

Description

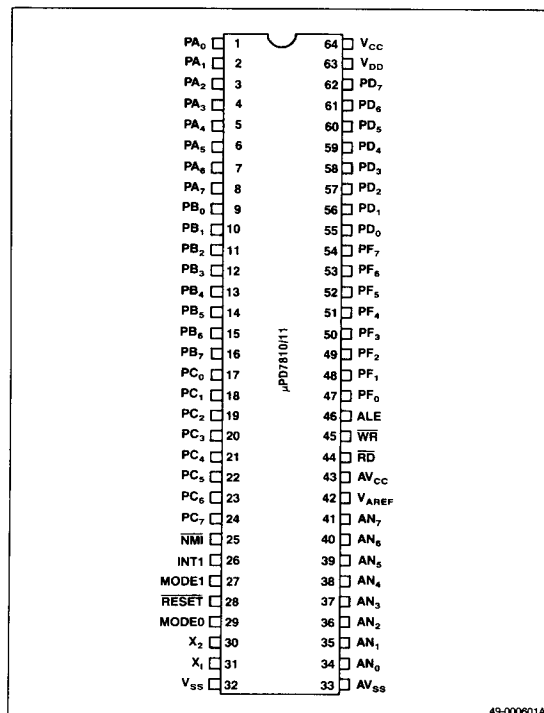
The μ PD7810 and μ PD7811 single-chip microcomputers integrate sophisticated on-chip peripheral functionality normally provided by external components. The device's internal 16-bit ALU and data paths, combined with a powerful instruction set and addressing, make the μ PD7810/11 appropriate in data processing as well as control applications. The devices integrate a 16-bit ALU, 4K-ROM, 256-byte RAM with an 8-channel A/D converter, a multifunction 16-bit timer/event counter, two 8-bit timers, a USART, and two zero-cross detect inputs on a single die, allowing their use in fast, high end processing applications. This involves analog signal interface and processing.

The μ PD7811 is the mask-ROM high volume production device embedded with custom customer program. The μ PD7810 is a ROM-less version for prototyping and small volume production. The μ PD78PG11E is a piggy-back EPROM version for design development.

Features

- ☐ NMOS silicon gate technology requiring +5 V power supply
- ☐ Complete single-chip microcomputer
 - 16-bit ALU
 - 4K x 8 ROM
 - 256-byte RAM
- ☐ 44 I/O lines
- ☐ Two zero-cross detect inputs
- ☐ Two 8-bit timers
- ☐ Expansion capabilities
 - 8085A bus-compatible
 - 60K-byte external memory address range
- ☐ 8-channel, 8-bit A/D converter
 - Autoscan mode
 - Channel select mode
- ☐ Full duplex USART
 - Synchronous and asynchronous
- ☐ 153 instructions
 - 16-bit arithmetic, multiply and divide
- ☐ 1 μ s instruction cycle time (12 MHz operation)
- ☐ Prioritized interrupt structure
 - 3 external
 - 8 internal
- ☐ Standby function
- ☐ On-chip clock generator
- ☐ 64-pin plastic QUIP or shrink DIP

Pin Configuration



Ordering Information

Part Number	Package Type	Max Frequency of Operation
μ PD7810G-36	64-pin plastic QUIP	12 MHz
μ PD7811G-36		
μ PD7810CW	64-pin plastic shrink DIP	12 MHz
μ PD7811CW		

Pin Identification

No.	Symbol	Function
1-8	PA ₀ -PA ₇	Port A I/O
9-16	PB ₀ -PB ₇	Port B I/O
17	PC ₀ /TxD	Port C I/O line 0/Transmit data output
18	PC ₁ /Rx _D	Port C I/O line 1/Receive data input
19	PC ₂ /SCK	Port C I/O line 2/Serial clock I/O
20	PC ₃ /TI/ INT ₂	Port C I/O line 3/Timer input/Interrupt request 2 input
21	PC ₄ /TO	Port C I/O line 4/Timer output
22	PC ₅ /CI	Port C I/O line 5/Counter input
23, 24	PC ₆ , PC ₇ / CO ₀ , CO ₁	Port C I/O lines 6, 7/Counter outputs 0, 1
25	NMI	Nonmaskable interrupt input
26	INT ₁	Interrupt request 1 input
27	MODE1/M ₁	Mode 1 input/Memory cycle 1 output
28	RESET	Reset input
29	MODE0/ I/O/M	Mode 0 input/I/O/Memory output
30, 31	X ₂ , X ₁	Crystal connections 1, 2
32	V _{SS}	Ground
33	AV _{SS}	Port T threshold voltage input
34-41	AN ₀ -AN ₇	A/D converter analog inputs 0-7
42	V _{AREF}	A/D converter reference voltage
43	AV _{CC}	A/D converter power supply
44	RD	Read strobe output
45	WR	Write strobe output
46	ALE	Address latch enable output
47-54	PF ₀ -PF ₇	Port F I/O/Expansion memory address bus (bits 8-15)
55-62	PD ₀ -PD ₇	Port D I/O/Expansion memory address/data bus
63	V _{DD}	RAM backup power supply
64	V _{CC}	5 V power supply

Pin Functions

PA₀-PA₇ [Port A]

Port A is an 8-bit three-state port. Each bit is independently programmable as either input or output. Reset makes all lines of port A inputs.

PB₀-PB₇ [Port B]

Port B is an 8-bit three-state port. Each bit is independently programmable as either input or output. Reset makes all lines of port B inputs.

PC₀-PC₇ [Port C]

Port C is an 8-bit three-state port. Each bit is independently programmable as either input or output. Alternatively, the lines of port C can be used as control lines for the USART and timer. Reset puts all lines of port C in port mode, input.

TxD [Transmit Data]. Serial data output terminal.

RxD [Receive Data]. Serial data input terminal.

SCK [Serial Clock]. Output for the serial clock when internal clock is used. Input for serial clock when external clock is used.

TI [Timer Input]. Timer input terminal.

INT₂ [Interrupt Request 2]. Falling-edge-triggered, maskable interrupt input terminal and AC-input, zero-cross detection terminal.

TO [Timer Output]. The output of TO is a square wave with a frequency determined by the timer/counter.

CI [Counter Input]. External pulse input to timer/event counter.

CO₀, CO₁ [Counter Outputs 0, 1]. Programmable rectangular wave outputs based on timer/event counter.

PD₀-PD₇ [Port D]

Port D is an 8-bit three-state port. It can be programmed as either 8 bits of input or 8 bits of output. When external expansion memory is used, port D acts as the multiplexed address/data bus.

PF₀-PF₇ [Port F]

Port F is an 8-bit three-state port. Each bit is independently programmable as an input or output. When external expansion memory is used, port F outputs the high-order address bits.

AN₀-AN₇

These are the eight analog inputs to the A/D converter. AN₄-AN₇ can also be used as a digital input for falling edge detection.

AV_{SS} [A/D Converter Power Ground]

AV_{SS} is the ground potential for the A/D converter power supply.

NMI [Nonmaskable Interrupt]

Falling-edge-triggered nonmaskable interrupt input.

INT1 [Interrupt Request 1]

INT1 is a rising-edge-triggered, maskable interrupt input. It is also an AC-input, zero-cross detection terminal.

RESET [Reset]

When the RESET input is brought low, it initializes the μPD7810/11.

MODE1, MODE0 [Mode 1, 0]

The MODE1 and MODE0 inputs select the memory expansion mode. MODE1 also outputs the M1 signal during each opcode fetch. MODE0 outputs the I/O/M signal.

VAREF [A/D Converter Reference]

VAREF set the upper limit for the A/D converter's conversion range.

AVCC [A/D Converter Power]

This is the power supply voltage for the A/D converter.

RD [Read Strobe]

The RD output goes low to gate data from external devices onto the data bus. RD goes high during reset.

WR [Write Strobe]

The WR output goes low to indicate that the data bus holds valid data. It is a strobe signal for external memory or I/O write operations. WR goes high during reset.

ALE [Address Latch Enable]

The ALE output latches the address signal to the output of PD₀-PD₇.

X1, X2 [Crystal Connections 1, 2]

X1 and X2 are the system clock crystal oscillator terminals. X1 is the input for an external clock.

VSS [Ground]

Ground potential.

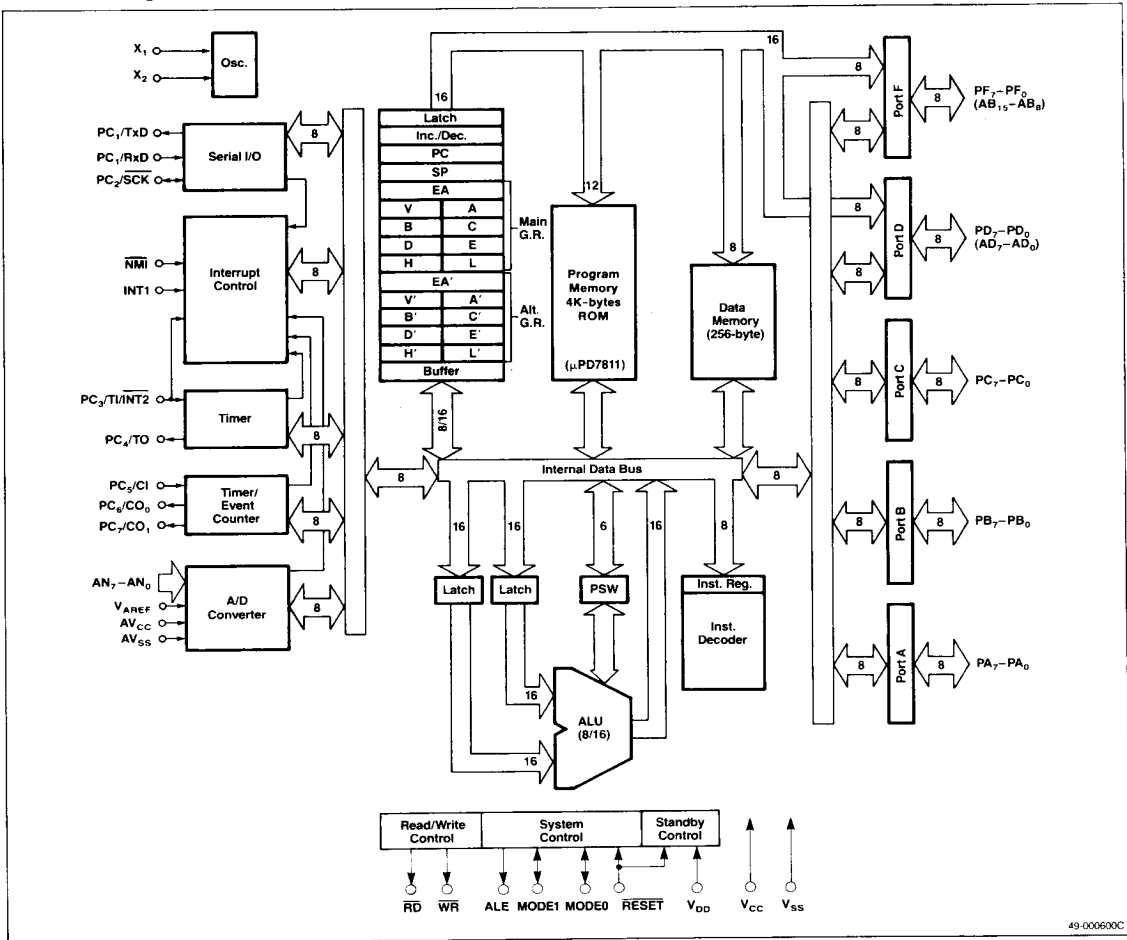
VDD [Backup Power]

Backup power for on-chip RAM.

