1	0100	1	1110	-12	1	0100	1	1110
21	1	0101	1	1111	-11	1	0101	1	1111
22	1	0110	1	1100	-10	1	0110	1	0000
23	1	0111	1	1101	-9	1	0111	1	0001
24	1	1000	1	1110	-8	1	1000	1	0010
25	1	1001	1	1111	-7	1	1001	1	0011
26	1	1010	1	1100	-6	1	1010	1	0100
27	1	1011	1	1101	-5	1	1011	1	0101
28	1	1100	1	1010	-4	1	1100	1	0110
29	1	1101	1	1011	-3	1	1101	1	0111
30	1	1110	1	1100	-2	1	1110	1	1000
31	1	1111	1	1101	-1	1	1111	1	1001

5.2.6 Performing Operations in the ALU Block

When arithmetic operations, logical operations, bit evaluations, comparison evaluations or rotations in a program are executed, the first data operand is stored in temporary register A and the second data operand is stored in temporary register B.

The first data operand is four bits of data used to specify the contents of an address in the general register or data memory. The second data operand is four bits of data used to either specify the contents of an address in data memory or to be used as an immediate value. For example, in the instruction



the first data operand, r, is used to specify the contents of an address in the general register. The second data operand, m, is used to specify the contents of an address in data memory. In the instruction

ADD m, #n4

the first data operand, m, is used to specify an address in data memory. The second operand, #n4, is immediate data. In the rotation instruction

RORC r

only the first data operand, r (used to specify the contents of an address in the general register) is used.

Next, using the data stored in temporary registers A and B, the ALU executes the operation specified by the instruction (arithmetic operation, logical operation, bit evaluation, comparison evaluation, or rotation). When the instruction being executed is an arithmetic operation, logical operation, or rotation, the data processed by the ALU is stored in the location specified by the first data operand (general register address or data memory address) and the operation terminates. When the instruction being executed is a bit evaluation or comparison evaluation, the result processed by the ALU is used to determine whether or not to skip the next instruction (whether to treat next instruction as a no operation instruction: NOP) and the operation terminates.

Caution should be taken with regard to the following points:

- (1) Arithmetic operations are affected by the CMP and BCD flags in the program status word.
- (2) Logical operations are not affected by the CMP or BCD flag in the program status word. Logical operations do not affect the Z or CY flags.
- (3) Bit evaluation causes the CMP flag in the program status word to be reset.

5.3 ARITHMETIC OPERATIONS (ADDITION AND SUBTRACTION IN 4-BIT BINARY AND BCD)

As shown in Table 5-3, arithmetic operations consist of addition, subtraction, addition with carry, and subtraction with borrow. These instructions are ADD, ADDC, SUB, and SUBC.

The ADD, ADDC, SUB, and SUBC instructions are further divided into addition and subtraction of the general register and data memory and addition and subtraction of data memory and immediate data. When the operands r and m are used, addition or subtraction is performed using the general register and data memory. When the operands m and #n4 are used, addition or subtraction is performed using data memory and immediate data.

Arithmetic operations are affected by the status flip-flop and the program status word (PSWORD) in the system register. The BCD flag in the program status word (PSWORD) is used to specify whether arithmetic operations are to be performed in 4-bit binary or in BCD. The CMP flag is used to specify whether or not the results of arithmetic operations are to be stored.

Sections 5.3.1 to 5.3.4 explain the relationship between each command and the program status word (PSWORD).

Table 5-3 Types of Arithmetic Operations

Arithmetic operation	Addition	Without carry ADD	General register and data memory	ADD r, m
			Data memory and immediate data	ADD m, #n4
		With carry ADDC	General register and data memory	ADDC r, m
			Data memory and immediate data	ADDC m, #n4
	Subtraction	Without borrow SUB	General register and data memory	SUB r, m
			Data memory and immediate data	SUB m, #n4
		With borrow SUBC	General register and data memory	SUBC r, m
			Data memory and immediate data	SUBC m, #n4

5.3.1 Addition and Subtraction When BCD = 0 and CMP = 0

Addition and subtraction are performed in 4-bit binary and the result is stored in the general register (or data memory).

When the result of the operation is greater than 1111B (carry generated) or less than 0000B (borrow generated), the CY flag is set (1); otherwise it is reset (0).

When the result of the operation is 0000B, the Z flag is set (1) regardless of whether there is carry or borrow; otherwise it is reset (0).

5.3.2 Addition and Subtraction When BCD = 0 and CMP = 1

Addition and subtraction are performed in 4-bit binary.

However, because the CMP flag is set (1), the result of the operation is not stored in either the general register (or data memory).

When there is a carry or borrow in the result of the operation, the CY flag is set (1); otherwise it is reset (0).

When the result of the operation is 0000B, the previous state of the Z flag is maintained; otherwise it is reset (0).

5.3.3 Addition and Subtraction When BCD = 1 and CMP = 0

BCD operations are performed.

The result of the operation is stored in the general register (or data memory). When the result of the operation is greater than 1001B (9D) or less than 0000B (0D), the carry flag is set (1), otherwise it is reset (0).

When the result of the operation is 0000B (0D), the Z flag is set (1), otherwise it is reset (0).

Operations in BCD are performed by first computing the result in binary and then by using the decimal conversion circuit to convert the result to decimal. For information concerning the binary to decimal conversion, see Table 5-2 in **Section 5.2.5**.

In order for operations in BCD to be performed properly, note the following:

- (1) Result of an addition must be in the range 0D to 19D.
- (2) Result of a subtraction must be in the range 0D to 9D, or in the range -10D to -1D.

The following shows which value is considered the CY flag in the range 0D to 19D (shown in hexadecimal):

0, 0000B to 1, 0011B
^{^^}_{CY} ^{^^}_{CY}

The following shows which value is considered the CY flag in the range -10D to -1D (shown in hexadecimal):

1, 0110B to 1, 1111B
^{^^}_{CY} ^{^^}_{CY}

When operations in BCD are performed outside of the limits of (1) and (2) stated above, the CY flag is set (1) and the result of operation is output as a value greater than or equal to 1010B (0AH).

5.3.4 Addition and Subtraction When BCD = 1 and CMP = 1

BCD operations are performed.

The result is not stored in either the general register (or data memory).

```

Example SET2  BCD, CMP      ; Sets the BCD flag and CMD flag (1).
          ADD  PEGX, MEMX    ; Adds the register REGX and data memory MEMX.
          CLR1 BCD           ; Clears the BCD flag (0).
          SKT1 CY            ; Checks the CY flag and clears the CMP flag (0).
          BR   UNDER10      ; REGX + MEMX < 10
          BR   OVER10       ; REGX + MEMX ≥ 10
    
```

In this example, the ALU checks whether the sum of the register REGX and data memory MEMX is greater than or equal to 10, without corrupting the contents of REGX and MEMX.

5.3.5 Warnings Concerning Use of Arithmetic Operations

When performing arithmetic operations with the PSW (address 7FH), note the followings:

When the CMP flag is cleared (0) and an arithmetic operation is performed on the PSW, the result is stored in the PSW. This means that there is no way to check the CY and Z flags in the PSW.

However, when the CMP flag is set (1), results of arithmetic operations are not stored. Therefore, even in the above case, the CY and Z flags can be checked.

5.4 LOGICAL OPERATIONS

As shown in Table 5-4, logical operations consist of logical OR, logical AND, and logical XOR. Accordingly, the logical operation instructions are OR, AND, and XOR.

The OR, AND, and XOR instructions can be performed on either the general register and data memory, or on data memory and immediate data. The operands of these instructions are specified in the same way as for arithmetic operations ("r, m" or "m, #n4").

Logical operations are not affected by the BCD or CMP flags in the program status word (PSWORD). The operations do not affect the CY and Z flags at all.

Table 5-4 Logical Operations

Logical operation	Logical OR	General register and data memory	OR r, m
		Data memory and immediate data	OR m, #n4
	Logical AND	General register and data memory	AND r, m
		Data memory and immediate data	AND m, #n4
	Logical XOR	General register and data memory	XOR r, m
		Data memory and immediate data	XOR m, #n4

Table 5-5 Table of True Values for Logical Operations

Logical AND C = A AND B			Logical OR C = A OR B			Logical XOR C = A XOR B		
A	B	C	A	B	C	A	B	C
0	0	0	0	0	0	0	0	0
0	1	0	0	1	1	0	1	1
1	0	0	1	0	1	1	0	1
1	1	1	1	1	1	1	1	0

5.5 BIT EVALUATIONS

As shown in Table 5-6, there are both TRUE (1) and FALSE (0) bit evaluation instructions.

The SKT instruction skips the next instruction when a bit is evaluated as TRUE (1) and the SKF instruction skips the next instruction when a bit is evaluated as FALSE (0).

The SKT and SKF instructions can only be used with data memory.

Bit evaluations are not affected by the BCD flag in the program status word (PSWORD). The evaluations do not affect the CY and Z flags at all. However, when an SKT or SKF instruction is executed, the CMP flag is reset (0).

Sections 5.5.1 and **5.5.2** explain TRUE (1) and FALSE (0) bit evaluations.

Table 5-6 Bit Evaluation Instructions

Bit evaluation	TRUE (1) bit evaluation SKT m, #n
	FALSE (0) bit evaluation SKF m, #n

5.5.1 TRUE (1) Bit Evaluation

The TRUE (1) bit evaluation instruction (SKT m, #n) is used to determine whether or not the bits specified by n in the four bits of data memory m are TRUE (1). When all bits specified by n are TRUE (1), this instruction causes the next instruction to be skipped.

```

Example MOV M1, #1011B
           SKT M1, #1011B ; ①
           BR A
           BR B
           ⋮
           SKT M1, #1101B ; ②
           BR C
           BR D
    
```

In this example, bits b₃, b₁, and b₀ of data memory M1 are evaluated in step number ①. Because all the bits are TRUE (1), the program branches to B. In step number ②, bits b₃, b₂, and b₀ of data memory M1 are evaluated. Since b₂ of data memory M1 is FALSE (0), the program branches to C.

5.5.2 FALSE (0) Bit Evaluation

The FALSE (0) bit evaluation instruction (SKF m, #n) is used to determine whether or not the bits specified by n in the four bits of data memory m are FALSE (0). When all bits specified by n are FALSE (0), this instruction causes the next instruction to be skipped.

```

Example MOV M1, #1001B
          SKF M1, #0110B ; ①
          BR A
          BR B
          :
          SKF M1, #1110B ; ②
          BR C
          BR D
    
```

In this example, bits b₂ and b₁ of data memory M1 are evaluated in step number ①. Because both bits are FALSE (0), the program branches to B. In step number ②, bits b₃, b₂, and b₁ of data memory M1 are evaluated. Since b₃ of data memory M1 is TRUE (1), the program branches to C.

