MC68HC11D3RG/AD

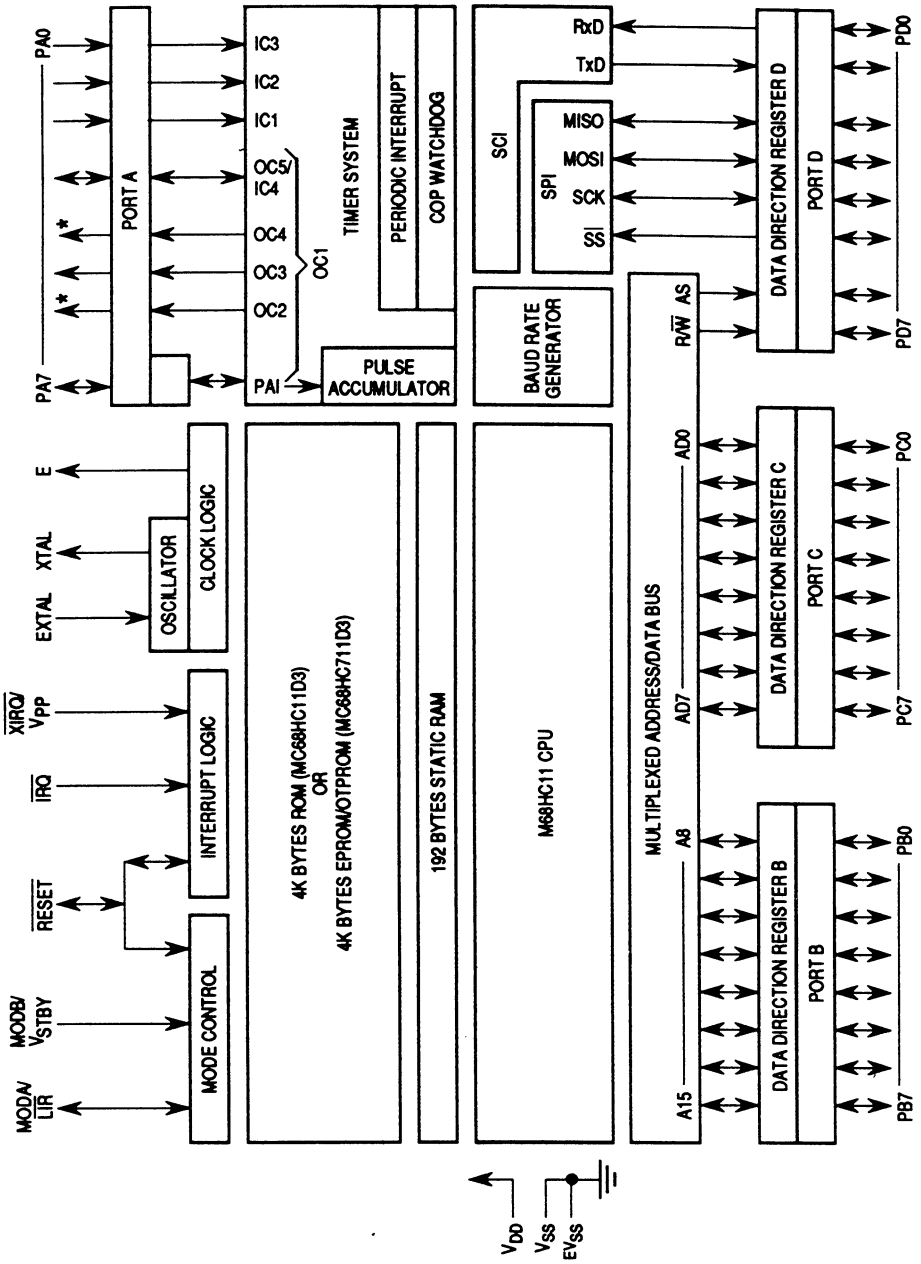
HC11

MC68HC11D3
MC68HC711D3

PROGRAMMING REFERENCE GUIDE

MOTOROLA

BLOCK DIAGRAM



*PA6 and PA4 not bonded in 40 pin DIP

PROGRAMMING MODEL
CRYSTAL DEPENDENT TIMING
INTERRUPTS

MEMORY MAP
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INSTRUCTIONS
ADDRESSING MODES
EXECUTION TIMES