VCC [Power Supply]

+5 V power supply.

Block Diagram



49-000600C

Functional Description

Memory Map

The μPD7811 can directly address up to 64K bytes of memory. Except for the on-chip ROM (0-4095) and RAM (65280-65535), any memory location can be used as ROM or RAM. The memory map, figure 1, defines the 0 to 64K byte memory space for the μPD7811.

Input/Output

The μPD7810/11 has 8 analog input lines (AN₀-AN₇), 44 digital I/O lines, five 8-bit ports (port A, port B, port C, port D, port F), and 4 input lines (AN₄-AN₇).

Analog Input Lines. AN₀-AN₇ are configured as analog input lines for on-chip A/D converter.

Port A, Port B, Port C, Port F. Each line of these ports can be individually programmed as an input or output. When used as I/O ports, all have latched outputs and high-impedance inputs.

Port D. Port D can be programmed as a byte input or a byte output.

AN₄-AN₇. The high order analog input lines, AN₄-AN₇, can be used as digital input lines for falling edge detection.

Control Lines. Under software control, each line of port C can be configured individually to provide control lines for the serial interface, timer, and timer/counter.

Memory Expansion. In addition to the single-chip operation mode, the μPD7811 has four memory expansion modes. Under software control, port D can provide a multiplexed low-order address and data bus; port F can provide a high-order address bus. Table 1 shows the relation between memory expansion modes and the pin configurations of port D and port F.

Table 1. Memory Expansion Modes and Port Configurations

Memory Expansion	Port Configuration	
None	Port D	I/O port
	Port F	I/O port
256 Bytes	Port D	Multiplexed address/data bus
	Port F	I/O port
4K Bytes	Port D	Multiplexed address/data bus
	Port F ₀ -F ₃	Address bus
	Port F ₄ -F ₇	I/O port
16K Bytes	Port D	Multiplexed address/data bus
	Port F ₀ -F ₅	Address bus
	Port F ₆ -F ₇	I/O port
60K Bytes	Port D	Multiplexed address/data bus
	Port F	Address bus

Timers

There are two 8-bit timers. The timers may be programmed independently or may be cascaded and used as an 8-bit timer with 8-bit prescaler. The timer can be software set to increment at intervals of four machine cycles (1 μs at 12 MHz operation) or 128 machine cycles (32 μs at 12 MHz), or to increment on receipt of a pulse at TI. Figure 2 shows the block diagram for the timer.

Timer/Event Counter

The 16-bit multifunctional timer/event counter (figure 3) can be used for the following operations:

- Interval timer
- External event counter
- Frequency measurement
- Pulse width measurement
- Programmable square-wave output

Figure 1. Memory Map

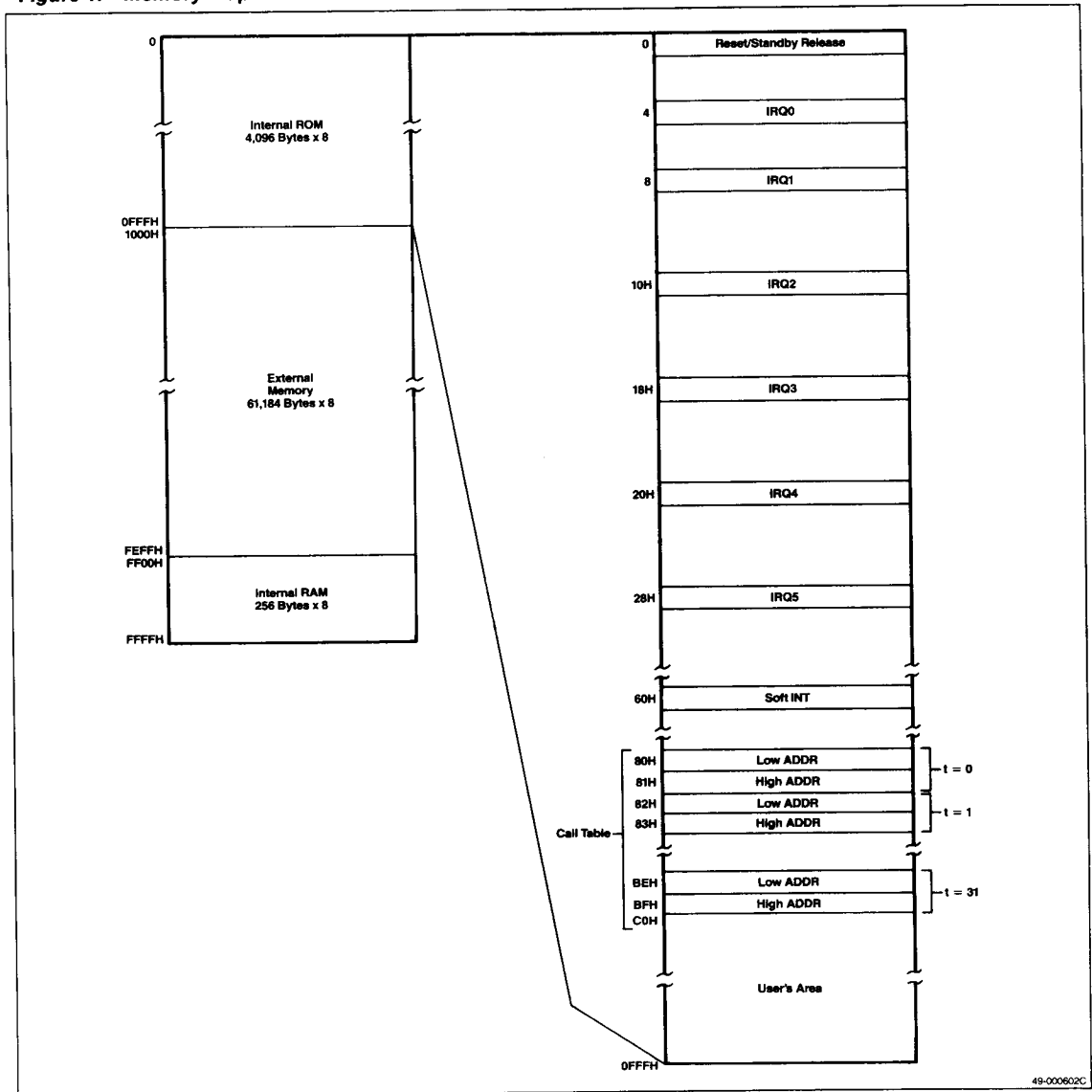


Figure 2. Timer Block Diagram

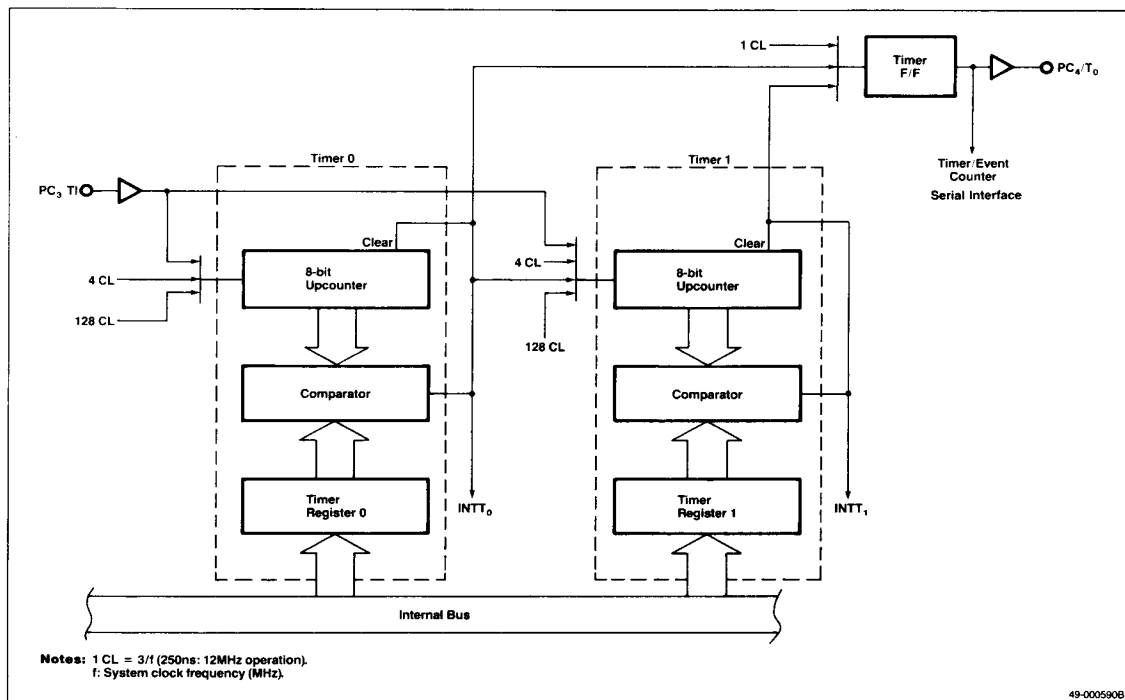
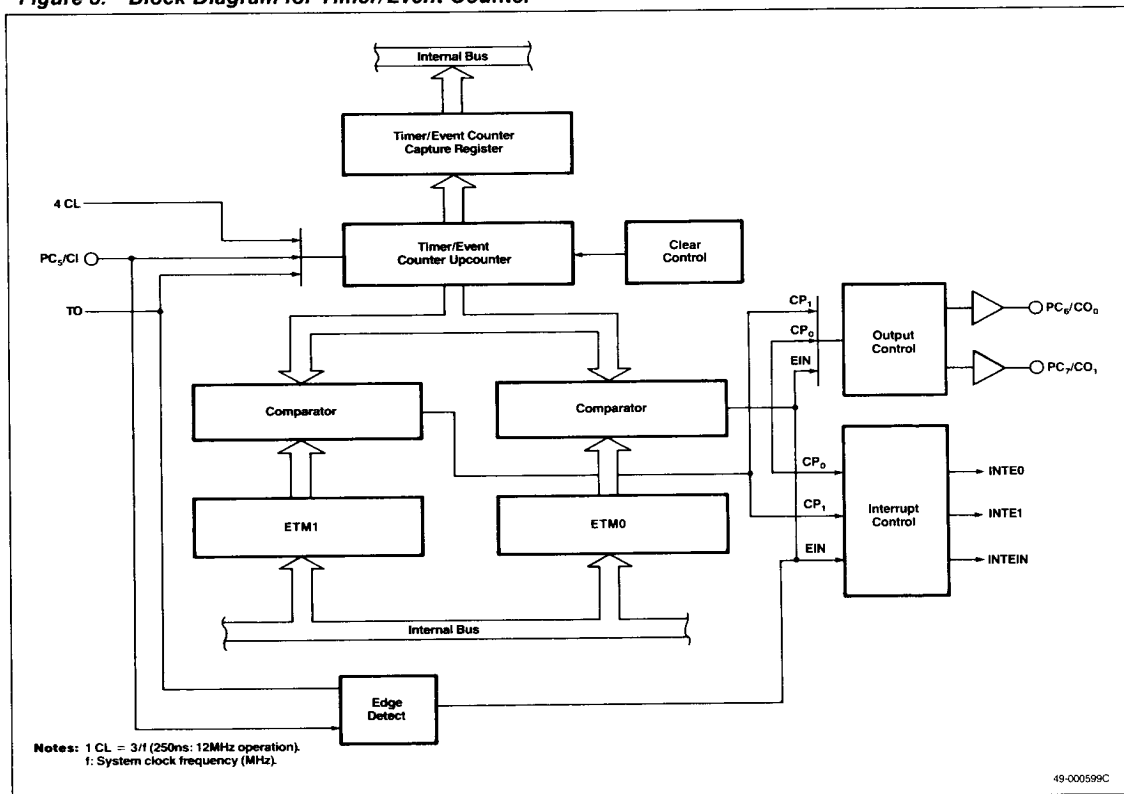