5.6 COMPARISON EVALUATIONS

As shown in Table 5-7, there are comparison evaluation instructions for determining if one value is "equal to," "not equal to," "greater than or equal to," or "less than" another.

The SKE instruction is used to determine if two values are equal. The SKNE instruction is used to determine two values are not equal. The SKGE instruction is used to determine if one value is greater than or equal to another and the SKLT instruction is used to determine if one value is less than another.

The SKE, SKNE, SKGE, and SKLT instructions perform comparisons between a value in data memory and immediate data. In order to compare values in the general register and data memory, a subtraction instruction is performed according to the values in the CMP and Z flags in the program status word (PSWORD). For more information concerning comparison of the general register and data memory, see **Section 5.3**.

Comparison evaluations are not affected by the BCD or CMP flags in the program status word (PSWORD). The evaluations do not affect the CY and Z flags at all.

Sections 5.6.1 to 5.6.4 explain the "equal," "not equal," "greater than or equal," and "less than" comparison evaluations.

Table 5-7 Comparison Evaluation Instructions

Comparison evaluation	Equal SKE m, #n4
	Not equal SKNE m, #n4
	Greater than or equal SKGE m, #n4
	Less than SKLT m, #n4

5.6.1 "Equal" Evaluation

The "equal" evaluation instruction (SKE m, #n4) is used to determine if immediate data and the contents of a location in data memory are equal.

This instruction causes the next instruction to be skipped when the immediate data and the contents of data memory are equal.

```
Example MOV  M1, #1010B
          SKE  M1, #1010B ; ①
          BR   A
          BR   B
          ⋮
          SKE  M1, #1000B ; ②
          BR   C
          BR   D
```

In this example, because the contents of data memory M1 and immediate data 1010B in step number ① are equal, the program branches to B. In step number ②, because the contents of data memory M1 and immediate data 1000B are not equal, the program branches to C.

5.6.2 "Not Equal" Evaluation

The "not equal" evaluation instruction (SKNE m, #n4) is used to determine if immediate data and the contents of a location in data memory are not equal.

This instruction causes the next instruction to be skipped when the immediate data and the contents of data memory are not equal.

```
Example MOV  M1, #1010B
          SKNE M1, #1000B ; ①
          BR   A
          BR   B
          ⋮
          SKNE M1, #1010B ; ②
          BR   C
          BR   D
```

In this example, because the contents of data memory M1 and immediate data 1000B in step number ① are not equal, the program branches to B. In step number ②, because the contents of data memory M1 and immediate data 1010B are equal, the program branches to C.

5.6.3 "Greater Than or Equal" Evaluation

The "greater than or equal" evaluation instruction (SKGE m, #n4) is used to determine if the contents of a location in data memory is a value greater than or equal to the value of the immediate data operand. If the value in data memory is greater than or equal to that of the immediate data, this instruction causes the next instruction to be skipped.

Example

```

MOV  M1, #1000B
SKGE M1, #0111B ; ①
BR   A
BR   B
      ⋮
SKGE M1, #1000B ; ②
BR   C
BR   D
      ⋮
SKGE M1, #1001B ; ③
BR   E
BR   F

```

In this example, the program will first branch to B since the value in data memory is larger than that of the immediate data (①). Next it will branch to D since the value in data memory is equal to that of the immediate data (②). Last it will branch to E since the value in data memory is less than that of the immediate data (③).

5.6.4 "Less Than" Evaluation

The "less than" evaluation instruction (SKLT m, #n4) is used to determine if the contents of a location in data memory is a value less than that of the immediate data operand. If the value in data memory is less than that of the immediate data, this instruction causes the next instruction to be skipped.

Example

```

MOV  M1, #1000B
SKLT M1, #1001B ; ①
BR   A
BR   B
      ⋮
SKLT M1, #1000B ; ②
BR   C
BR   D
      ⋮
SKLT M1, #0111B ; ③
BR   E
BR   F

```

In this example, the program will first branch to B since the value in data memory is less than that of the immediate data (①). Next it will branch to C since the value in data memory is equal to that of the immediate data (②). Last it will branch to E since the value in data memory is greater than that of the immediate data (③).

5.7 ROTATIONS

There are rotation instructions for rotation to the right and for rotation to the left.

The RORC instruction is used for rotation to the right.

The RORC instruction can only be used with the general register.

Rotation using the RORC instruction is not affected by the BCD or CMP flags in the program status word (PSWORD). The rotation does not affect the Z flag at all.

Rotation to the left is performed by using the addition instruction ADDC.

Sections 5.7.1 and **5.7.2** explain rotation.

5.7.1 Rotation to the Right

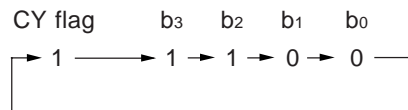
The instruction used for rotation to the right (RORC r) rotates the contents of the general register in the direction of its least significant bit.

When this instruction is executed, the contents of the CY flag becomes the most significant bit of the general register (bit b₃) and the least significant bit of the general register (bit b₀) is placed in the CY flag.

```

Examples 1. MOV PSW, #0100B ; Sets CY flag to 1.
              MOV R1, #1100B
              RORC R1
    
```

When these instructions are executed, the following operation is performed.



Basically, when rotation to the right is performed, the following operation is executed:

CY flag → b₃, b₃ → b₂, b₂ → b₁, b₁ → b₀, b₀ → CY flag.

```

2. MOV PSW, #0000B ; Resets CY flag to 0.
      MOV R1, #1000B ; Most significant bit
      MOV R2, #0100B
      MOV R3, #0010B ; Least significant bit
      RORC R1
      RORC R2
      RORC R3
    
```

The program code above rotates 13 bits in CY, R1, R2, and R3 to the right.

5.7.2 Rotation to the Left

Rotation to the left is performed by using the addition instruction, "ADDC r, m".

```
Example MOV   PSW, #0000B ; Resets CY flag to 0.
          MOV   R1, #1000B ; Most significant bit
          MOV   R2, #0100B
          MOV   R3, #0010B ; Least significant bit
          ADDC  R3, R3
          ADDC  R2, R2
          ADDC  R1, R1
          SKF1  CY
          OR    R3, #0001B
```

The program code above rotates 13 bits in CY, R1, R2, and R3 to the left.

6. PORTS

6.1 PORT 0B (P0B₀/RLS_{HALT}, P0B₁/RLS_{STOP}, P0B₂)

Port 0B is a three-bit input/output port. Only N-ch open-drain outputs appear on the pins of port 0B. The N-ch open-drain output mode allows application of 9 V, so it can be used for interfacing with a circuit operating on a different power supply voltage.

Input and output are set in units of nibbles. The input mode is set at reset, and the output mode is set by writing data to the port register in address 71H of the data memory. The output mode is maintained until the system is reset.

Output to the port is executed via the port register. Once data is written to the port register, all pins of port 0B are placed in the output mode to continue to output written data. The data is retained unless new data is written to the register.

Writing 1 to the port register makes the N-ch open-drain output pin high-impedance. Therefore, the pin which outputs 1 can be used as an input pin.

Whenever the port register is read, the read data indicates the states of the pins^{Note}, not the contents of the port register, regardless of whether the pins are in the input or output mode. In this case, the contents of the port register remain unchanged.

The port register for port 0B consists of four bits but its highest bit is always set to 0. This means that if an attempt is made to write data to the highest bit of 71H, the data is invalidated and if an attempt is made to read it, 0 is always returned.

A P0B₀ input signal releases the HALT mode as a pseudo interrupt. A P0B₁ input signal releases the STOP mode as a pseudo interrupt. (See **Chapter 7**.)

6.2 PORT 0C (P0C₀ TO P0C₃)

Port 0C is a four-bit input/output port. CMOS (push-pull) outputs appear on those pins.

Input and output are set in units of nibbles. The input mode is set at reset, and the output mode is set by writing data to the port register in address 72H of the data memory. The output mode is maintained until the system is reset.

Output to the port is executed via the port register. Once data is written to the port register, all pins of the port 0C are placed in the output mode to continue to output written data. The data is retained unless new data is written to the register.

Whenever the port register is read, the read data indicates the states of the pins^{Note}, not the contents of the port register, regardless of whether the pins are in the input or output mode. In this case, the contents of the port register remain unchanged.

6.3 PORT 0D (P0D₀ TO P0D₃)

Port 0D is a four-bit input/output port. CMOS (push-pull) outputs appear on these pins.

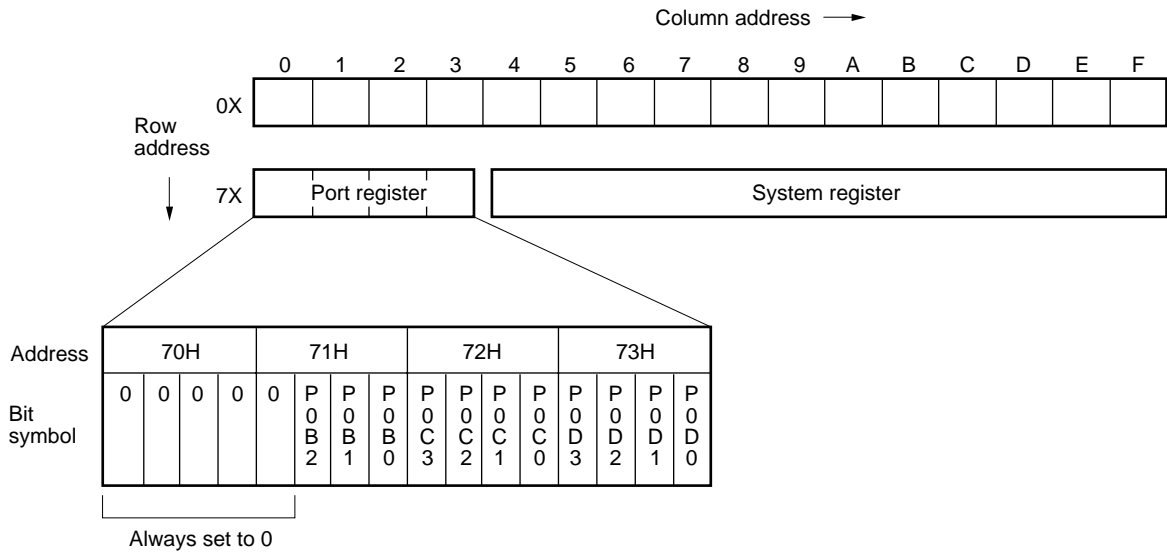
Input and output are set in units of nibbles. The input mode is set at reset, and the output mode is set by writing data to the port register in address 73H of the data memory. The output mode is maintained until the system is reset.