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REGISTER AND
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MECHANICAL DATA
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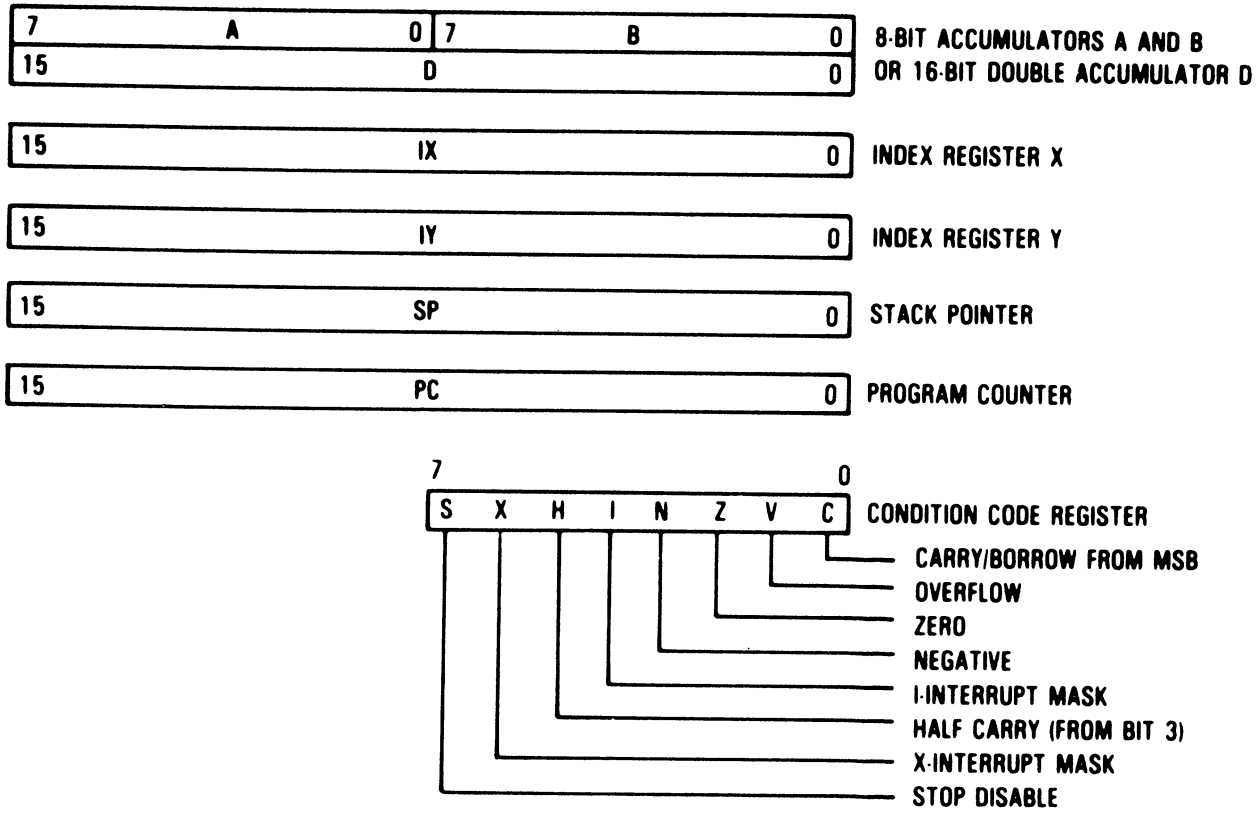

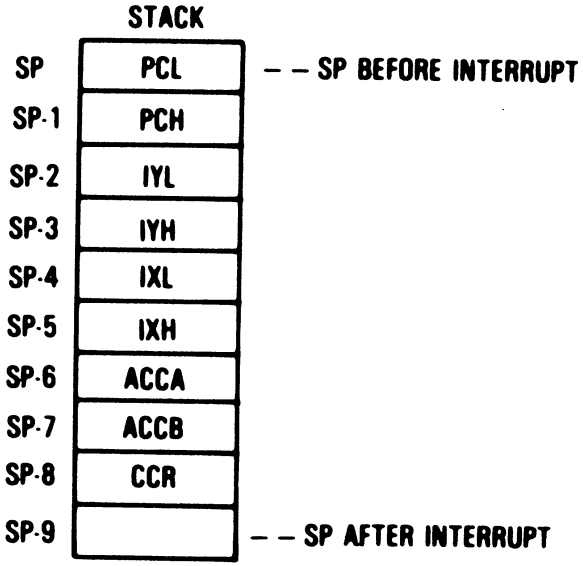

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CRYSTAL DEPENDENT TIMING SUMMARY