Figure 3. Block Diagram for Timer/Event Counter



8-Bit A/D Converter

- 8 input channels
- 4 conversion result registers
- 2 powerful operation modes
 - Autoscan mode
 - Channel select mode
- Successive approximation technique
- Absolute accuracy: ± 1.5 LSB ($\pm 0.6\%$)
- Conversion range: 0 to 5 V
- Conversion time: 48 μ s
- Interrupt generation

Analog/Digital Converter

The μPD7810/11 features an 8-bit, high speed, high accuracy A/D converter. The A/D converter is made up of a 256-resistor ladder and a successive approximation register (SAR). There are four conversion result registers (CR₀-CR₃). The 8-channel analog input may be operated in either of two modes. In the select mode, the conversion value of one analog input is sequentially stored in CR₀-CR₃. In the scan mode, the upper four channels or the lower four channels may be specified. Then those four channels will be consecutively selected and the conversion results stored sequentially in the four conversion result registers. Figure 4 shows the block diagram for the A/D converter.

Interrupt Structure

There are 11 interrupt sources. Three are external interrupts and eight are internal. The following, table 2, shows 11 interrupt sources divided into six priority levels. See figure 5.

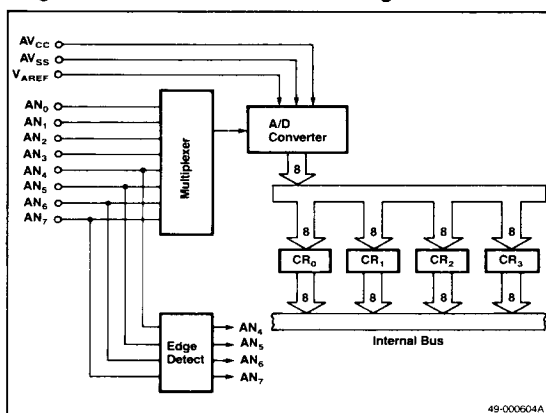
Standby Function

The standby function saves the top 32 bytes of RAM with backup power (V_{DD}) if the main power (V_{CC}) fails. On power-up, you can check the standby flag (SB) to determine whether recovery was made from standby mode or from a cold start.

Table 2. Interrupt Sources

Interrupt Request	Interrupt Address	Type of Interrupt	Internal/ External
IRQ0	4	NMI (Nonmaskable interrupt)	Ext
IRQ1	8	INTT0 (Coincidence signal from timer 0)	Int
		INTT1 (Coincidence signal from timer 1)	
IRQ2	16	INT1 (Maskable interrupt)	Ext
		INT2 (Maskable interrupt)	
IRQ3	24	INTE0 (Coincidence signal from timer/event counter)	Int
		INTE1 (Coincidence signal from timer/event counter)	
IRQ4	32	INTEIN (Falling signal of CI and TO counter)	Int/Ext
		INTAD (A/D converter interrupt)	
IRQ5	40	INTSR (Serial receive interrupt)	Int
		INST (Serial send interrupt)	

Figure 4. A/D Converter Block Diagram



Universal Serial Interface

The serial interface can operate in one of three modes: synchronous, asynchronous, and I/O interface. The I/O interface mode transfers data MSB first, for easy interfacing to certain NEC peripheral devices. Synchronous and asynchronous modes transfer data LSB first. Synchronous operation offers two modes of data reception: search and nonsearch. In the search mode, data is transferred one bit at a time from the serial register to the receive buffer. This allows a software search for a sync character. In the nonsearch mode, data transfer from the serial register to the transmit buffer occurs eight bits at a time. Figure 6 shows the universal serial interface block diagram.

Figure 5. Interrupt Structure Block Diagram

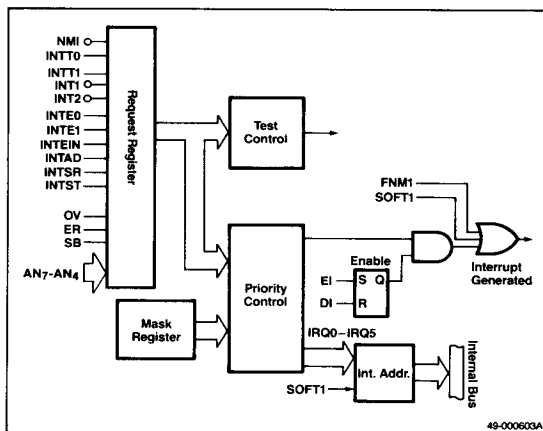
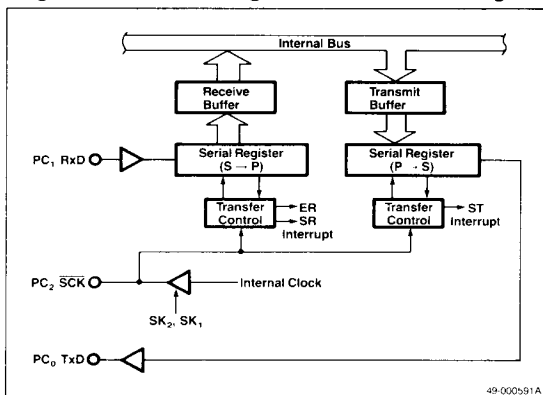


Figure 6. Universal Signal Interface Block Diagram



Zero-Crossing Detector

The INT1 and $\overline{\text{INT2}}$ terminals (used common to T1 and PC₃) can detect the zero-crossing point of low-frequency AC signals. When driven directly, these pins respond as a normal digital input. Figure 7 shows the zero-crossing detection circuitry.

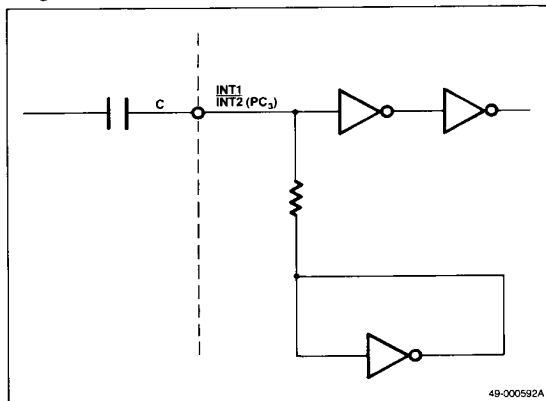
The zero-crossing detection capability allows you to make the 50-60 Hz power signal the basis for system timing and to control voltage phase-sensitive devices.

To use the zero-cross detection mode, an AC signal of approximately 1-3 V AC (peak-to-peak) and a maximum frequency of 1 kHz is coupled through an external capacitor to the INT1 and $\overline{\text{INT2}}$ pins.

For the INT1 pin, the internal digital state is sensed as a 0 until the rising edge crosses the average DC level, when it becomes a 1 and INT1 interrupt is generated.

For the $\overline{\text{INT2}}$ pin, the state is sensed as a 1 until the falling edge crosses the average DC level, when it becomes a 0 and $\overline{\text{INT2}}$ interrupt is generated.

Figure 7. Zero-Crossing Detection Circuit



Absolute Maximum Ratings

Power supply voltages, V_{CC}	-0.5 V to +7.0 V
V_{DD}	-0.5 V to +7.0 V
AV_{CC}	-0.5 V to +7.0 V
AV_{SS}	-0.5 V to +0.5 V
Input voltage, V_I	-0.5 V to +7.0 V
Output voltage, V_O	-0.5 V to +7.0 V
Reference input voltage, V_{AREF}	-0.5 V to V_{CC}
Operating temperature, T_{OPR} $10 \text{ MHz} \leq f_{XTAL} \leq 12 \text{ MHz}$	-10°C to +70°C
$f_{XTAL} \leq 10 \text{ MHz}$	-40°C to -85°C
Storage temperature, T_{STG}	-65°C to +150°C

Comment: Exposing the device to stresses above those listed in absolute maximum ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Operating Conditions

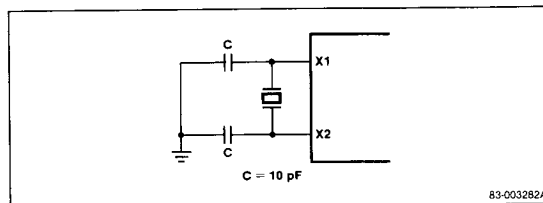
Oscillating Frequency	T_A	V_{CC}, AV_{CC}
$f_{XTAL} \leq 10 \text{ MHz}$	-40°C to +85°C	+5.0 V $\pm 10\%$
$10 \text{ MHz} \leq f_{XTAL} \leq 12 \text{ MHz}$	-10°C to +70°C	+5.0 V $\pm 5\%$

Capacitance

$T_A = 25^\circ\text{C}; V_{CC} = V_{DD} = V_{SS} = 0 \text{ V}$

Parameter	Symbol	Limits			Unit	Test Conditions
		Min	Typ	Max		
Capacitance	C_I			10	pF	$Af_c = 1 \text{ MHz}$. Unmeasured pins returned to 0 V.
Output capacitance	C_O			20	pF	
I/O capacitance	C_{IO}			20	pF	

Recommended XTAL Oscillation Circuit



DC Characteristics

$T_A = -10^\circ\text{C}$ to $+70^\circ\text{C}$; $V_{CC} = +5.0\text{ V} \pm 5\%$; $V_{SS} = 0\text{ V}$; $V_{DD} = V_{CC} - 0.8\text{ V}$ to V_{CC}

Parameter	Symbol	Limits			Unit	Test Conditions
		Min	Typ	Max		
Input low voltage	V_{IL}	0		0.8	V	
Input high voltage	V_{IH1}	2.0		V_{CC}	V	All except SCK, RESET, X1 and X2
	V_{IH2}	$0.8 V_{CC}$		V_{CC}	V	SCK, X1, X2
	V_{IH3}	$0.8 V_{DD}$		V_{CC}	V	RESET
Output low voltage	V_{OL}			0.45	V	$I_{OL} = 2.0\text{ mA}$
Output high voltage	V_{OH}	2.4			V	$I_{OH} = -200\text{ }\mu\text{A}$
Data retention voltage	V_{DDDR}	3.2			V	$V_{CC} = 0\text{ V}$; RESET = V_{IL}
Input current	I_I			± 200	μA	INT1, TI(PC3); $+0.45\text{ V} \leq V_I < V_{CC}$
Input leakage current	I_{LI}			± 10	μA	All except INT, TI(PC3) $0\text{ V} \leq V_I \leq V_{CC}$
Output leakage current	I_{LO}			± 10	μA	$+0.45\text{ V} \leq V_O \leq V_{CC}$
AV_{CC} supply current	I_{CC}	6	12		mA	
V_{DD} supply current	I_{DD}	1.5	3.5		mA	$T_A = -40$ to $+85^\circ\text{C}$
			3.2		mA	$V_{CC} = V_{DD} = 5\text{ V}$ $T_A = -10$ to $+70^\circ\text{C}$
V_{CC} supply current	I_{CC}	150	220		mA	$T_A = -40$ to $+85^\circ\text{C}$; $V_{CC} = V_{DD} = 5\text{ V}$