Output to the port is executed via the port register. Once data is written to the port register, all pins of the port 0D are placed in the output mode to continue to output written data. The data is retained until new data is written to the register.

Whenever the port register is read, the read data indicates the states of the pins^{Note}, not the contents of the port register, regardless of whether the pins are in the input or output mode. In this case, the contents of the port register remain unchanged.

Note In the output mode, design an external circuit appropriately depending on the output data.

Fig. 6-1 Port Register Map



6.4 NOTES ON MANIPULATING PORT REGISTERS

The states of the I/O port pins of the μPD17107(A1) can be read even when the port pins have been set to output mode.

When a port register is manipulated with a built-in macro instruction (such as SETn or CLRn) or AND, OR, or XOR instruction, the states of those pins for which the state should remain unchanged may change unexpectedly.

Especially when using some of the port 0B pins (N-ch open-drain outputs) as input pins, with the remaining port 0B pins being used as output pins, always take the possibility of this change in the states of the pins into consideration.

When a CLR1 P0B2 instruction (identical to an AND 71H, #1011B instruction) is applied to the port 0B pins, the corresponding port register and internal states are changed, as shown in Fig. 6-2.

Assume that the states of port 0B are those shown in Fig. 6-2 ①. Pins P0B3 and P0B2, used as output pins, output high level, while pins P0B1 and P0B0, used as input pins, receive low level.

It is required that high level be output, inside the chip, from the port 0B pins to be used as input pins. Although the μPD17103, μPD17103L, μPD17107, and μPD17107L do not support pin P0B3, it is virtually assumed to exist within a program.

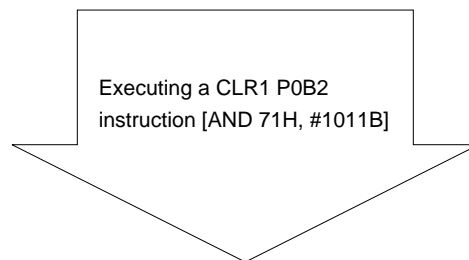
When a CLR1 P0B2 instruction is executed to set pin P0B2 to low, the states of the port 0B pins change as shown in Fig. 6-2 ②. The port register changes such that pins P0B1 and P0B0, required to output high level, actually output low level. This is because the CLR1 P0B2 instruction has been applied to the states of the port 0B pins, but not to the states of the port register.

To prevent this problem, use another instruction, such as a MOV instruction, to specify the states of all port 0B pins, not merely the states of those pins whose states are to be changed. In this example, it is recommended that a MOV 71H, #1011B instruction be used to set only pin P0B2 to low.

Fig. 6-2 Changes in the Port Register According to the Execution of a CLR1 P0B2 Instruction

① **Before the instruction is executed**

State	P0B3	P0B2	P0B1	P0B0
Port register	1	1	1	1
Internal	H output	H output	H output	H output
Pin	H	H	L (input)	L (input)



② **After the instruction is executed**

State	P0B3	P0B2	P0B1	P0B0
Port register	1	0	0	0
Internal	H output	L output	L output	L output
Pin	H	L	L	L

H: High level, L: Low level

7. STANDBY FUNCTIONS

The μPD17107(A1) provides two standby modes, the HALT mode and the STOP mode.

7.1 HALT MODE

The HALT mode stops the program counter (PC) while allowing the system clock to continue operating. The HALT mode can be entered with the HALT instruction, and can be released by a reset signal ($\overline{\text{RESET}}$) or high-level input to the P0B₀ pin. When the HALT mode is released by a high-level signal input to the P0B₀ pin, the system does not wait for the system clock oscillation to settle. The instruction immediately after the HALT instruction is executed.

When the HALT mode is released forcibly by the reset signal ($\overline{\text{RESET}}$), normal reset occurs, and the program starts at address 0H.

7.2 STOP MODE

The STOP mode stops the system clock oscillation so that data can be retained at low power voltage. The STOP mode can be entered with the STOP instruction, and can be released by a reset signal ($\overline{\text{RESET}}$) or high-level input to the P0B₁ pin. When the mode is released by a high-level signal input to the P0B₁ pin, the program starts with the instruction immediately after the STOP instruction.

When the STOP mode is released forcibly by the reset signal ($\overline{\text{RESET}}$), normal reset occurs, and the program starts at address 0H.

7.3 SETTING AND RELEASING THE STANDBY MODES

(1) Setting and releasing the HALT mode

Conditions for releasing the HALT mode are selected with the least significant bit of the operand in the HALT instruction as shown in Table 7-1. The high-order three bits of the operand must be set to 0.

Table 7-1 Conditions for Setting/Releasing the HALT Mode

HALT 000XB ← 4-bit data in the operand

X	Conditions for setting/releasing the HALT mode
0	After executing a HALT instruction, the system enters the HALT mode unconditionally. The mode can be released only by the reset signal ($\overline{\text{RESET}}$). After the mode is released, the program starts at address 0H.
1	When a HALT instruction is executed with the P0B ₀ pin being at low level, the system enters the HALT mode. The mode can be released by the reset signal ($\overline{\text{RESET}}$). When the mode is released, the program starts at address 0H. This mode can also be released when a high-level signal is applied to the P0B ₀ pin. In this case, the program starts with the instruction immediately after the HALT instruction. When a HALT instruction is executed with the P0B ₀ pin being at high level, the instruction is ignored (regarded as a NOP instruction) and the system does not enter the HALT mode.

(2) Setting and releasing the STOP mode

Conditions to release the STOP mode are selected with the least significant bit of the operand in the STOP instruction as shown in Table 7-2. The high-order three bits of the operand must be set to 0.

Table 7-2 Conditions for Setting/Releasing the STOP Mode

STOP 000XB ← 4-bit data in the operand

X	Conditions for setting/releasing the STOP mode
0	After executing a STOP instruction, the system enters the STOP mode unconditionally. All peripheral circuits are placed in the same initial state as when the system is reset, then they stop operating. The mode can be released only by the reset signal ($\overline{\text{RESET}}$). After the mode is released, the program starts at address 0H.
1	When a STOP instruction is executed with the P0B ₁ pin being at low level, the system enters the STOP mode. The mode can be released by the reset signal ($\overline{\text{RESET}}$). When the mode is released, the program starts at address 0H. This mode can also be released when a high-level signal is applied to the P0B ₁ pin. In this case, the program starts with the instruction immediately after the STOP instruction. When a STOP instruction is executed with the P0B ₁ pin being at high level, the instruction is ignored (regarded as a NOP instruction) and the system does not enter the STOP mode.

7.4 HARDWARE STATUSES IN STANDBY MODE

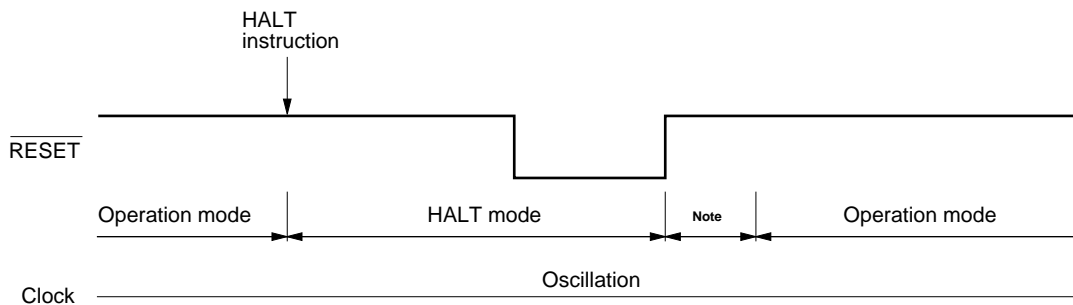
Hardware statuses in standby mode are as follows:

Table 7-3 Hardware Statuses in Standby Mode

Hardware	HALT or STOP 0001B instruction	STOP 0000B instruction
Clock generator	HALT instruction: Oscillation continued STOP instruction: Oscillation disabled	Oscillation disabled
Program counter	Address following a HALT or STOP instruction is indicated.	000H
Data memory (00H to 0FH)	Previous data is retained.	Previous data is retained.
Program status word (PSWORD)	Previous data is retained.	All bits are set to 0.
Port register (71H to 73H)	Previous data is retained. (Input/output mode of pins is also retained.)	Previous data is retained. (All pins are placed in input mode.)

7.5 TIMING FOR RELEASING THE STANDBY MODES

Fig. 7-1 Releasing the HALT Mode by $\overline{\text{RESET}}$ Input



When the $\overline{\text{RESET}}$ signal is applied to release the HALT mode, the $\overline{\text{RESET}}$ input makes a transition from low to high, then an operation mode is entered.

Note The HALT mode remains effective in this period, waiting for the operation mode. An operation starts after eight clock pulses on the OSC₀ pin are counted.

Fig. 7-2 Releasing the HALT Mode by High-Level Input to the P0B₀ Pin

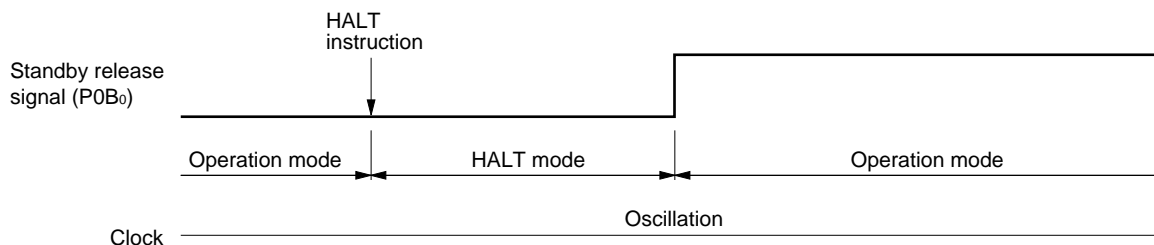
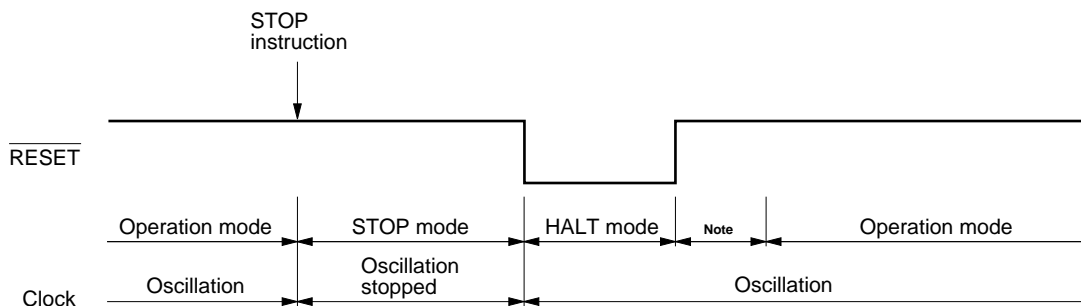