	Selected Crystal			Common Xtal Frequencies (others could be used)		
				2^{23} Hz 8.389 MHz	8.0 MHz	4.0 MHz
CPU Clock			**(E)**	**2.1 MHz**	**2.0 MHz**	**1.0 MHz**
Cycle Time			**(1/E)**	**477 ns**	**500 ns**	**1000 ns**
Periodic (RTI) Interrupt Rates	RTR_	1	0			
($E/2^{13}$)		0	0	3.91 ms	4.10 ms	8.19 ms
($E/2^{14}$)		0	1	7.81 ms	8.19 ms	16.38 ms
($E/2^{15}$)		1	0	15.62 ms	16.38 ms	32.77 ms
($E/2^{16}$)		1	1	31.25 ms	32.77 ms	65.54 ms
SPI Bit Rates (baud)	SPR_	1	0			
(E/2)		0	0	1.05 MHz	1.0 MHz	500 K
(E/4)		0	1	524 K	500 K	250 K
(E/16)		1	0	131 K	125 K	62.5 K
(E/32)		1	1	65.5 K	62.5 K	31.25 K

SCI Baud Rates	Control Bits					Only the max and min baud rates are shown in this table (SCR2–0 = 000 or 111). Additional rates are simple multiples of 2 from min to max.		
	SCP_		SCR_					
	1	0	2	1	0			
(E/1)	0	0				custom	—	—
(pre out/16)			0	0	0	131.07 K	124.80 K	62.40 K
(pre out/2048)			1	1	1	1024	976.6	488.3
(E/3)	0	1				—	—	—
(pre out/16)			0	0	0	43.691 K	41.6 K	20.8 K
(pre out/2048)			1	1	1	341.3	325.5	162.8
(E/4)	1	0				custom	—	—
(pre out/16)			0	0	0	32.768 K	31.2 K	15.6 K
(pre out/2048)			1	1	1	256	244.1	122.1
(E/13)	1	1				—	common	common
(pre out/16)			0	0	0	10.082 K	9600	4800
(pre out/2048)			1	1	1	78.77	75	37.56

	Selected Crystal		Common Xtal Frequencies (others could be used)		
			2^{23} Hz 8.389 MHz	8.0 MHz	4.0 MHz
CPU Clock		**(E)**	**2.1 MHz**	**2.0 MHz**	**1.0 MHz**
Cycle Time		**(1/E)**	**477 ns**	**500 ns**	**1000 ns**
COP Watchdog Timeout Rates	CR_ 1	0			
($E/2^{15}$)	0	0	15.625 ms	16.384 ms	32.768 ms
($E/2^{17}$)	0	1	62.5 ms	65.536 ms	131.07 ms
($E/2^{19}$)	1	0	250 ms	262.14 ms	524.29 ms
($E/2^{21}$)	1	1	1 s	1.049 s	2.1 s
($E/2^{15}$)	Timeout Tolerance (−0 ms/+ . . .)		15.6 ms	16.4 ms	32.8 ms
Pulse Accumulator (in gated mode)					
($E/2^{6}$)	1 count –		30.52 μs	32 μs	64 μs
($E/2^{14}$)	overflow –		7.80 ms	8.19 ms	16.38 ms

Main Timer Count Rates	PR_ 1 0			
	0 0			
(E/1) ($E/2^{16}$)	1 count – overflow –	477 ns 31.25 ms	500 ns 32.77 ms	1.0 μs 65.54 ms
	0 1			
(E/4) ($E/2^{18}$)	1 count – overflow –	1.91 μs 125 ms	2.0 μs 131.1 ms	4.0 μs 262.1 ms
	1 0			
(E/8) ($E/2^{19}$)	1 count – overflow –	3.81 μs 250 ms	4.0 μs 262.1 ms	8.0 μs 524.3 ms
	1 1			
(E/16) ($E/2^{20}$)	1 count – overflow –	7.63 μs 0.5 s	8.0 μs 524.3 ms	16.0 μs 1.049 s