Serial Operation

Parameter	Symbol	Limits		Unit	Test Conditions
		Min	Max		
SCK cycle time	t_{CYK}	1		μs	SCK input (1)
			500	ns	(2)
			2	μs	SCK output
SCK width low	t_{KKL}	750		ns	SCK input(1)
			200	ns	SCK input (2)
			900	ns	SCK output
SCK width high	t_{KKH}	750		ns	SCK input (1)
			200	ns	SCK input (2)
			900	ns	SCK output
RxD set-up time to SCK $\uparrow$	t_{RXK}	80		ns	(1)
RxD hold time after SCK $\uparrow$	t_{KRX}		80	ns	(1)
SCK $\downarrow$ TxD delay time	t_{KTX}		210	ns	(1)

Note:

- (1) 1x baud rate in asynchronous, synchronous, or I/O interface mode.
- (2) 16x baud rate or 64x baud rate in asynchronous mode.

Zero-Cross Characteristics

Parameter	Symbol	Limits		Unit	Test Conditions
		Min	Max		
Zero-cross detection input	V_{ZX}	1	3	V ac, p-p	Ac coupled
Zero-cross accuracy	A_{ZX}		± 135	mV	60-Hz sine wave
Zero-cross detection input frequency	f_{ZX}	0.05	1	kHz	

AC Characteristics

Read/Write Operation

$V_{SS} = 0\text{ V}$, $V_{CC} - 0.8\text{ V} \leq V_{DD} \leq V_{CC}$

Parameter	Symbol	Limits				Unit	Test Conditions (1)
		$f_{XTAL} = 10\text{ MHz}$		$f_{XTAL} = 12\text{ MHz}$			
		Min	Max	Min	Max		
RESET pulse width	t_{RP}	6.0		5.0		μs	
Interrupt pulse width	t_{IP}	3.6		3.0		μs	
Counter input pulse width	t_{CI}	600		500		ns	Event counter mode
	t_{CI}	4.8		4.0		μs	Pulse width measurement mode
Timer input pulse width	t_{TI}	600		500		ns	
X1 Input cycle time	t_{CYC}	100	250	83	250	ns	
Address set-up to ALE ↓	t_{AL}	100		65		ns	
Address hold after ALE ↓	t_{LA}	70		50		ns	
Address to RD ↓ delay time	t_{AR}	200		150		ns	
$\overline{\text{RD}}$ ↓ to address floating	t_{AFR}		20		20	ns	
Address to data input	t_{AD}		480		360	ns	
ALE ↓ to data input	t_{LDR}		300		215	ns	
$\overline{\text{RD}}$ ↓ to data input	t_{RD}		250		180	ns	
ALE ↓ to RD ↓ delay time	t_{LR}	50		35		ns	
Data hold time to $\overline{\text{RD}}$ ↑	t_{RDH}	0		0		ns	
$\overline{\text{RD}}$ ↑ to ALE ↑ delay time	t_{RL}	150		115		ns	
$\overline{\text{RD}}$ width low	t_{RR}	350		280		ns	Data read
		650		530		ns	Opcode fetch
ALE width high	t_{LL}	160		125		ns	
$\overline{\text{M1}}$ setup time to ALE ↓	t_{ML}	100		65		ns	
$\overline{\text{M1}}$ hold time after ALE ↓	t_{LM}	70		50		ns	
$\overline{\text{IO}}/\text{M}$ setup time to ALE ↓	t_{IL}	100		65		ns	
$\overline{\text{IO}}/\text{M}$ hold time after ALE ↓	t_{LI}	70		50		ns	
Address to $\overline{\text{WR}}$ ↓ delay	t_{AW}	200		150		ns	
ALE ↓ to data output	t_{LDW}		210		195	ns	
$\overline{\text{WR}}$ ↓ to data output	t_{WD}		100		100	ns	
ALE ↓ to $\overline{\text{WR}}$ ↓ delay	t_{LW}	50		35		ns	
Data set-up time to $\overline{\text{WR}}$ ↑	t_{DW}	300		230		ns	
Data hold time to $\overline{\text{WR}}$ ↑	t_{WDH}	130		95		ns	
$\overline{\text{WR}}$ ↑ to ALE ↑ delay time	t_{WL}	150		115		ns	
$\overline{\text{WR}}$ width low	t_{WW}	350		280		ns	

Note:

(1) Load capacitance: $C_L = 150\text{ pF}$.

A/D Converter Characteristics

T_A = -10°C to +70°C; V_{CC} = AV_{CC} = 5.0 V ±5%; V_{SS} = AV_{SS} = 0 V;
V_{AREF} = AV_{CC} - 0.5 V to AV_{CC}.

Parameter	Symbol	Limits			Unit	Test Conditions
		Min	Typ	Max		
Resolution		8			Bits	
Absolute accuracy				0.4% ± 1/2	LSB	T _A = -10°C to +50°C
				0.6% ± 1/2	LSB	T _A = -10°C to +70°C (Note 1)
Conversion time	t _{CONV}	576			t _{CYC}	83 ns ≤ t _{CYC} ≤ 110 ns
		432			t _{CYC}	110 ns ≤ t _{CYC} ≤ 170 ns
Sampling time	t _{SAMP}	96			t _{CYC}	83 ns ≤ t _{CYC} ≤ 110 ns
		72			t _{CYC}	110 ns ≤ t _{CYC} ≤ 170 ns
Analog input voltage	V _{IA}	0		V _{AREF}	V	
Analog resistance	R _{AN}		1000		MΩ	
Analog reference current	I _{AREF}	0.2	0.5	1.5	mA	

Note:

(1) In case of f_{X_{TAL}} ≤ 10 MHz, T_A = -40°C to +85°C.

Bus Timing Depending on t_{CYC}

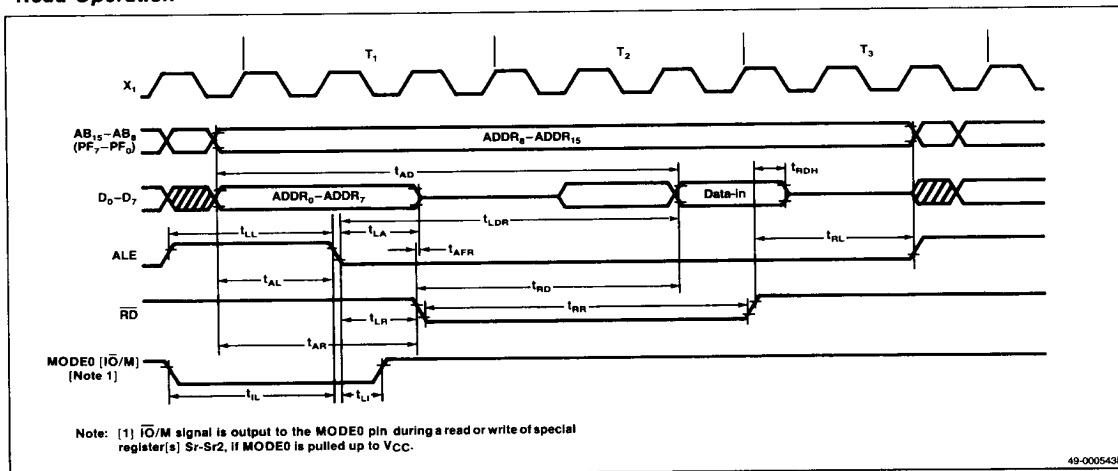
Symbol	Calculating Expression	Min/Max
t _{RP}	60T	Min
t _{TI}	6T	Min
t _{CI} (2)	6T	Min
t _{CI} (3)	48T	Min
t _{IP}	36T	Min
t _{AL}	2T - 100	Min
t _{LA}	T - 30	Min
t _{AR}	3T - 100	Min
t _{AD}	7T - 220	Max
t _{LDR}	5T - 200	Max
t _{RD}	4T - 150	Max
t _{LR}	T - 50	Min
t _{RL}	2T - 50	Min
t _{RR}	4T - 50 (Data Read)	Min
	7T - 50 (Opcode Fetch)	
t _{LL}	2T - 40	Min
t _{AW}	3T - 100	Min
t _{LDW}	T + 110	Max
t _{LW}	T - 50	Min
t _{DW}	4T - 100	Min
t _{WDH}	2T - 70	Min
t _{WL}	2T - 50	Min
t _{WW}	4T - 50	Min
t _{CYK}	20T (SCK input)(1)	Min
	24T (SCK output)	
t _{KKL}	10T - 80 (SCK input)(1)	Min
	12T - 100 (SCK output)	
t _{KKH}	10T - 80 (SCK input)(1)	Min
	12T - 100 (SCK output)	

Note:

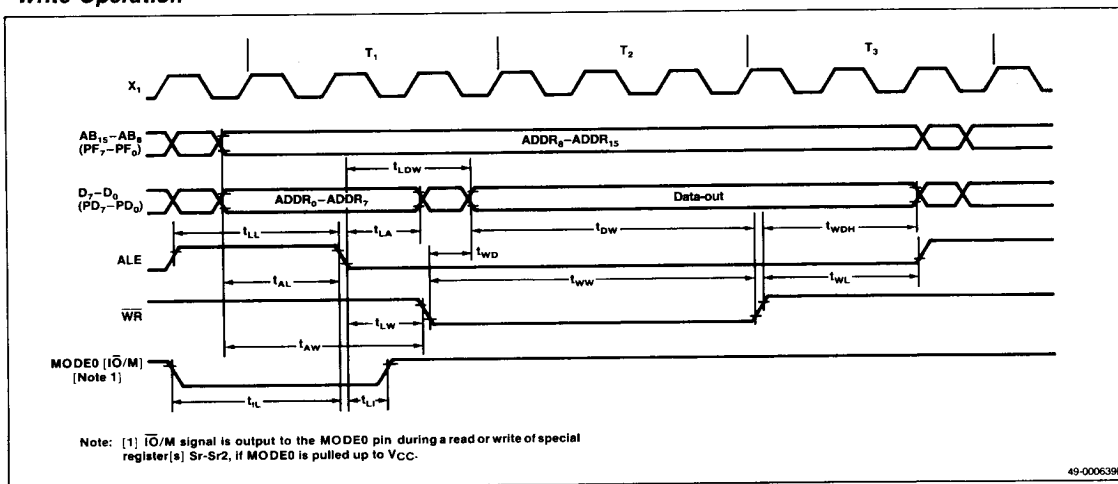
- (1) 1x Baud rate in asynchronous, synchronous, or I/O interface mode.
T = t_{CYC} = 1/f_{X_{TAL}}.
The items not included in this list are independent of oscillator frequency (f_{X_{TAL}}).
- (2) Event counter mode.
- (3) Pulse width measurement mode.