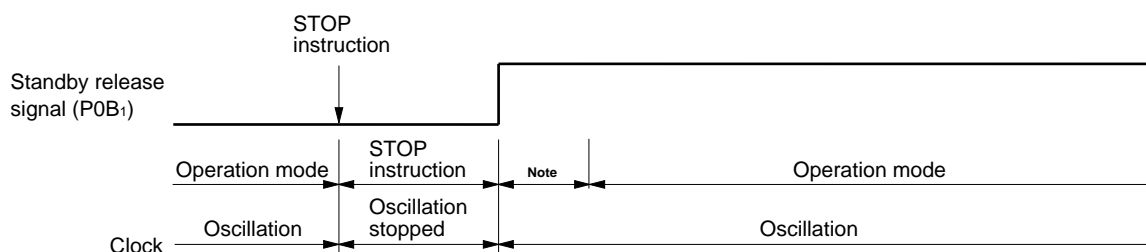
Fig. 7-3 Releasing the STOP Mode by $\overline{\text{RESET}}$ Input



As soon as the $\overline{\text{RESET}}$ input makes a transition from high to low in the STOP mode, the system clock starts generating clock pulses.

Note The HALT mode remains effective in this period, waiting for the generation of clock pulses to settle. An operation starts after eight clock pulses on the OSC₀ pin are counted.

Fig. 7-4 Releasing the STOP Mode by High-Level Input to the P0B₁ Pin



Note The HALT mode remains effective in this period, waiting for the generation of clock pulses to settle. An operation starts after eight clock pulses on the OSC₀ pin are counted.

8. RESET FUNCTION

8.1 RESET FUNCTION

A low-level signal, applied to the $\overline{\text{RESET}}$ pin, resets the system, then the hardware is initialized.

The system clock oscillates as long as the power supply voltage is supplied, even if a low-level signal is applied to the $\overline{\text{RESET}}$ pin.

A low to high transition on the $\overline{\text{RESET}}$ pin releases the reset status and causes the system to enter the operating mode once the 8-clock oscillation settling wait time has elapsed.

Table 8-1 Hardware Status after Reset

Hardware		<ul style="list-style-type: none"> • Reset immediately after power on • Reset during operation 	Reset in standby mode ^{Note}
Program counter		000H	000H
Data memory (00H to 0FH)		Undefined	Data existing before reset is retained.
Program status word (PSWORD)		All bits are set to 0.	All bits are set to 0.
Port	Input/output mode	Input	Input
	Output latch	Undefined	Data existing before reset is retained.

Note The hardware is initialized when the STOP 0000B instruction is executed.

9. RESERVED WORDS USED IN ASSEMBLY LANGUAGE

9.1 MASK-OPTION PSEUDO INSTRUCTIONS

Source programs in the assembly language for the μPD17107(A1) must include mask-option pseudo instructions to select pin options.

To do this, be sure to catalog the D17107.OPT file in AS17103 (device file for the μPD17107(A1)) into the current directory beforehand.

Specify mask options for the following pins:

- P0B₀
- P0B₁
- P0B₂
- $\overline{\text{RESET}}$

9.1.1 OPTION and ENDOP Pseudo Instructions

The part starting with the OPTION pseudo instruction and ending with the ENDOP pseudo instruction is referred to as a mask-option definition block. The coding format of the mask-option definition block is as follows.

Only the two pseudo instructions listed in Table 9-1 can be coded in the block.

Format:

Symbol	Mnemonic	Operand	Comment
[label:]	OPTION		[:comment]
	⋮		
	ENDOP		

9.1.2 Mask-Option Definition Pseudo Instructions

Table 9-1 lists the pseudo instructions to define a mask option for each pin.

Table 9-1 Mask-Option Definition Pseudo Instructions

Pin	Mask-option pseudo instruction	Number of operands	Operand
P0B ₂ - P0B ₀	OPTP0B	3	P0BPLUP (pull-up resistor provided) OPEN (no pull-up resistor provided)
$\overline{\text{RESET}}$	OPTRES	1	RESPLUP (pull-up resistor provided) OPEN (no pull-up resistor provided)

The coding format of OPTP0B is as follows. To define the mask option, specify P0B₂ (first operand), P0B₁, and P0B₀ in the operand field.

Format:

Symbol	Mnemonic	Operand	Comment
[label:]	OPTP0B	(P0B ₂),(P0B ₁),(P0B ₀)	[:comment]

The coding format of OPTRES is as follows.

Format:

Symbol	Mnemonic	Operand	Comment
[label:]	OPTRES	(RESET)	[:comment]

Example The following mask options are set in a μPD17107(A1) source file to be assembled:
 P0B2: Pull-up, P0B1: Open, P0B0: Open
 RESET: Pull-up

```

        :
;17107(A1)
Setting mask options: OPTION
                    OPTP0B  P0BPLUP, OPEN, OPEN
                    OPTRES  RESPLUP
                    ENDOP
        :
    
```

9.2 RESERVED SYMBOLS

Table 9-2 lists the reserved symbols defined in the μPD17107(A1) device file (AS17103).

Table 9-2 Reserved Symbols

Name	Attribute	Value	R/W	Description
P0B0	FLG	0.71H.0	R/W	Bit 0 of port 0B
P0B1	FLG	0.71H.1	R/W	Bit 1 of port 0B
P0B2	FLG	0.71H.2	R/W	Bit 2 of port 0B
P0B3 ^{Note}	FLG	0.71H.3	R	Always set to 0
P0C0	FLG	0.72H.0	R/W	Bit 0 of port 0C
P0C1	FLG	0.72H.1	R/W	Bit 1 of port 0C
P0C2	FLG	0.72H.2	R/W	Bit 2 of port 0C
P0C3	FLG	0.72H.3	R/W	Bit 3 of port 0C
P0D0	FLG	0.73H.0	R/W	Bit 0 of port 0D
P0D1	FLG	0.73H.1	R/W	Bit 1 of port 0D
P0D2	FLG	0.73H.2	R/W	Bit 2 of port 0D
P0D3	FLG	0.73H.3	R/W	Bit 3 of port 0D
BCD	FLG	0.7EH.0	R/W	BCD arithmetic flag
PSW	MEM	0.7FH	R/W	Program status word
Z	FLG	0.7FH.1	R/W	Zero flag
CY	FLG	0.7FH.2	R/W	Carry flag
CMP	FLG	0.7FH.3	R/W	Compare flag

R/W: Read/write

Note Although a pin corresponding to P0B3 does not exist in the μPD17107(A1), P0B3 is defined as a read-only flag so that it is used in a built-in macro.

10. INSTRUCTION SET

10.1 INSTRUCTION SET LIST

b ₁₄ -b ₁₁		b ₁₅		0	1
		BIN	HEX		
0 0 0 0	0	ADD	r, m	ADD	m, #n4
0 0 0 1	1	SUB	r, m	SUB	m, #n4
0 0 1 0	2	ADDC	r, m	ADDC	m, #n4
0 0 1 1	3	SUBC	r, m	SUBC	m, #n4
0 1 0 0	4	AND	r, m	AND	m, #n4
0 1 0 1	5	XOR	r, m	XOR	m, #n4
0 1 1 0	6	OR	r, m	OR	m, #n4
0 1 1 1	7	RET RETSK RORC STOP HALT NOP	r s h		
1 0 0 0	8	LD	r, m	ST	m, r
1 0 0 1	9	SKE	m, #n4	SKGE	m, #n4
1 0 1 0	A				
1 0 1 1	B	SKNE	m, #n4	SKLT	m, #n4
1 1 0 0	C	BR	addr	CALL	addr
1 1 0 1	D			MOV	m, #n4
1 1 1 0	E			SKT	m, #n
1 1 1 1	F			SKF	m, #n

10.2 INSTRUCTIONS

Legend

- ASR : Address stack register pointed to by the stack pointer
- addr : Program memory address (11 bits, high-order two bits are always set to 0)
- CMP: Compare flag
- CY : Carry flag
- h : Halt release condition
- m : Data memory address specified by m_R or m_C
 - m_R: Data memory row address (high order)
 - m_C: Data memory column address (low order)
- n : Bit position (4 bits)
- n4 : Immediate data (4 bits)
- PC : Program counter
- r : General register column address
- SP : Stack pointer
- s : Stop release condition
- (\times) : Contents addressed by \times

Instruction set	Mnemonic	Operand	Operation	Machine code			
				Op code	Operand		
Add	ADD	r,m	$(r) \leftarrow (r) + (m)$	00000	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) + n4$	10000	m _R	mc	n4
	ADDC	r,m	$(r) \leftarrow (r) + (m) + CY$	00010	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) + n4 + CY$	10010	m _R	mc	n4
Subtract	SUB	r,m	$(r) \leftarrow (r) - (m)$	00001	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) - n4$	10001	m _R	mc	n4
	SUBC	r,m	$(r) \leftarrow (r) - (m) - CY$	00011	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) - n4 - CY$	10011	m _R	mc	n4
Logical operation	OR	r,m	$(r) \leftarrow (r) \vee (m)$	00110	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) \vee n4$	10110	m _R	mc	n4
	AND	r,m	$(r) \leftarrow (r) \wedge (m)$	00100	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) \wedge n4$	10100	m _R	mc	n4
	XOR	r,m	$(r) \leftarrow (r) \nabla (m)$	00101	m _R	mc	r
		m,#n4	$(m) \leftarrow (m) \nabla n4$	10101	m _R	mc	n4
Test	SKT	m,#n	CMP $\leftarrow 0$, if $(m) \wedge n = n$, then skip	11110	m _R	mc	n
	SKF	m,#n	CMP $\leftarrow 0$, if $(m) \wedge n = 0$, then skip	11111	m _R	mc	n
Compare	SKE	m,#n4	$(m) - n4$, skip if zero	01001	m _R	mc	n4
	SKNE	m,#n4	$(m) - n4$, skip if not zero	01011	m _R	mc	n4
	SKGE	m,#n4	$(m) - n4$, skip if not borrow	11001	m _R	mc	n4
	SKLT	m,#n4	$(m) - n4$, skip if borrow	11011	m _R	mc	n4
Rotation	RORC	r		00111	000	0111	r
Transfer	LD	r,m	$(r) \leftarrow (m)$	01000	m _R	mc	r
	ST	m,r	$(m) \leftarrow (r)$	11000	m _R	mc	r
	MOV	m,#n4	$(m) \leftarrow n4$	11101	m _R	mc	n4
Branch	BR	addr	PC \leftarrow addr	01100	addr		
Subroutine	CALL	addr	SP \leftarrow SP - 1, ASR \leftarrow PC, PC \leftarrow addr	11100	addr		
	RET		PC \leftarrow ASR, SP \leftarrow SP + 1	00111	000	1110	0000
	RETSK		PC \leftarrow ASR, SP \leftarrow SP + 1 and skip	00111	001	1110	0000
Others	STOP	s	STOP	00111	010	1111	s
	HALT	h	HALT	00111	011	1111	h
	NOP		No operation	00111	100	1111	0000

10.3 ASSEMBLER (AS17K) BUILT-IN MACRO INSTRUCTIONS

Legend

flag n : FLG symbol

< > : Characters enclosed in < > can be omitted.