Interrupt Vector Assignments

Vector Address	Interrupt Source	CC Register Mask	Local Mask
FFC0, C1	Reserved	—	—
•	•		
•	•		
FFD4, D5	Reserved	—	—
FFD6, D7	SCI Serial System	I Bit	See Table
FFD8, D9	SPI Serial Transfer Complete	I Bit	SPIE
FFDA, DB	Pulse Accumulator Input Edge	I Bit	PAII
FFDC, DD	Pulse Accumulator Overflow	I Bit	PAOVI
FFDE, DF	Timer Overflow	I Bit	TOI
FFE0, E1	Timer Input Capture 4/Output Compare 5	I Bit	I4O5I
FFE2, E3	Timer Output Compare 4	I Bit	OC4I
FFE4, E5	Timer Output Compare 3	I Bit	OC3I
FFE6, E7	Timer Output Compare 2	I Bit	OC2I
FFE8, E9	Timer Output Compare 1	I Bit	OC1I
FFEA, EB	Timer Input Capture 3	I Bit	IC3I
FFEC, ED	Timer Input Capture 2	I Bit	IC2I
FFEE, EF	Timer Input Capture 1	I Bit	IC1I
FFF0, F1	Real-Time Interrupt	I Bit	RTII
FFF2, F3	$\overline{\text{IRQ}}$ (External Pin)	I Bit	None
	SEE HPRIO REGISTER FOR HIGHEST PRIORITY I-BIT SOURCE		
FFF4, F5	$\overline{\text{XIRQ}}$ Pin (Pseudo Nonmaskable Interrupt)	X Bit	None
FFF6, F7	SWI	None	None
FFF8, F9	Illegal Opcode Trap	None	None
FFFA, FB	COP Failure (Reset)	None	NOCOP
FFFC, FD	COP Clock Monitor Fail (Reset)	None	CME
FFFE, FF	$\overline{\text{RESET}}$	None	None

LOWEST — RELATIVE PRIORITY — HIGHEST

SCI Serial System Interrupts

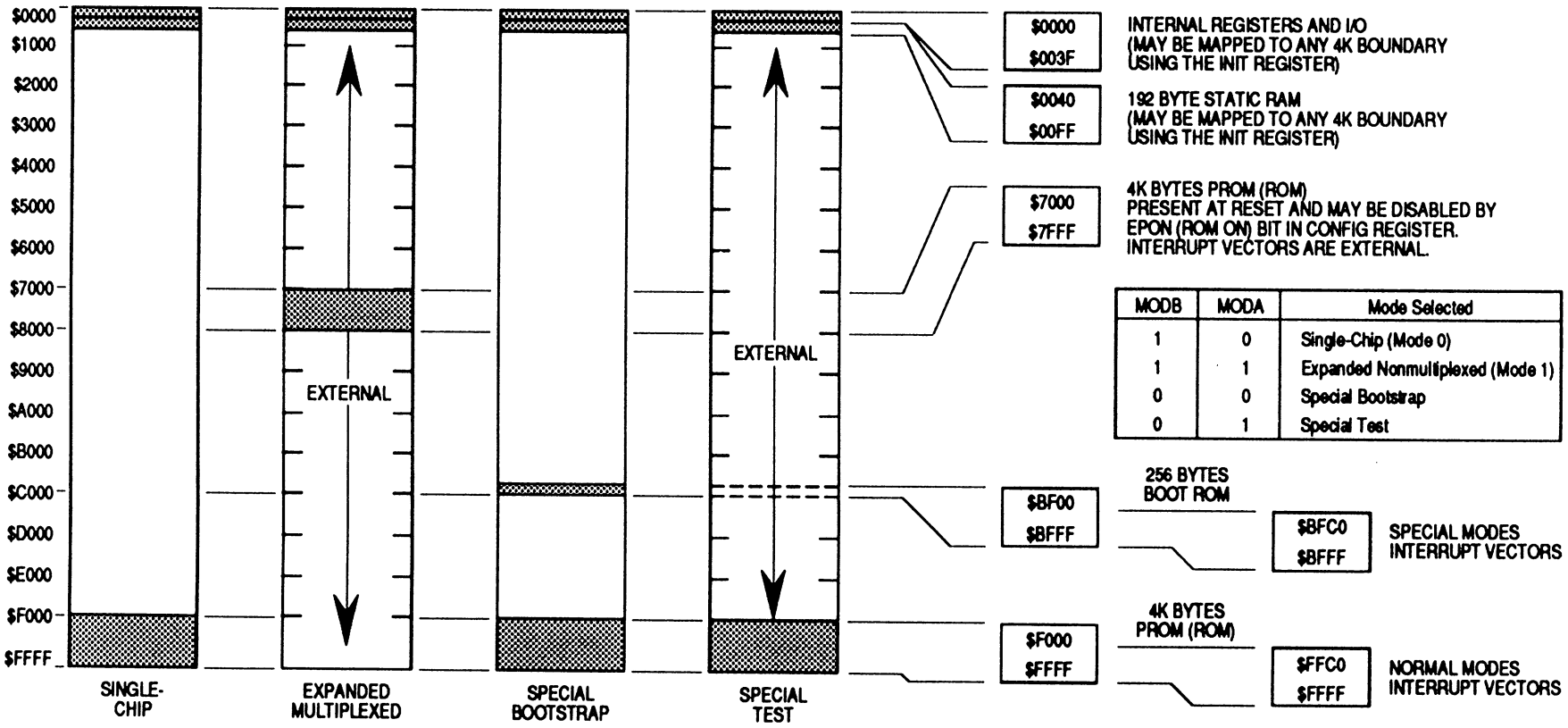
Interrupt Cause	Local Mask
Receive Data Register Full	RIE
Receiver Overrun	RIE
Idle Line Detected	ILIE
Transmit Data Register Empty	TIE
Transmit Complete	TCIE