Timing Waveforms

Read Operation

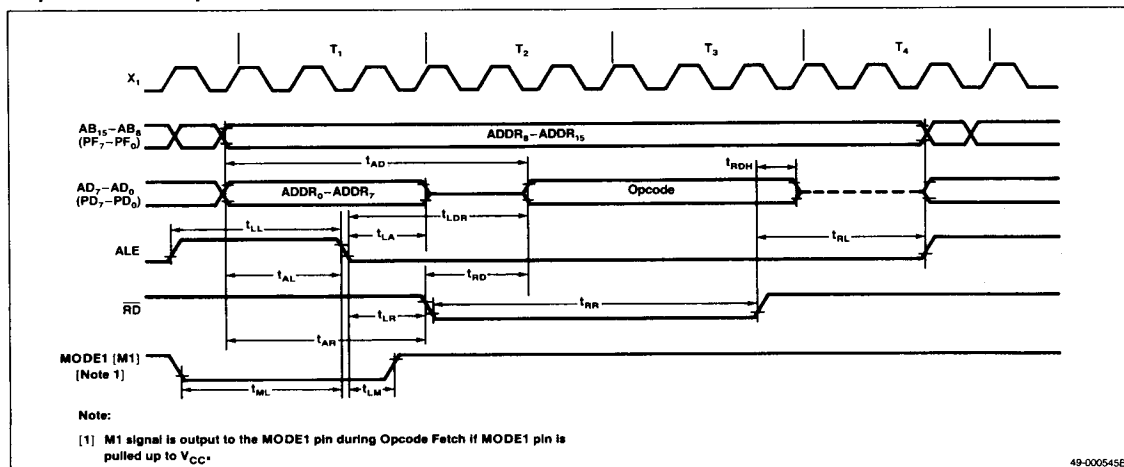


Write Operation

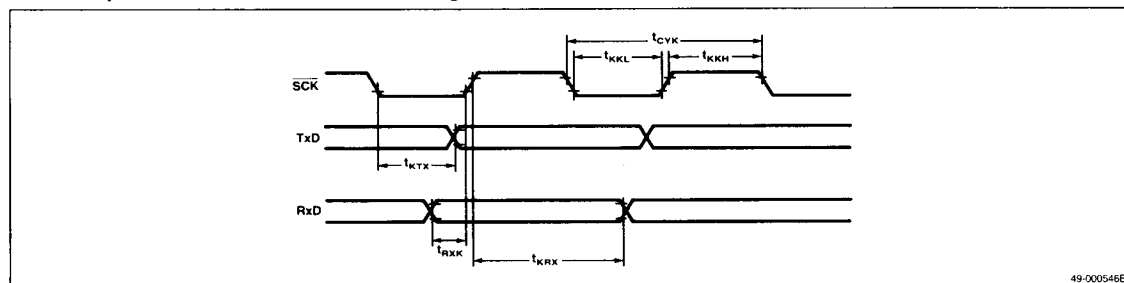


Timing Waveforms (cont)

Opcode Fetch Operation



Serial Operation Transmit/Receive Timing



Operand Format/Description

Format	Description
r	V, A, B, C, D, E, H, L
r1	EAH, EAL, B, C, D, E, H, L
r2	A, B, C
sr	PA, PB, PC, PD, PF, MKH, MKL, ANM, SMH, SML, EOM, ETMM, TMM, MM, MCC, MA, MB, MC, MF, TxB, TM ₀ , TM ₁
sr1	PA, PB, PC, PD, PF, MKH, MKL, ANM, SMH, EOM, TMM, RXB, CR0, CR1, CR2, CR3
sr2	PA, PB, PC, PD, PF, MKH, ANM, MKL, SMH, EOM, TMM
sr3	ETM ₀ , ETM ₁
sr4	ECNT, ECPT
rp	SP, B, D, H
rp1	V, B, D, H, EA
rp2	SP, B, D, H, EA
rp3	B, D, H
rpa	B, D, H, D+, H+, D-, H-
rpa1	B, D, H
rpa2	B, D, H, D+, H+, D-, H-, D + byte, H + A, H + B, H + EA, H + byte
rpa3	D, H, D + +, H + +, D + byte, H + A, H + B, H + EA, H + byte
wa	8-Bit immediate data
word	16-Bit immediate data
byte	8-Bit immediate data
bit	3-Bit immediate data
f	CY, HC, Z
irf	FNMI, FT0, FT1, F1, F2, FE0, FE1, FEIN, FAD, FSR, FST, ER, OV, AN ₄ , AN ₅ , AN ₆ , AN ₇ , SB

Instruction Set Symbol Definitions

Symbol	Description
←	Transfer direction, result
∧	Logical product (logical AND)
∨	Logical sum (logical OR)
⊕	Exclusive OR
—	Complement
•	Concatenation

Remarks

1. sr-sr4 (special register)

PA = Port A	ECNT = Timer/Event Counter Upcounter
PB = Port B	ECPT = Timer/Event Counter Capture
PC = Port C	
PD = Port D	
PF = Port F	
MA = Mode A	ETMM = Timer/Event Counter Mode
MB = Mode B	EOM = Timer/Event Counter Output Mode
MC = Mode C	
MCC = Mode Control C	
MF = Mode F	
MM = Memory Mapping	TxB = TX Buffer
TM ₀ = Timer Register 0	RxB = RX Buffer
TM ₁ = Timer Register 1	SMH = Serial Mode High
TMM = Timer Mode	SML = Serial Mode Low
ETM ₀ = Timer/Event Counter Register 0	MKH = Mask High
ETM ₁ = Timer/Event Counter Register 1	MKL = Mask Low
	ANM = A/D Channel Mode
	CR ₀ = A/D Conversion Result 0-3 to CR ₃

2. rp-rp3 (register pair)

SP = Stack Pointer	H = HL
B = BC	V = VA
D = DE	EA = Extended Accumulator

3. rpa-rpa3 (rp addressing)

B = (BC)	D + + = (DE) ++
D = (DE)	H + + = (HL) ++
H = (HL)	D + byte = (DE) + byte
D + = (DE) +	H + A = (HL) + (A)
H - = (HL) -	H + B = (HL) + (B)
D - = (DE) -	H + EA = (HL) + (EA)
H - = (HL) -	H + byte = (HL) + byte

4. f (flag)

CY = Carry	HC = Half Carry	Z = Zero
------------	-----------------	----------

5. irf (interrupt flag)

NMI = NMI* Input	FEIN = INTFEIN
	FAD = INTFAD
FT0 = INTFT0	FSR = INTFSR
FT1 = INTFT1	FST = INTFST
F1 = INTF1	ER = Error
F2 = INTF2	OV = Overflow
FE0 = INTFE0	AN ₄ to AN ₇ = Analog Input 4-7
FE1 = INTFE1	SB = Standby

Instruction Set

Mnemonic		Operand	Operation	Operation Code																Bytes	State(I)	Skip Condition
				B1				B2				B3				B4						
8-Bit Data Transfer																						
MOV	r1,A	(r1) ← (A)		0	0	0	1	1	T ₂	T ₁	T ₀									4	1	
	A, r1	(A) ← (r1)		0	0	0	0	1	T ₂	T ₁	T ₀									4	1	
	*sr,A	(sr) ← (A)		0	1	0	0	1	1	0	1	1	S ₅	S ₄	S ₃	S ₂	S ₁	S ₀	10	2		
	*A,sr1	(A) ← (sr1)		0	1	0	0	1	1	0	0	1	S ₅	S ₄	S ₃	S ₂	S ₁	S ₀	10	2		
	r,word	(r) ← (word)		0	1	1	1	0	0	0	0	0	0	1	1	0	1	R ₂	R ₁	R ₀	17	4
Low addr High addr																						
word,r		(word) ← (r)		0	1	1	1	0	0	0	0	0	1	1	1	1	R ₂	R ₁	R ₀	17	4	
MVI	*r,byte	(r) ← byte set L1 if r = A set L0 if r = L		0	1	1	0	1	R ₂	R ₁	R ₀	Data				High addr				7	2	L1 = 1 and r = A L0 = 1 and r = L
	sr2,byte	(sr2) ← byte		0	1	1	0	0	1	0	0	S ₃	0	0	0	0	S ₂	S ₁	S ₀	14	3	
	Data																					
MVIW	*wa,byte	((V)←(wa)) ← byte		0	1	1	1	0	0	0	1	Offset								13	3	
	Data																					
MOVX	*rpa1,byte	(rpa1) ← byte		0	1	0	0	1	0	A ₁	A ₀	Data								10	2	
	*wa	((V)←(wa)) ← A		0	1	1	0	0	0	1	1	Offset								10	2	
	LDAW	*wa (A) ← ((V)←(wa))		0	0	0	0	0	0	0	1	Offset								10	2	
	STAX	*rpa2 (rpa2) ← (A)		A ₃	0	1	1	1	A ₂	A ₁	A ₀	Data (2)				7/13(3)				2	2	
	LDAX	*rpa2 (A) ← ((rpa2))		A ₃	0	1	0	1	A ₂	A ₁	A ₀	Data (2)				7/13(3)				2	2	
EXX	(B) ↔ (B'), (C) ↔ (C'), (D) ↔ (D') (E) ↔ (E'), (H) ↔ (H'), (L) ↔ (L')		0	0	0	1	0	0	0	0	1									4	1	
EXA	(V) ↔ (V'), (A) ↔ (A'), (EA) ↔ (EA')		0	0	0	1	0	0	0	0	0									4	1	
EXH	(H) ↔ (H'), (L) ↔ (L')		0	1	0	1	0	0	0	0	0									4	1	
16-Bit Data Transfer																						
BLOCK	D	((DE) ← ((HL)), (DE) ← (DE + 1), (HL) ← (HL) + 1, (C) ← (C) - 1 End if borrow		0	0	1	1	0	0	0	1									13 x (C + 1)	1	
DMOV	rp3, EA	(rp3 _L) ← (EAL), (rp3 _H) ← (EAH)		1	0	1	1	0	1	P ₁	P ₀									4	1	
	EA, rp3	(EA) ← (rp3 _L), (EAH) ← (rp3 _H)		1	0	1	0	0	1	P ₁	P ₀									4	1	

Instruction Set (cont)