	Mnemonic	Operand	Operation	n
Built-in macro	SKTn	flag 1, ...,flag n	if (flag 1) – (flag n) = all "1", then skip	1 ≤ n ≤ 4
	SKFn	flag 1, ...,flag n	if (flag 1) – (flag n) = all "0", then skip	1 ≤ n ≤ 4
	SETn	flag 1, ...,flag n	(flag 1) – (flag n) ← 1	1 ≤ n ≤ 4
	CLRn	flag 1, ...,flag n	(flag 1) – (flag n) ← 0	1 ≤ n ≤ 4
	NOTn	flag 1, ...,flag n	if (flag n) = "0", then (flag n) ← 1 if (flag n) = "1", then (flag n) ← 0	1 ≤ n ≤ 4
	INITFLG	<NOT> flag 1, ... <<NOT> flag n>	if description = NOT flag n, then (flag n) ← 0 if description = flag n, then (flag n) ← 1	1 ≤ n ≤ 4

11. ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS (T_A = 25 °C)

Parameter	Symbol	Conditions	Rated value	Unit	
Supply voltage	V _{DD}		-0.3 to +7.0	V	
Input voltage	V _i	P0C, P0D, $\overline{\text{RESET}}$	-0.3 to V _{DD} + 0.3	V	
		P0B	When a built-in pull-up resistor is connected	-0.3 to V _{DD} + 0.3	V
			When a built-in pull-up resistor is not connected	-0.3 to +11	V
Output voltage	V _o	P0C, P0D	-0.3 to V _{DD} + 0.3	V	
		P0B	When a built-in pull-up resistor is connected	-0.3 to V _{DD} + 0.3	V
			When a built-in pull-up resistor is not connected	-0.3 to +11	V
High-level output current	I _{OH}	Each of P0C and P0D	-5	mA	
		Total of all pins	-15	mA	
Low-level output current	I _{OL}	Each of P0B, P0C, and P0D	30	mA	
		Total of all pins	100	mA	
Operating ambient temperature	T _A		-40 to +110	°C	
Storage temperature	T _{stg}		-65 to +150	°C	
Allowable dissipation	P _d	T _A = 110 °C	16-pin plastic DIP	100	mW
			16-pin plastic SOP	90	

Caution Absolute maximum ratings are rated values beyond which some physical damages may be caused to the product; if any of the parameters in the table above exceeds its rated value even for a moment, the quality of the product may deteriorate. Be sure to use the product within the rated values.

CAPACITANCE (T_A = 25 °C, V_{DD} = 0 V)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input capacitance	C _{IN}	f = 1 MHz			15	pF
I/O capacitance	C _{IO}	0 V for pins other than pins to be measured			15	pF

I/O: Input/output

DC CHARACTERISTICS (T_A = -40 to +110 °C, V_{DD} = 2.5 to 6.0 V)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
High-level input voltage	V _{IH1}	P0C, P0D		0.7V _{DD}		V _{DD}	V
	V _{IH2}	RESET		0.8V _{DD}		V _{DD}	V
	V _{IH3}	P0B	Note 1	0.8V _{DD}		V _{DD}	V
	V _{IH4}		Note 2	0.8V _{DD}		9	V
Low-level input voltage	V _{IL1}	P0C, P0D		0		0.3V _{DD}	V
	V _{IL2}	RESET		0		0.2V _{DD}	V
	V _{IL3}	P0B		0		0.2V _{DD}	V
High-level output voltage	V _{OH1}	P0C, P0D	V _{DD} = 4.5 to 6.0 V, I _{OH} = -2 mA	V _{DD} - 2.0			V
	V _{OH2}		I _{OH} = -200 μA,	V _{DD} - 1.0			V
Low-level output voltage	V _{OL1}	P0B, P0C, P0D	V _{DD} = 4.5 to 6.0 V, I _{OL} = 15 mA			2.0	V
	V _{OL2}		I _{OL} = 600 μA			0.5	V
High-level input leakage current	I _{LIH1}	P0C, P0D, V _{IN} = V _{DD}				5	μA
	I _{LIH2}	P0B, V _{IN} = V _{DD}				5	μA
	I _{LIH3}	P0B, V _{IN} = 9 V>Note 2				10	μA
Low-level input leakage current	I _{LIL1}	P0C, P0D, V _{IN} = 0 V				-5	μA
	I _{LIL2}	P0B, V _{IN} = 0 V				-5	μA
High-level output leakage current	I _{LOH1}	P0C, P0D, V _{OUT} = V _{DD}				5	μA
	I _{LOH2}	P0B, V _{OUT} = V _{DD}				5	μA
	I _{LOH3}	P0B, V _{OUT} = 9 V>Note 2				10	μA
Low-level output leakage current	I _{LOL}	P0B, P0C, P0D, V _{OUT} = 0 V				-5	μA
Built-in pull-up resistor for pin RESET	R _{RES}			20	47	110	kΩ
Built-in pull-up resistor for pin P0B	R _{P0B}			5	15	35	kΩ
Power supply current>Note 3	I _{DD1}	Operation mode	V _{DD} = 5 V ±10 %, f _{CC} = 1.0 MHz ±20 %		0.4	1.2	mA
			V _{DD} = 3 V ±10 %, f _{CC} = 250 kHz ±20 %		50	150	μA
	I _{DD2}	HALT mode	V _{DD} = 5 V ±10 %, f _{CC} = 1.0 MHz ±20 %		0.3	0.9	mA
			V _{DD} = 3 V ±10 %, f _{CC} = 250 kHz ±20 %		40	120	μA
	I _{DD3}	STOP mode	V _{DD} = 5 V ±10 %		0.1	15	μA
			V _{DD} = 3 V ±10 %		0.1	10	μA

- Notes**
1. When a built-in pull-up resistor is connected
 2. When a built-in pull-up resistor is not connected
 3. This current excludes the current which flows through the built-in pull-up resistors.

CHARACTERISTICS OF DATA MEMORY FOR HOLDING DATA ON LOW SUPPLY VOLTAGE IN THE STOP MODE ($T_A = -40$ to $+110$ °C)

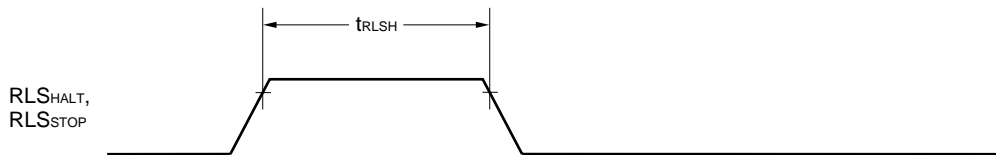
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Data hold supply voltage	V_{DDDR}		2.0		6.0	V
Data hold supply current	I_{DDDR}	$V_{DDDR} = 2.0$ V		0.1	10	μA

AC CHARACTERISTICS ($T_A = -40$ to $+110$ °C, $V_{DD} = 2.5$ to 6.0 V)

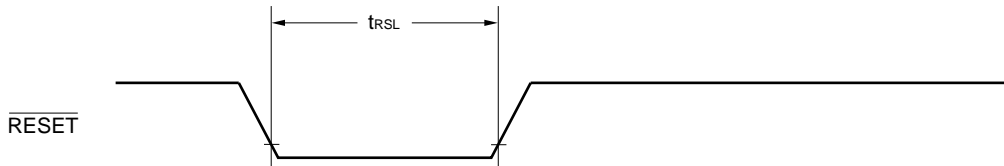
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
CPU clock cycle time (instruction execution time)	t_{CY}	$V_{DD} = 4.5$ to 6.0 V	6.1		180	μs
			21		180	μs
High level width on RLS_{HALT} and RLS_{STOP}	t_{RLSH}		10			μs
Low level width on \overline{RESET}	t_{RSL}		10			μs

Remark $t_{CY} = 8/f_{CC}$ (f_{CC} : frequency of the system clock oscillator)

RLS_{HALT} and RLS_{STOP} input timing



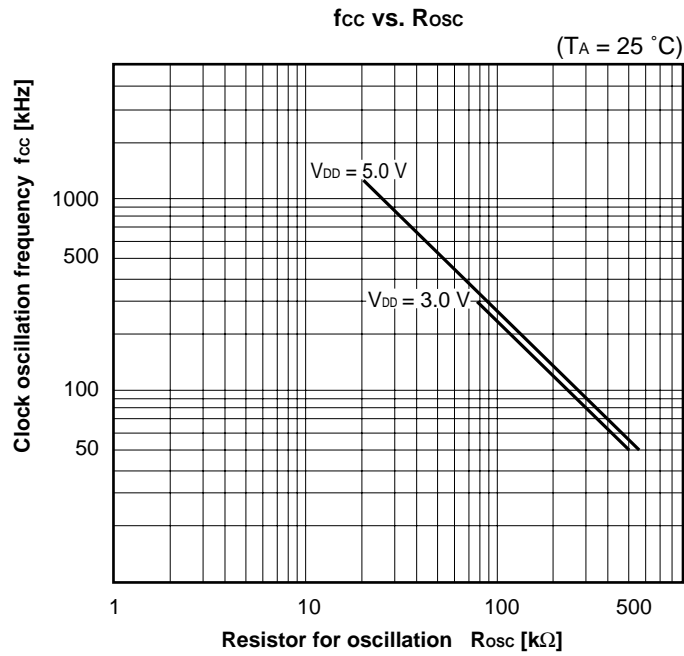
\overline{RESET} input timing



SYSTEM CLOCK OSCILLATOR CHARACTERISTICS ($T_A = -40$ to $+110$ °C)

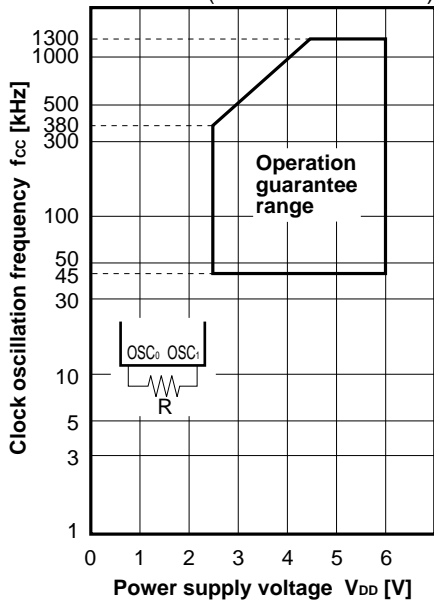
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
System clock oscillation frequency	f _{cc}	V _{DD} = 4.5 to 5.5 V, R _{osc} = 24 kΩ	700	1000	1300	kHz
		V _{DD} = 2.7 to 3.3 V, R _{osc} = 100 kΩ	170	250	330	kHz
		V _{DD} = 2.5 to 6.0 V, R _{osc} = 100 kΩ	120	250	380	kHz

Caution The above conditions do not allow a resistance error.

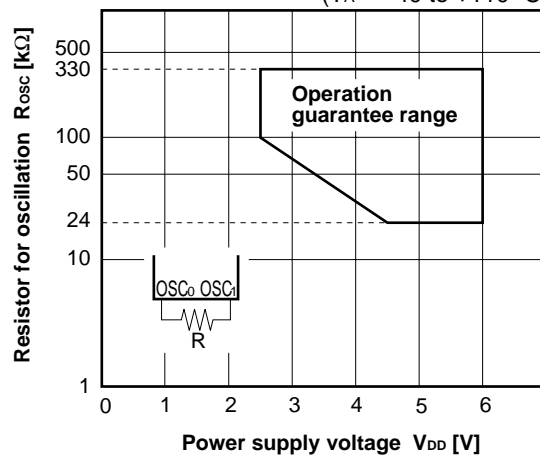


12. CHARACTERISTIC CURVES (REFERENCE)

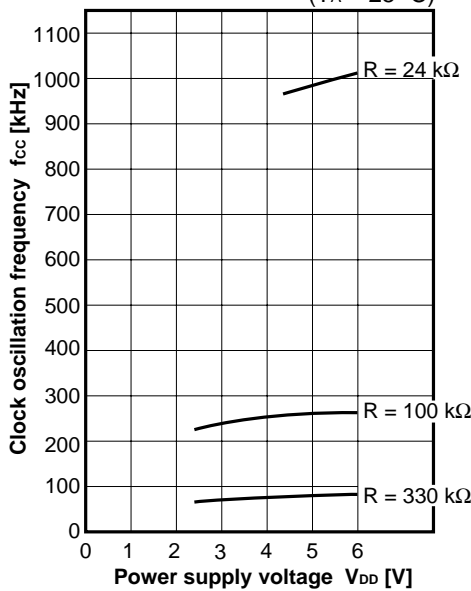
f_{cc} vs. V_{DD} for Operation Guarantee Range
(T_A = -40 to +110 °C)



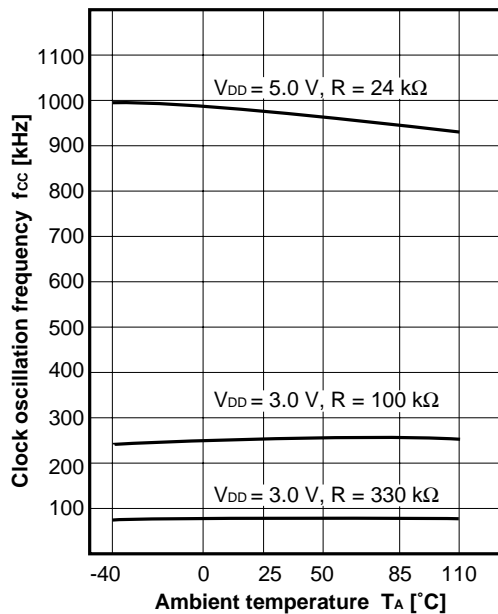
R_{osc} vs. V_{DD} for Operation Guarantee Range
(T_A = -40 to +110 °C)

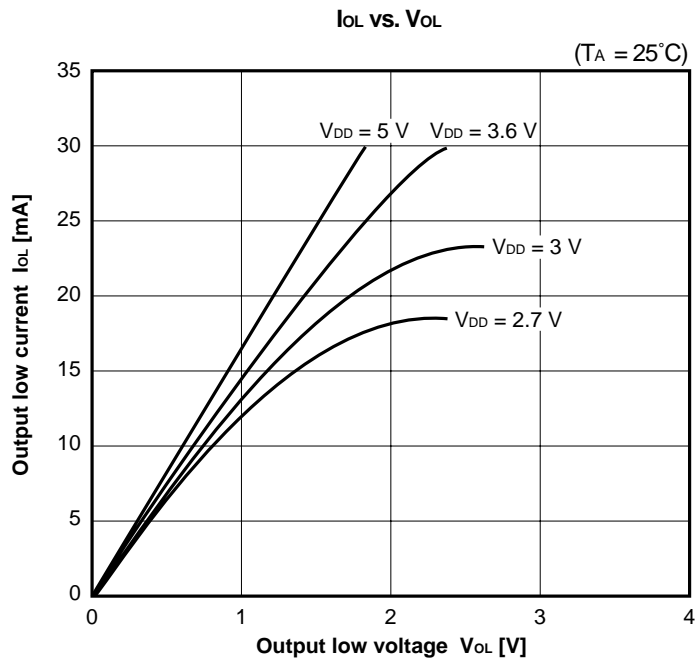
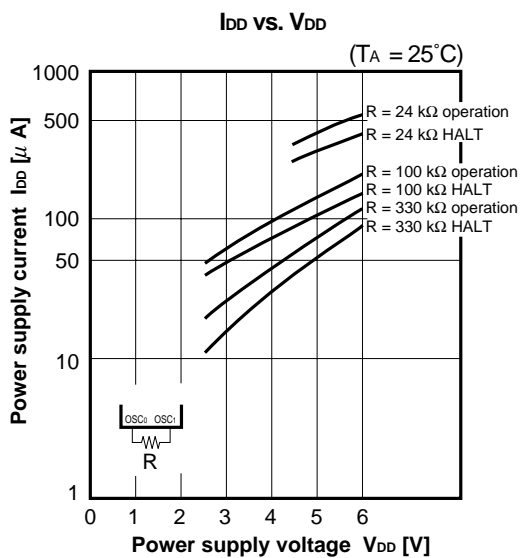


f_{cc} vs. V_{DD}
(T_A = 25 °C)

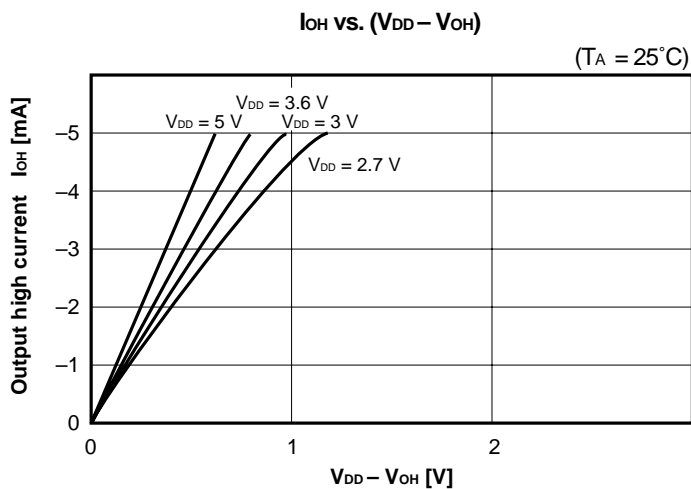


f_{cc} vs. T_A





Caution The maximum absolute rating is 30 mA per pin.

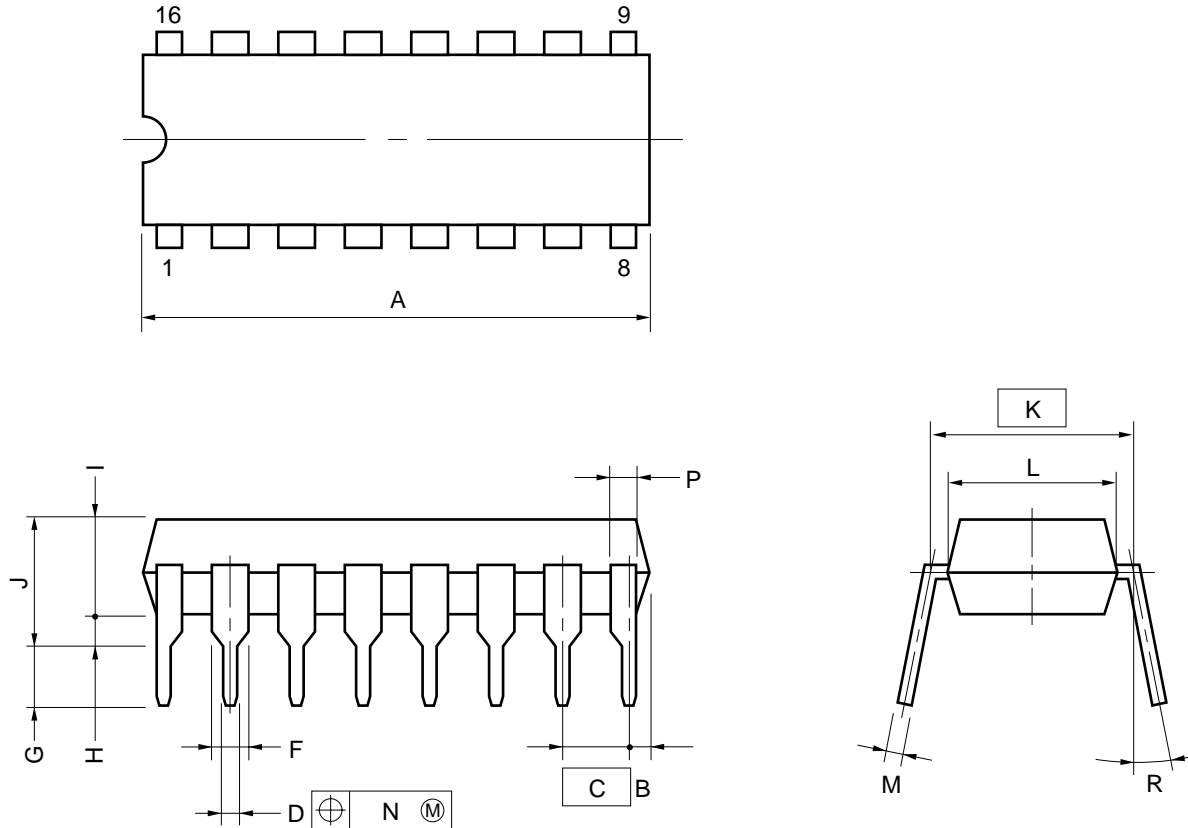


Caution The maximum absolute rating is -5 mA per pin.