Instruction Set (Cont)																					
Mnemonic	Operand	Operation	Operation Code																Bytes	Skip Condition	
			B1				B2				B3				B4						
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	State(I)		
16-Bit Data Transfer (cont)																					
DMOV	sr3, EA (sr3) ← (EA)		0	1	0	0	1	0	0	0	1	1	0	1	0	0	1	U ₀	14	2	
	EA, sr4 (EA) ← (sr4)		0	1	0	0	1	0	0	0	1	1	0	0	0	0	V ₁	V ₀	14	2	
SBCD	word (word) ← (C), (word + 1) ← (B)		0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	20	4	
	Low addr																High addr				
SDED	word (word) ← (E), (word + 1) ← (D)		0	1	1	1	0	0	0	0	0	0	1	0	1	1	1	0	20	4	
	Low addr																High addr				
SHLD	word (word) ← (L), (word + 1) ← (H)		0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	20	4	
	Low addr																High addr				
SSPD	word (word) ← (SP _L), (word + 1) ← (SP _H)		0	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	20	4	
	Low addr																High addr				
STEAX	rpa3 ((rpa3)) ← (EAL), ((rpa3) + 1) ← (EAH)		0	1	0	0	1	0	0	0	1	0	0	1	C ₃	C ₂	C ₁	C ₀	14/20(3)	3	
	Data(4)																				
LBCD	word (C) ← (word), (B) ← (word + 1)		0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	20	4	
	Low addr																High addr				
LDED	word (E) ← (word), (D) ← (word + 1)		0	1	1	1	0	0	0	0	0	0	1	0	1	1	1	1	20	4	
	Low addr																High addr				
LHLD	word (L) ← (word), (H) ← (word + 1)		0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	20	4	
	Low addr																High addr				
LSPD	word (SP _L) ← (word), (SP _H) ← ((word) + 1)		0	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	20	4	
	Low addr																High addr				
LDEAX	rpa3 (EAL) ← ((rpa3)), (EAH) ← ((rpa3) + 1)		0	1	0	0	1	0	0	0	1	0	0	0	C ₃	C ₂	C ₁	C ₀	14/20(3)	3	
	Data(4)																				
PUSH	rp1 ((SP) - 1) ← (rp1 _H), ((SP) - 2) ← (rp1 _L) (SP) ← (SP) - 2		1	0	1	1	0	Q ₂	Q ₁	Q ₀									13	1	
POP	rp1 (rp1 _L) ← (SP), (rp1 _H) ← ((SP) + 1) (SP) ← (SP) + 2		1	0	1	0	0	Q ₂	Q ₁	Q ₀									10	1	
LXI	*rp2, word (rp2) ← (word) set L0 if rp2 = H		0	P ₂	P ₁	P ₀	0	1	0	0									10	3	
	High byte																				
TABLE	(C) ← ((PC)+3+(A)), B ← ((PC)+3+(A)+1)		0	1	0	0	1	0	0	0	1	0	1	0	1	0	0	0	17	2	
8-Bit Arithmetic (Register)																					
ADD	A, r (A) ← (A) + (r)		0	1	1	0	0	0	0	0	1	1	0	0	0	R ₂	R ₁	R ₀	8	2	
	r, A (r) ← (r) + (A)		0	1	1	0	0	0	0	0	0	1	0	0	0	R ₂	R ₁	R ₀	8	2	
ADC	A, r (A) ← (A) + (r) + (CY)		0	1	1	0	0	0	0	0	1	1	0	1	0	R ₂	R ₁	R ₀	8	2	
	r, A (r) ← (r) + (A) + (CY)		0	1	1	0	0	0	0	0	0	1	0	1	0	R ₂	R ₁	R ₀	8	2	

Instruction Set (cont)

Mnemonic	Operand	Operation	Operation Code																Bytes	Skip Condition	
			B1								B2										
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			
8-Bit Arithmetic Register [cont]																					
ADDNC	A,r	(A) ← (A) + (r)	0	1	1	0	0	0	0	0	1	0	1	0	0	R ₂	R ₁	R ₀	8	2	No carry
	r,A	(r) ← (r) + (A)	0	1	1	0	0	0	0	0	0	0	1	0	0	R ₂	R ₁	R ₀	8	2	No carry
SUB	A,r	(A) ← (A) − (r)	0	1	1	0	0	0	0	0	1	1	1	0	0	R ₂	R ₁	R ₀	8	2	
	r,A	(r) ← (r) − (A)	0	1	1	0	0	0	0	0	0	1	1	0	0	R ₂	R ₁	R ₀	8	2	
SBB	A,r	(A) ← (A) − (r) − (CY)	0	1	1	0	0	0	0	0	1	1	1	1	0	R ₂	R ₁	R ₀	8	2	
	r,A	(r) ← (r) − (A) − (CY)	0	1	1	0	0	0	0	0	0	1	1	1	0	R ₂	R ₁	R ₀	8	2	
SUBNB	A,r	(A) ← (A) − (r)	0	1	1	0	0	0	0	0	1	0	1	1	0	R ₂	R ₁	R ₀	8	2	No borrow
	r,A	(r) ← (r) − (A)	0	1	1	0	0	0	0	0	0	0	1	1	0	R ₂	R ₁	R ₀	8	2	No borrow
ANA	A,r	(A) ← (A) ∧ (r)	0	1	1	0	0	0	0	0	1	0	0	0	1	R ₂	R ₁	R ₀	8	2	
	r,A	(r) ← (r) ∧ (A)	0	1	1	0	0	0	0	0	0	0	0	0	1	R ₂	R ₁	R ₀	8	2	
ORA	A,r	(A) ← (A) ∨ (r)	0	1	1	0	0	0	0	0	1	0	0	1	1	R ₂	R ₁	R ₀	8	2	
	r,A	(r) ← (r) ∨ (A)	0	1	1	0	0	0	0	0	0	0	0	1	1	R ₂	R ₁	R ₀	8	2	
XRA	A,r	(A) ← (A) ⊙ (r)	0	1	1	0	0	0	0	0	1	0	0	1	0	R ₂	R ₁	R ₀	8	2	
	r,A	(r) ← (r) ⊙ (A)	0	1	1	0	0	0	0	0	0	0	0	1	0	R ₂	R ₁	R ₀	8	2	
GTA	A,r	(A) − (r) − 1	0	1	1	0	0	0	0	0	1	0	1	0	1	R ₂	R ₁	R ₀	8	2	No borrow
	r,A	(r) − (A) − 1	0	1	1	0	0	0	0	0	0	0	1	0	1	R ₂	R ₁	R ₀	8	2	No borrow
LTA	A,r	(A) − (r)	0	1	1	0	0	0	0	0	1	0	1	1	1	R ₂	R ₁	R ₀	8	2	Borrow
	r,A	(r) − (A)	0	1	1	0	0	0	0	0	0	0	1	1	1	R ₂	R ₁	R ₀	8	2	Borrow
NEA	A,r	(A) − (r)	0	1	1	0	0	0	0	0	1	1	1	0	1	R ₂	R ₁	R ₀	8	2	No zero
	r,A	(r) − (A)	0	1	1	0	0	0	0	0	0	1	1	0	1	R ₂	R ₁	R ₀	8	2	No zero
EQA	A,r	(A) − (r)	0	1	1	0	0	0	0	0	1	1	1	1	1	R ₂	R ₁	R ₀	8	2	Zero
	r,A	(r) − (A)	0	1	1	0	0	0	0	0	0	1	1	1	1	R ₂	R ₁	R ₀	8	2	Zero
ONA	A,r	(A) ∧ (r)	0	1	1	0	0	0	0	0	1	1	0	0	1	R ₂	R ₁	R ₀	8	2	No zero
	OFFA	(A) ∧ (r)	0	1	1	0	0	0	0	0	1	1	0	1	1	R ₂	R ₁	R ₀	8	2	Zero
8-Bit Arithmetic Memory																					
ADDX	rpa	(A) ← (A) + ((rpa))	0	1	1	1	0	0	0	0	1	1	0	0	0	A ₂	A ₁	A ₀	11	2	
ADCX	rpa	(A) ← (A) + ((rpa)) + (CY)	0	1	1	1	0	0	0	0	1	1	0	1	0	A ₂	A ₁	A ₀	11	2	
ADDNCX	rpa	(A) ← (A) + ((rpa))	0	1	1	1	0	0	0	0	1	0	1	0	0	A ₂	A ₁	A ₀	11	2	No carry
SUBX	rpa	(A) ← (A) − ((rpa))	0	1	1	1	0	0	0	0	1	1	1	0	0	A ₂	A ₁	A ₀	11	2	
SBBX	rpa	(A) ← (A) − ((rpa)) − (CY)	0	1	1	1	0	0	0	0	1	1	1	1	0	A ₂	A ₁	A ₀	11	2	
SUBNBX	rpa	(A) ← (A) − ((rpa))	0	1	1	1	0	0	0	0	1	0	1	1	0	A ₂	A ₁	A ₀	11	2	No borrow
ANAX	rpa	(A) ← (A) ∧ ((rpa))	0	1	1	1	0	0	0	0	1	0	0	0	1	A ₂	A ₁	A ₀	11	2	
ORAX	rpa	(A) ← (A) ∨ ((rpa))	0	1	1	1	0	0	0	0	1	0	0	1	1	A ₂	A ₁	A ₀	11	2	

Instruction Set (cont)

Instruction Set (cont.)																				
		Operation Code																Bytes	Skip Condition	
		B1				B2				B3				B4						
Mnemonic	Operand	Operation	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	State(1)	
8-Bit Arithmetic (Memory) (cont.)																				
XRAX	rpa (A) ← (A) ∨ ((rpa))		0	1	1	1	0	0	0	0	1	0	0	1	0	A ₂	A ₁	A ₀	11	
GTAX	rpa (A) ← ((rpa)) − 1		0	1	1	1	0	0	0	0	1	0	1	0	1	A ₂	A ₁	A ₀	11	
LTAX	rpa (A) ← ((rpa))		0	1	1	1	0	0	0	0	1	0	1	1	1	A ₂	A ₁	A ₀	11	
NEAX	rpa (A) ← ((rpa))		0	1	1	1	0	0	0	0	1	1	1	0	1	A ₂	A ₁	A ₀	11	
EQAX	rpa (A) ← ((rpa))		0	1	1	1	0	0	0	0	1	1	1	1	1	A ₂	A ₁	A ₀	11	
ONAX	rpa (A) ∧ ((rpa))		0	1	1	1	0	0	0	0	1	1	0	0	1	A ₂	A ₁	A ₀	11	
OFFAX	rpa (A) ∧ ((rpa))		0	1	1	1	0	0	0	0	1	1	0	1	1	A ₂	A ₁	A ₀	11	
Immediate Data																				
ADI	*A,byte (A) ← (A) + byte		0	1	0	0	0	1	1	0	Data				Data				7	2
	r,byte (r) ← (r) + byte		0	1	1	1	0	1	0	0	0	1	0	0	0	R ₂	R ₁	R ₀	11	3
			Data				Data				Data				Data				3	
	sr2,byte (sr2) ← (sr2) + byte		0	1	1	0	0	1	0	0	S ₃	1	0	0	0	S ₂	S ₁	S ₀	20	3
Data																				
ACI	*A,byte (A) ← (A) + byte + (CY)		0	1	0	1	0	1	1	0	Data				Data				7	2
	r,byte (r) ← (r) + byte + (CY)		0	1	1	0	1	0	0	0	0	1	0	1	0	R ₂	R ₁	R ₀	11	3
			Data				Data				Data				Data				3	
	sr2,byte (sr2) ← (sr2) + byte + (CY)		0	1	1	0	0	1	0	0	S ₃	1	0	1	0	S ₂	S ₁	S ₀	20	3
Data																				
ADINC	*A,byte (A) ← (A) + byte		0	0	1	0	0	1	1	0	Data				Data				7	2
	r,byte (r) ← (r) + byte		0	1	1	1	0	1	0	0	0	0	1	0	0	R ₂	R ₁	R ₀	11	3
			Data				Data				Data				Data				3	
	sr2,byte (sr2) ← (sr2) + byte		0	1	1	0	0	1	0	0	S ₃	0	1	0	0	S ₂	S ₁	S ₀	20	3
Data																				
SUI	*A,byte (A) ← (A) − byte		0	1	1	0	0	1	1	0	Data				Data				7	2
	r,byte (r) ← (r) − byte		0	1	1	1	0	1	0	0	0	1	1	0	0	R ₂	R ₁	R ₀	11	3
			Data				Data				Data				Data				3	
	sr2,byte (sr2) ← (sr2) − byte		0	1	1	0	0	1	0	0	S ₃	1	1	0	0	S ₂	S ₁	S ₀	20	3
Data																				
SBI	*A,byte (A) ← (A) − byte − (CY)		0	1	1	1	0	1	1	0	Data				Data				7	2
	r,byte (r) ← (r) − byte − (CY)		0	1	1	1	0	1	0	0	0	1	1	1	0	R ₂	R ₁	R ₀	11	3
			Data				Data				Data				Data				3	
	sr2,byte (sr2) ← (sr2) − byte − (CY)		0	1	1	0	0	1	0	0	S ₃	1	1	1	0	S ₂	S ₁	S ₀	20	3
Data																				

Instruction Set (cont)

Mnemonic	Operand	Operation	Operation Code																Bytes	Skip Condition
			B1				B2				B3				B4					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0		
Immediate Data [cont]																				
SUNB	*A.byte (A) ← (A) – byte		0	0	1	1	0	1	1	0	Data						7	2	No borrow	
	r.byte (r) ← (r) – byte		0	1	1	1	0	1	0	0	0 0 1 1 0 R ₂ R ₁ R ₀						11	3	No borrow	
			Data																	
	sr2.byte (sr2) ← (sr2) – byte		0	1	1	0	0	1	0	0	S ₃ 0 1 1 0 S ₂ S ₁ S ₀						20	3	No borrow	
			Data																	
ANI	*A.byte (A) ← (A) ∧ byte		0	0	0	0	1	1	1	1	Data						7	2		
	r.byte (r) ← (r) ∧ byte		0	1	1	1	0	1	0	0	0 0 0 0 1 R ₂ R ₁ R ₀						11	3		
			Data																	
	sr2.byte (sr2) ← (sr2) ∧ byte		0	1	1	0	0	1	0	0	S ₃ 0 0 0 1 S ₂ S ₁ S ₀						20	3		
			Data																	
ORI	*A.byte (A) ← (A) V byte		0	0	0	1	0	1	1	1	Data						7	2		
	r.byte (r) ← (r) V byte		0	1	1	1	0	1	0	0	0 0 0 1 1 R ₂ R ₁ R ₀						11	3		
			Data																	
	sr2.byte (sr2) ← (sr2) V byte		0	1	1	0	0	1	0	0	S ₃ 0 0 1 1 S ₂ S ₁ S ₀						20	3		
			Data																	
XRI	*A.byte (A) ← (A) ≠ byte		0	0	0	1	0	1	1	0	Data						7	2		
	r.byte (r) ← (r) ≠ byte		0	1	1	1	0	1	0	0	0 0 0 1 0 R ₂ R ₁ R ₀						11	3		
			Data																	
	sr2.byte (sr2) ← (sr2) V byte		0	1	1	0	0	1	0	0	S ₃ 0 0 1 0 S ₂ S ₁ S ₀						20	3		
			Data																	
GTI	*A.byte (A) – byte – 1		0	0	1	0	0	1	1	1	Data						7	2	No borrow	
	r.byte (r) – byte – 1		0	1	1	1	0	1	0	0	0 0 1 0 1 R ₂ R ₁ R ₀						11	3	No borrow	
			Data																	
	sr2.byte (sr2) – byte – 1		0	1	1	0	0	1	0	0	S ₃ 0 1 0 1 S ₂ S ₁ S ₀						14	3	No borrow	
			Data																	
LTI	*A.byte (A) – byte		0	0	1	1	0	1	1	1	Data						7	2	Borrow	
	r.byte (r) – byte		0	1	1	1	0	1	0	0	0 0 1 1 1 R ₂ R ₁ R ₀						11	3	Borrow	
			Data																	
	sr2.byte (sr2) – byte		0	1	1	0	0	1	0	0	S ₃ 0 1 1 1 S ₂ S ₁ S ₀						14	3	Borrow	
			Data																	
NEI	*A.byte (A) – byte		0	1	1	0	0	1	1	1	Data						7	2	No zero	
	r.byte (r) – byte		0	1	1	1	0	1	0	0	0 1 1 0 1 R ₂ R ₁ R ₀						11	3	No zero	
			Data																	

Instruction Set (cont)

Instruction Set (cont.)																								
Mnemonic	Operand	Operation	Operation Code																		Bytes	State(1)	Skip Condition	
			B1								B2													
			B3								B4													
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0						
Immediate Data (cont)																								
NEI	sr2.byte (sr2) - byte		0	1	1	0	0	1	0	0	S ₃	1	1	0	1	S ₂	S ₁	S ₀	14	3	No zero			
			Data																					
EQI	*A.byte (A) - byte		0	1	1	1	0	1	1	1	Data										7	2	Zero	
	r.byte (r) - byte		0	1	1	1	0	1	0	0	0	1	1	1	1	R ₂	R ₁	R ₀	11	3	Zero			
			Data																					
	sr2.byte (sr2) - byte		0	1	1	0	0	1	0	0	S ₃	1	1	1	1	S ₂	S ₁	S ₀	14	3	Zero			
			Data																					
ONI	*A.byte (A) ^ byte		0	1	0	0	0	1	1	1	Data										7	2	No zero	
	r.byte (r) ^ byte		0	1	1	1	0	1	0	0	0	1	0	0	1	R ₂	R ₁	R ₀	11	3	No zero			
			Data																					
	sr2.byte (sr2) ^ byte		0	1	1	0	0	1	0	0	S ₃	1	0	0	1	S ₂	S ₁	S ₀	14	3	No zero			
			Data																					
OFFI	*A.byte (A) ^ byte		0	1	0	1	0	1	1	1	Data										7	2	Zero	
	r.byte (r) ^ byte		0	1	1	1	0	1	0	0	0	1	0	1	1	R ₂	R ₁	R ₀	11	3	Zero			
			Data																					
	sr2.byte (sr2) ^ byte		0	1	1	0	0	1	0	0	S ₃	1	0	1	1	S ₂	S ₁	S ₀	14	3	Zero			
			Data																					
Working Register																								
ADDW	wa (A) ← (A) + ((V)^(wa))		0	1	1	1	0	1	0	0	1	1	0	0	0	0	0	0	14	3				
			Offset																					
ADCW	wa (A) ← (A) + ((V)^(wa)) + (CY)		0	1	1	1	0	1	0	0	1	1	0	1	0	0	0	0	14	3				
			Offset																					
ADDNCW	wa (A) ← (A) + ((V)^(wa))		0	1	1	1	0	1	0	0	1	0	1	0	0	0	0	0	14	3	No carry			
			Offset																					
SUBW	wa (A) ← (A) - ((V)^(wa))		0	1	1	1	0	1	0	0	1	1	1	0	0	0	0	0	14	3				
			Offset																					
SBBW	wa (A) ← (A) - ((V)^(wa)) - (CY)		0	1	1	1	0	1	0	0	1	1	1	1	0	0	0	0	14	3				
			Offset																					
SUBNBW	wa (A) ← (A) - ((V)^(wa))		0	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	14	3	No borrow			
			Offset																					
ANAW	wa (A) ← (A) ^ ((V)^(wa))		0	1	1	1	0	1	0	0	1	0	0	0	1	0	0	0	14	3				
			Offset																					

Instruction Set (cont)

Mnemonic	Operand	Operation	Operation Code																Skip Condition	
			B1				B2				B3				B4					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0		
Working Register (cont)																				
ORAW	wa	$(A) \leftarrow (A) \vee ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	0	0	1	0	0	0	0	14	3
		Offset																		
XRAW	wa	$(A) \leftarrow (A) \oplus ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	0	0	1	0	0	0	0	14	3
		Offset																		
GTAW	wa	$(A) \leftarrow ((V) \bullet (wa)) - 1$	0	1	1	1	0	1	0	0	1	0	1	0	1	0	0	0	14	3
		Offset																		
LTAW	wa	$(A) \leftarrow ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	0	1	1	1	0	0	0	14	3
		Offset																		
NEAW	wa	$(A) \leftarrow ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	1	1	0	1	0	0	0	14	3
		Offset																		
EQAW	wa	$(A) \leftarrow ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	1	1	1	1	0	0	0	14	3
		Offset																		
ONAW	wa	$(A) \wedge ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	1	0	0	1	0	0	0	14	3
		Offset																		
OFFAW	wa	$(A) \wedge ((V) \bullet (wa))$	0	1	1	1	0	1	0	0	1	1	0	1	0	0	0	0	14	3
		Offset																		
ANIW	*wa.byte	$((V) \bullet (wa)) \leftarrow ((V) \bullet (wa)) \wedge \text{byte}$	0	0	0	0	0	1	0	1	Offset				Offset				19	3
		Data																		
ORIW	*wa.byte	$((V) \bullet (wa)) \leftarrow ((V) \bullet (wa)) \vee \text{byte}$	0	0	0	1	0	1	0	1	Offset				Offset				19	3
		Data																		
GTIW	*wa.byte	$((V) \bullet (wa)) - \text{byte} - 1$	0	0	1	0	0	1	0	1	Offset				Offset				13	3
		Data																		
LTIW	*wa.byte	$((V) \bullet (wa)) - \text{byte}$	0	0	1	1	0	1	0	1	Offset				Offset				13	3
		Data																		
NEIW	*wa.byte	$((V) \bullet (wa)) - \text{byte}$	0	1	1	0	0	1	0	1	Offset				Offset				13	3
		Data																		
EQIW	*wa.byte	$((V) \bullet (wa)) - \text{byte}$	0	1	1	1	0	1	0	1	Offset				Offset				13	3
		Data																		
ONIW	*wa.byte	$((V) \bullet (wa)) \wedge \text{byte}$	0	1	0	0	1	0	1	0	Offset				Offset				13	3
		Data																		
OFFIW	*wa.byte	$((V) \bullet (wa)) \wedge \text{byte}$	0	1	0	1	0	1	0	1	Offset				Offset				13	3
		Data																		

Instruction Set (cont)

Instruction Set (cont)