13. PACKAGE DRAWINGS

PACKAGE DRAWINGS OF MASS-PRODUCED PRODUCTS (1/2)

16 PIN PLASTIC DIP (300 mil)



NOTES

- 1) Each lead centerline is located within 0.25 mm (0.01 inch) of its true position (T.P.) at maximum material condition.
- 2) Item "K" to center of leads when formed parallel.

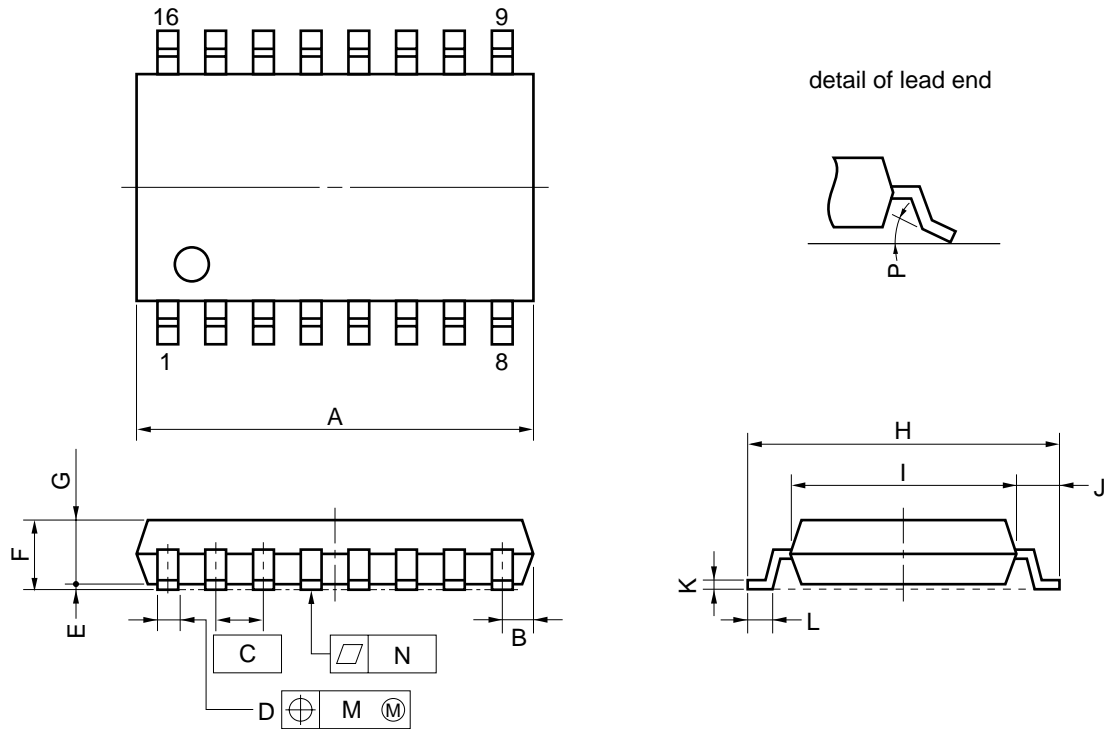
ITEM	MILLIMETERS	INCHES
A	20.32 MAX.	0.800 MAX.
B	1.27 MAX.	0.050 MAX.
C	2.54 (T.P.)	0.100 (T.P.)
D	0.50±0.10	0.020 ^{+0.004} _{-0.005}
F	1.1 MIN.	0.043 MIN.
G	3.5±0.3	0.138±0.012
H	0.51 MIN.	0.020 MIN.
I	4.31 MAX.	0.170 MAX.
J	5.08 MAX.	0.200 MAX.
K	7.62 (T.P.)	0.300 (T.P.)
L	6.5	0.256
M	0.25 ^{+0.10} _{-0.05}	0.010 ^{+0.004} _{-0.003}
N	0.25	0.01
P	1.1 MIN.	0.043 MIN.
R	0~15°	0~15°

P16C-100-300B-1

Caution The ES is different from the corresponding mass-produced products in shape and material. See "ES PACKAGE DRAWINGS (1/2)."

PACKAGE DRAWINGS OF MASS-PRODUCED PRODUCTS (2/2)

16 PIN PLASTIC SOP (300 mil)



NOTE

Each lead centerline is located within 0.12 mm (0.005 inch) of its true position (T.P.) at maximum material condition.

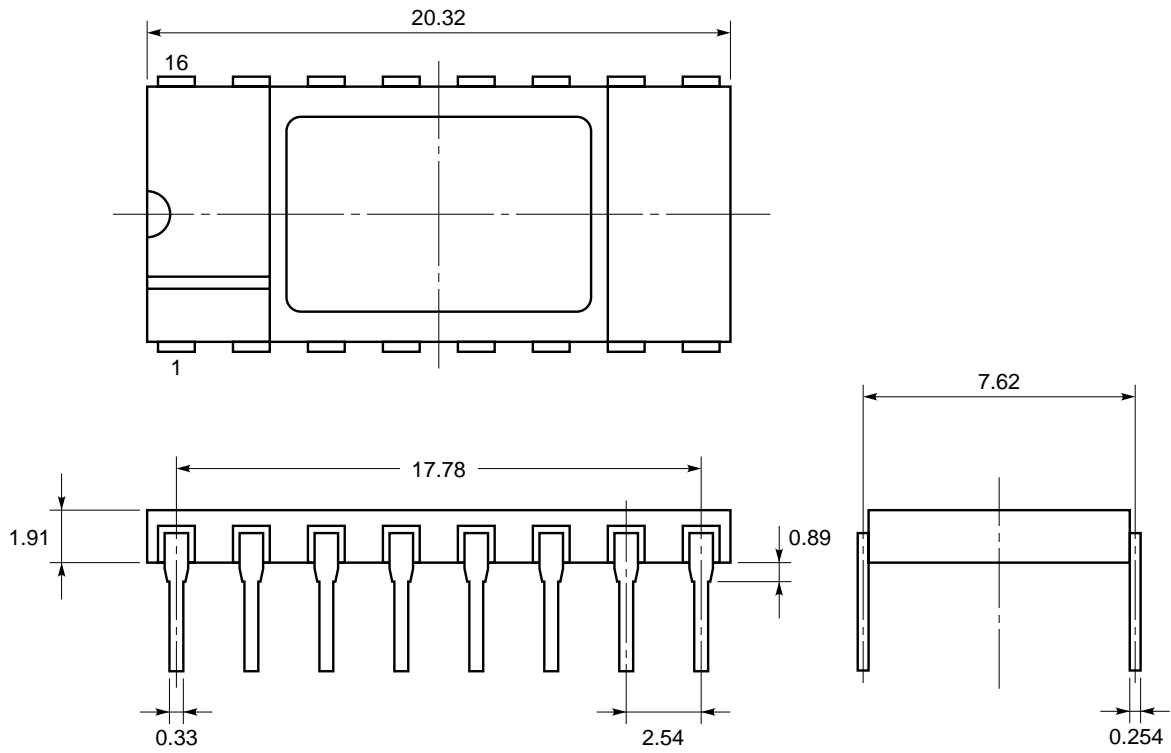
ITEM	MILLIMETERS	INCHES
A	10.46 MAX.	0.412 MAX.
B	0.78 MAX.	0.031 MAX.
C	1.27 (T.P.)	0.050 (T.P.)
D	0.40 ^{+0.10} _{-0.05}	0.016 ^{+0.004} _{-0.003}
E	0.1±0.1	0.004±0.004
F	1.8 MAX.	0.071 MAX.
G	1.55	0.061
H	7.7±0.3	0.303±0.012
I	5.6	0.220
J	1.1	0.043
K	0.20 ^{+0.10} _{-0.05}	0.008 ^{+0.004} _{-0.002}
L	0.6±0.2	0.024 ^{+0.008} _{-0.009}
M	0.12	0.005
N	0.10	0.004
P	3° ^{+7°} _{-3°}	3° ^{+7°} _{-3°}

P16GM-50-300B-4

Caution The ES is different from the corresponding mass-produced products in shape and material. See "ES PACKAGE DRAWINGS (2/2)."

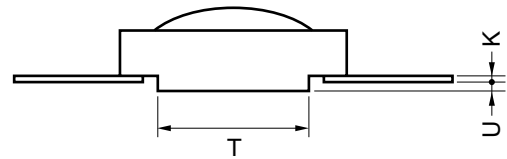
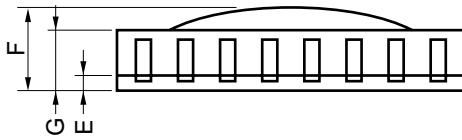
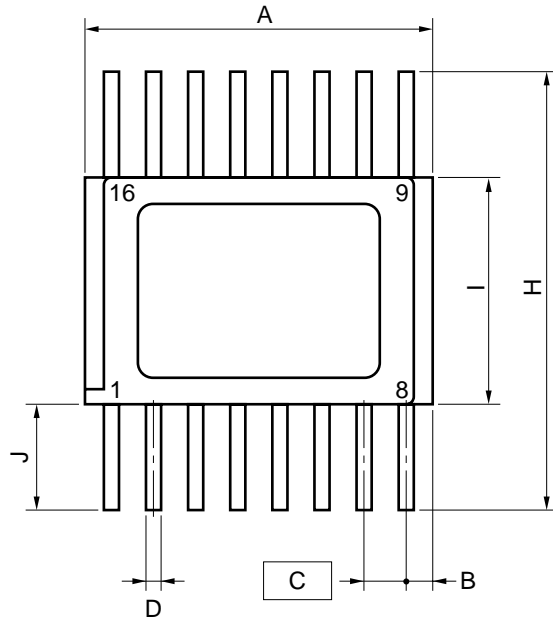
ES PACKAGE DRAWINGS (1/2)

16 PIN PLASTIC SOP (300 mil) (UNIT: mm)



ES PACKAGE DRAWINGS (2/2)

16 PIN CERAMIC SOP (FOR ES)



ITEM	MILLIMETERS	INCHES
A	10.16	0.40
B	1.02 MAX.	0.041 MAX.
C	1.27 (T.P.)	0.05 (T.P.)
D	0.43	0.017
E	0.48 MAX.	0.019 MAX.
F	2.54 MAX.	0.10 MAX.
G	1.7	0.067
H	12.1	0.476
I	6.9	0.272
J	2.35	0.093
K	0.13	0.005
T	4.8	0.189
U	0.025 MIN.	0.0 MIN.