Mnemonic	Operand	Operation	Operation Code																Bytes	State(I)	Skip Condition	
			B1								B2											
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0				
16-Bit Arithmetic																						
EADD	EA, r2	$(EA) \leftarrow (EA) + (r2)$	0	1	1	1	0	0	0	0	0	1	0	0	0	0	R ₁	R ₀	11	2		
DADD	EA, rp3	$(EA) \leftarrow (EA) + (rp3)$	0	1	1	1	0	1	0	0	1	1	0	0	0	1	P ₁	P ₀	11	2		
DADC	EA, rp3	$(EA) \leftarrow (EA) + (rp3) + (CY)$	0	1	1	1	0	1	0	0	1	1	0	1	0	1	P ₁	P ₀	11	2		
DADDNC	EA, rp3	$(EA) \leftarrow (EA) + (rp3)$	0	1	1	1	0	1	0	0	1	0	1	0	0	1	P ₁	P ₀	11	2	No carry	
ESUB	EA, r2	$(EA) \leftarrow (EA) - (r2)$	0	1	1	1	0	0	0	0	0	1	1	0	0	0	R ₁	R ₀	11	2		
DSUB	EA, rp3	$(EA) \leftarrow (EA) - (rp3)$	0	1	1	1	0	1	0	0	1	1	1	0	0	1	P ₁	P ₀	11	2		
DSBB	EA, rp3	$(EA) \leftarrow (EA) - (rp3) - (CY)$	0	1	1	1	0	1	0	0	1	1	1	0	1	1	P ₁	P ₀	11	2	No borrow	
DSUBNB	EA, rp3	$(EA) \leftarrow (EA) - (rp3)$	0	1	1	1	0	1	0	0	1	0	1	1	0	1	P ₁	P ₀	11	2		
DAN	EA, rp3	$(EA) \leftarrow (EA) \wedge (rp3)$	0	1	1	1	0	1	0	0	1	0	0	1	1	1	P ₁	P ₀	11	2		
DOR	EA, rp3	$(EA) \leftarrow (EA) \vee (rp3)$	0	1	1	1	0	1	0	0	1	0	0	1	1	1	P ₁	P ₀	11	2		
DXR	EA, rp3	$(EA) \leftarrow (EA) \oplus (rp3)$	0	1	1	1	0	1	0	0	1	0	0	1	1	1	P ₁	P ₀	11	2		
DGT	EA, rp3	$(EA) \leftarrow (rp3) - 1$	0	1	1	1	0	1	0	0	1	0	0	1	0	1	P ₁	P ₀	11	2	No borrow	
DLT	EA, rp3	$(EA) \leftarrow (rp3)$	0	1	1	1	0	1	0	0	1	0	1	1	1	1	P ₁	P ₀	11	2	Borrow	
DNE	EA, rp3	$(EA) \leftarrow (rp3)$	0	1	1	1	0	1	0	0	1	1	1	0	1	1	P ₁	P ₀	11	2	No zero	
DEQ	EA, rp3	$(EA) \leftarrow (rp3)$	0	1	1	1	0	1	0	0	1	1	1	1	1	1	P ₁	P ₀	11	2	Zero	
DON	EA, rp3	$(EA) \wedge (rp3)$	0	1	1	1	0	1	0	0	1	1	0	0	1	1	P ₁	P ₀	11	2	No zero	
DOFF	EA, rp3	$(EA) \wedge (rp3)$	0	1	1	1	0	1	0	0	1	1	0	1	1	1	P ₁	P ₀	11	2	Zero	
Multiply/Divide																						
MUL	r2	$(EA) \leftarrow (A) \times (r2)$	0	1	0	0	1	0	0	0	0	0	1	0	1	1	R ₁	R ₀	32	2		
DIV	r2	$(EA) \leftarrow (EA) \div (r2), (r2) \leftarrow \text{Remainder}$	0	1	0	0	1	0	0	0	0	0	1	1	1	1	R ₁	R ₀	59	2		
Increment/Decrement																						
INR	r2	$(r2) \leftarrow (r2) + 1$	0	1	0	0	0	0	0	R ₁	R ₀							4	1	Carry		
INRW	*wa	$((V) \bullet (wa)) \leftarrow ((V) \bullet (wa)) + 1$	0	0	1	0	0	0	0	0								Offset	16	2	Carry	
INX	rp	$(rp) \leftarrow (rp) + 1$	0	0	P ₁	P ₀	0	0	1	0									7	1		
	EA	$(EA) \leftarrow (EA) + 1$	1	0	1	0	1	0	0	0									7	1		
DCR	r2	$(r2) \leftarrow (r2) - 1$	0	1	0	1	0	0	0	R ₁	R ₀							4	1	Borrow		
DCRW	*wa	$((V) \bullet (wa)) \leftarrow ((V) \bullet (wa)) - 1$	0	0	1	1	0	0	0	0									Offset	16	2	Borrow
DCX	rp	$(rp) \leftarrow (rp) - 1$	0	0	P ₁	P ₀	0	0	1	1									7	1		
	EA	$(EA) \leftarrow (EA) - 1$	1	0	1	0	1	0	0	1									7	1		
Others																						
DAA		Decimal Adjust Accumulator	0	1	1	0	0	0	0	1									4	1		
STC		$(CY) \leftarrow 1$	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	1	8	2		
CLC		$(CY) \leftarrow 0$	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	8	2		

Instruction Set (cont)

Mnemonic		Operand	Operation	Operation Code																Bytes	State[!]	Skip Condition		
				B1				B3				B2				B4								
				7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0					
Others (cont)																								
NEGA		(A) ← (A) + 1		0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	1	0	8	2		
Rotate and Shift																								
RLD		Rotate left digit		0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	17	2		
RRD		Rotate right digit		0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	1	17	2		
RLL	r2	(r2 _m + 1) ← (r2 _m), (r2 ₀) ← (CY), (CY) ← (r2 ₇)		0	1	0	0	1	0	0	0	0	0	0	1	1	0	1	R ₀	R ₀	8	2		
RLR	r2	(r2 _m - 1) ← (r2 _m), (r2 ₇) ← (CY), (CY) ← (r2 ₀)		0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	R ₀	R ₀	8	2		
SLL	r2	(r2 _m + 1) ← (r2 _m), (r2 ₀) ← 0, (CY) ← (r2 ₇)		0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	R ₁	R ₀	8	2		
SLR	r2	(r2 _m - 1) ← (r2 _m), (r2 ₇) ← 0, (CY) ← (r2 ₀)		0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	R ₁	R ₀	8	2		
SLLC	r2	(r2 _m + 1) ← (r2 _m), (r2 ₀) ← 0, (CY) ← (r2 ₇)		0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	R ₁	R ₀	8	2	Carry	
SLRC	r2	(r2 _m - 1) ← (r2 _m), (r2 ₇) ← 0, (CY) ← (r2 ₀)		0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	R ₁	R ₀	8	2	Carry	
DRLL	EA	(EA _m + 1) ← (EA _m), (EA ₀) ← (CY), (CY) ← (EA ₁₅)		0	1	0	0	1	0	0	0	1	0	1	1	0	1	0	0	0	8	2		
DRLR	EA	(EA _m - 1) ← (EA _m), (EA ₁₅) ← (CY), (CY) ← (EA ₀)		0	1	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	8	2		
DSLL	EA	(EA _m + 1) ← (EA _m), (EA ₀) ← 0, (CY) ← (EA ₁₅)		0	1	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	8	2		
DSLR	EA	(EA _m - 1) ← (EA _m), (EA ₁₅) ← 0, (CY) ← (EA ₀)		0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	8	2		
Jump																								
JMP	*word	(PC) ← word		0	1	0	1	0	1	0	0	High addr				Low addr				10	3			
JB		(PC _H) ← (B), (PC _L) ← (C)		0	0	1	0	0	0	0	1									4	1			
JR	word	(PC) ← (PC) + 1 + jdisp 1		1	1	←	jdisp1	→												10	1			
JRE	*word	(PC) ← (PC) + 2 + jdisp		0	1	0	0	1	1	1	←					jdisp				→	10	2		
JEA		(PC) ← (EA)		0	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	8	2		
Call																								
CALL	*word	((SP) - 1) ← ((PC) + 3) _H , ((SP) - 2) ← ((PC) + 3) _L , (PC) ← word, (SP) ← (SP) - 2		0	1	0	0	0	0	0	0	High addr				Low addr				16	3			
CALB		((SP) - 1) ← ((PC) + 2) _H , ((SP) - 2) ← ((PC) + 2) _L , (PC _H) ← (B), (PC _L) ← (C), (SP) ← (SP) - 2		0	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	17	2		
CALF	*word	((SP) - 1) ← ((PC) + 2) _H , ((SP) - 2) ← ((PC) + 2) _L , (PC _{15:11}) ← 00001, (PC _{10:0}) ← fa, (SP) ← (SP) - 2		0	1	1	1	1	←					fa				→				13	2	

Instruction Set (cont)

Operation Code																					
Mnemonic	Operand	Operation	B1																Bytes	Skip Condition	
			B3				B2				B4										
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	State(I)		
Call (cont)																					
CALL	word	$(SP) - 1 \leftarrow ((PC) + 1)_H$ $((SP) - 2) \leftarrow ((PC) + 1)_L$ $(PC)_L \leftarrow (128 + 2ta), (PC)_H \leftarrow (129 + 2ta), (SP) \leftarrow (SP) - 2$	1	0	0			ta											16	1	
SOFTI																					
		$((SP) - 1) \leftarrow (PSW), ((SP) - 2) \leftarrow ((PC) + 1)_H, ((SP) - 3) \leftarrow ((PC) + 1)_L, (PC) \leftarrow 0060H, (SP) \leftarrow (SP) - 3$	0	1	1	1	0	0	1	0									16	1	
Return																					
RET		$(PC)_L \leftarrow ((SP)), (PC)_H \leftarrow ((SP) + 1), (SP) \leftarrow (SP) + 2$	1	0	1	1	1	0	0	0									10	1	
RETS		$(PC)_L \leftarrow ((SP)), (PC)_H \leftarrow ((SP) + 1), (SP) \leftarrow (SP) + 2, (PC) \leftarrow (PC) + n$	1	0	1	1	1	0	0	1									10	Unconditional Skip	
RETI		$(PC)_L \leftarrow ((SP)), (PC)_H \leftarrow ((SP) + 1), (PSW) \leftarrow ((SP) + 2), (SP) \leftarrow (SP) + 3$	0	1	1	0	0	0	1	0									13	1	
Skip																					
Bit	bit, wa		0	1	0	1	1	B2	B1	B0	Offset								10	2	Bit Test
CPU Control																					
SK	f	Skip if f = 1	0	1	0	0	1	0	0	0	0	0	0	0	1	F2	F1	F0	8	2 f = 1	
SKN	f	Skip if f = 0	0	1	0	0	1	0	0	0	0	0	0	1	1	F2	F1	F0	8	2 f = 0	
SKIT	irf	Skip if irf = 1, then reset irf	0	1	0	0	1	0	0	0	0	1	0	l4	l3	l2	l1	l0	8	2 irf = 1	
SKNIT	irf	Skip if irf = 0 Reset irf if irf = 1	0	1	0	0	1	0	0	0	0	1	1	l4	l3	l2	l1	l0	8	2 irf = 0	
NOP		No operation	0	0	0	0	0	0	0	0									4	1	
EI		Enable interrupt	1	0	1	0	1	0	1	0									4	1	
DI		Disable interrupt	1	0	1	1	0	1	0	0									4	1	
HLT		Halt	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	1	11	2	

Notes:

- (1) In the case of skip condition, the idle states are as follows:
1-byte instruction: 4 states
2-byte instruction: 8 states
3-byte instruction: 11 states
- (2) B2 (Data): rpa2 = D + byte, H + byte.
- (3) Right side of slash (/) in states indicates case rpa2, rpa3 = D + byte, H + A, H + B, H + EA, H + byte.
- (4) B3 (Data): rpa3 = D + byte, H + byte