X16B-50B-1

14. RECOMMENDED SOLDERING CONDITIONS

The conditions listed below shall be met when soldering the μPD17107(A1).

For details of the recommended soldering conditions, refer to our document *SMD Surface Mount Technology Manual* (IEI-1207).

Please consult with our sales offices in case any other soldering process is used, or in case soldering is done under different conditions.

Table 14-1 Soldering Conditions for Surface-Mount Devices

μPD17107GS(A1)-xxx: 16-pin plastic SOP (300 mil)

Soldering process	Soldering conditions	Recommended conditions
Infrared ray reflow	Peak package's surface temperature: 235 °C Reflow time: 30 seconds or less (210 °C or more) Maximum allowable number of reflow processes: 2 <Cautions> (1) Do not start reflow-soldering the device if its temperature is higher than the room temperature because of a previous reflow soldering. (2) Do not use water for flux cleaning before a second reflow soldering.	IR35-00-2
VPS	Peak package's surface temperature: 215 °C Reflow time: 40 seconds or less (200 °C or more) Maximum allowable number of reflow processes: 2 <Cautions> (1) Do not start reflow-soldering the device if its temperature is higher than the room temperature because of a previous reflow soldering. (2) Do not use water for flux cleaning before a second reflow soldering.	VP15-00-2
Partial heating method	Terminal temperature: 300 °C or less Heat time: 3 seconds or less (for each side of device)	—

Caution Do not apply two or more different soldering methods to one chip (except for partial heating method for terminal sections).

Table 14-2 Soldering Conditions for Through Hole Mount Devices

μPD17107CX(A1)-xxx: 16-pin plastic DIP (300 mil)

Soldering process	Soldering conditions
Wave soldering (Only for terminal sections)	Solder temperature: 260 °C or less Flow time: 10 seconds or less
Partial heating method	Terminal temperature: 300 °C or less Heat time: 3 seconds or less (for each terminal)

Caution In wave soldering, apply solder only to the terminal section. Care must be taken that jet solder does not come in contact with the main body of the package.

APPENDIX DEVELOPMENT TOOLS

The following support tools are available for developing programs for the μPD17107(A1).

Hardware

Name	Description
In-circuit emulator [IE-17K IE-17K-ET ^{Note 1} EMU-17K ^{Note 2}]	The IE-17K, IE-17K-ET, and EMU-17K are in-circuit emulators applicable to the 17K series. The IE-17K and IE-17K-ET are connected to the PC-9800 series (host machine) or IBM PC/AT™ through the RS-232-C interface. The EMU-17K is inserted into the extension slot of the PC-9800 series (host machine). Use the system evaluation board (SE board) corresponding to each product together with one of these in-circuit emulators. <i>SIMPLEHOST</i> ®, a man machine interface, implements an advanced debug environment. The EMU-17K also enables user to check the contents of the data memory in real time.
SE board (SE-17107)	The SE-17107 is an SE board for the μPD17107, μPD17107L, or μPD17P107. It is used solely for evaluating the system. It is also used for debugging in combination with the in-circuit emulator.
Emulation probe (EP-17103CX)	The EP-17103CX is an emulation probe for the μPD17103, μPD17103L, μPD17P103, μPD17107, μPD17107L, or μPD17P107.
PROM Programmer [AF-9703 ^{Note 3} AF-9704 ^{Note 3} AF-9705 ^{Note 3} AF-9706 ^{Note 3}]	The AF-9703, AF-9704, AF-9705, and AF-9706 are PROM writers for the μPD17P107. Use one of these PROM writers with the program adapter, AF-9799, to program the μPD17P107.
Programmer adapter (AF-9799 ^{Note 3})	The AF-9799 is a socket unit for the μPD17P103, μPD17P104, μPD17P107, and μPD17P108. It is used with the AF-9703, AF-9704, AF-9705, or AF-9706.

- Notes**
1. Low-end model, operating on an external power supply
 2. The EMU-17K is a product of IC Co., Ltd. Contact IC Co., Ltd. (Tokyo, 03-3447-3793) for details.
 3. The AF-9703, AF-9704, AF-9705, AF-9706, and AF-9799 are products of Ando Electric Co., Ltd. Contact Ando Electric Co., Ltd. (Tokyo, 03-3733-1151) for details.

Software

Name	Description	Host machine	OS		Distribution media	Part number
17K series assembler (AS17K)	AS17K is an assembler applicable to the 17K series. In developing μPD17107(A1) programs, AS17K is used in combination with a device file (AS17103).	PC-9800 series	MS-DOS™		5.25-inch, 2HD	μS5A10AS17K
					3.5-inch, 2HD	μS5A13AS17K
		IBM PC/AT	PC DOS™		5.25-inch, 2HC	μS7B10AS17K
					3.5-inch, 2HC	μS7B13AS17K
Device file (AS17103)	AS17103 contains a device file for the μPD17107(A1) and μPD17P107. It is used together with the assembler (AS17K) which is applicable to the 17K series.	PC-9800 series	MS-DOS		5.25-inch, 2HD	μS5A10AS17103 Note
					3.5-inch, 2HD	μS5A13AS17103 Note
		IBM PC/AT	PC DOS		5.25-inch, 2HC	μS7B10AS17103 Note
					3.5-inch, 2HC	μS7B13AS17103 Note
Support software (SIMPLEHOST)	SIMPLEHOST, running on the Windows™, provides man-machine-interface in developing programs by using a personal computer and the in-circuit emulator.	PC-9800 series	MS-DOS	Windows	5.25-inch, 2HD	μS5A10IE17K
					3.5-inch, 2HD	μS5A13IE17K
		IBM PC/AT	PC DOS		5.25-inch, 2HC	μS7B10IE17K
					3.5-inch, 2HC	μS7B13IE17K

Note μSxxxxAS17103 contains a device file for the μPD17103, μPD17104, μPD17107, μPD17108, μPD17103L, μPD17104L, μPD17107L, or μPD17108L.

Remark The following table lists the versions of the operating systems described in the above table.

OS	Versions
MS-DOS	Ver. 3.30 to Ver. 5.00A Note
PC DOS	Ver. 3.1 to Ver. 5.0 Note
Windows	Ver. 3.0 to Ver. 3.1

Note MS-DOS versions 5.00 and 5.00A and PC DOS Ver. 5.0 are provided with a task swap function. This function, however, cannot be used in these software packages.

Cautions on CMOS Devices

① **Countermeasures against static electricity for all MOSs**

Caution When handling MOS devices, take care so that they are not electrostatically charged.

Strong static electricity may cause dielectric breakdown in gates. When transporting or storing MOS devices, use conductive trays, magazine cases, shock absorbers, or metal cases that NEC uses for packaging and shipping. Be sure to ground MOS devices during assembling. Do not allow MOS devices to stand on plastic plates or do not touch pins.

Also handle boards on which MOS devices are mounted in the same way.

② **CMOS-specific handling of unused input pins**

Caution Hold CMOS devices at a fixed input level.

Unlike bipolar or NMOS devices, if a CMOS device is operated with no input, an intermediate-level input may be caused by noise. This allows current to flow in the CMOS device, resulting in a malfunction. Use a pull-up or pull-down resistor to hold a fixed input level. Since unused pins may function as output pins at unexpected times, each unused pin should be separately connected to the V_{DD} or GND pin through a resistor.

If handling of unused pins is documented, follow the instructions in the document.

③ **Statuses of all MOS devices at initialization**

Caution The initial status of a MOS device is unpredictable when power is turned on.

Since characteristics of a MOS device are determined by the amount of ions implanted in molecules, the initial status cannot be determined in the manufacture process. NEC has no responsibility for the output statuses of pins, input and output settings, and the contents of registers at power on. However, NEC assures operation after reset and items for mode setting if they are defined.

When you turn on a device having a reset function, be sure to reset the device first.

SIMPLEHOST is a registered trademark of NEC Corporation.
MS-DOS and Windows are trademarks of Microsoft Corporation.
PC/AT and PC DOS are trademarks of IBM Corporation.

The export of this product from Japan is regulated by the Japanese government. To export this product may be prohibited without governmental license, the need for which must be judged by the customer. The export or re-export of this product from a country other than Japan may also be prohibited without a license from that country. Please call an NEC sales representative.

No part of this document may be copied or reproduced in any form or by any means without the prior written consent of NEC Corporation. NEC Corporation assumes no responsibility for any errors which may appear in this document.

NEC Corporation does not assume any liability for infringement of patents, copyrights or other intellectual property rights of third parties by or arising from use of a device described herein or any other liability arising from use of such device. No license, either express, implied or otherwise, is granted under any patents, copyrights or other intellectual property rights of NEC Corporation or others.

While NEC Corporation has been making continuous effort to enhance the reliability of its semiconductor devices, the possibility of defects cannot be eliminated entirely. To minimize risks of damage or injury to persons or property arising from a defect in an NEC semiconductor device, customer must incorporate sufficient safety measures in its design, such as redundancy, fire-containment, and anti-failure features.

NEC devices are classified into the following three quality grades:

“Standard”, “Special”, and “Specific”. The Specific quality grade applies only to devices developed based on a customer designated “quality assurance program” for a specific application. The recommended applications of a device depend on its quality grade, as indicated below. Customers must check the quality grade of each device before using it in a particular application.

Standard: Computers, office equipment, communications equipment, test and measurement equipment, audio and visual equipment, home electronic appliances, machine tools, personal electronic equipment and industrial robots

Special: Transportation equipment (automobiles, trains, ships, etc.), traffic control systems, anti-disaster systems, anti-crime systems, safety equipment and medical equipment (not specifically designed for life support)

Specific: Aircrafts, aerospace equipment, submersible repeaters, nuclear reactor control systems, life support systems or medical equipment for life support, etc.

The quality grade of NEC devices in “Standard” unless otherwise specified in NEC's Data Sheets or Data Books. If customers intend to use NEC devices for applications other than those specified for Standard quality grade, they should contact NEC Sales Representative in advance.

Anti-radioactive design is not implemented in this product.