OPCODE MAP (PAGE 1)

DIR

		INH	INH	REL	INH	ACCA	ACCB	IND,X	EXT	ACCA IMM	ACCA DIR	ACCA IND,X	ACCA EXT	ACCB IMM	ACCB DIR	ACCB IND,X	ACCB EXT	
MSB		0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111	
LSB		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0000	0	TEST	SBA	BRA	TSX	NEG				SUB								0
0001	1	NOP	CBA	BRN	INS					CMP								1
0010	2	IDIV	BRSET	BHI	PULA					SBC								2
0011	3	FDIV	BRCLR	BLS	PULB	COM				SUBD				ADDD				3
0100	4	LSRD	BSET	BCC	DES	LSR				AND								4
0101	5	ASLD	BCLR	BCS	TXS					BIT								5
0110	6	TAP	TAB	BNE	PSHA	ROR				LDA								6
0111	7	TPA	TBA	BEQ	PSHB	ASR					STA				STA			7
1000	8	INX	PG 2	BVC	PULX	ASL				EOR								8
1001	9	DEX	DAA	BVS	RTS	ROL				ADC								9
1010	A	CLV	PG 3	BPL	ABX	DEC				ORA								A
1011	B	SEV	ABA	BMI	RTI					ADD								B
1100	C	CLC	BSET	BGE	PSHX	INC				CPX				LDD				C
1101	D	SEC	BCLR	BLT	MUL	TST				BSR	JSR			PG 4	STD			D
1110	E	CLI	BRSET	BGT	WAI			JMP		LDS				LDX				E
1111	F	SEI	BRCLR	BLE	SWI	CLR				XGDX	STS			STOP	STX			F
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	

IND,X



MODB	MODA	Mode Selected
1	0	Single-Chip (Mode 0)
1	1	Expanded Nonmultiplexed (Mode 1)
0	0	Special Bootstrap
0	1	Special Test

OPCODE MAP (PAGE 2) (18 xx)

		INH			INH			IND,Y		ACCA IMM	ACCA DIR	ACCA IND,Y	ACCA EXT	ACCB IMM	ACCB DIR	ACCB IND,Y	ACCB EXT	
MSB		0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111	
LSB		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0000	0				TSY			NEG				SUB				SUB		0
0001	1											CMP				CMP		1
0010	2											SBC				SBC		2
0011	3							COM				SUBD				ADDD		3
0100	4							LSR				AND				AND		4
0101	5				TYS							BIT				BIT		5
0110	6							ROR				LDA				LDA		6
0111	7							ASR				STA				STA		7
1000	8	INY			PULY			ASL				EOR				EOR		8
1001	9	DEY						ROL				ADC				ADC		9
1010	A				ABY			DEC				ORA				ORA		A
1011	B											ADD				ADD		B
1100	C		BSET		PSHY			INC		CPY						LDD		C
1101	D		BCLR					TST				JSR				STD		D
1110	E		BRSET					JMP				LDS		LDY				E
1111	F		BRCLR					CLR		XGDY		STS		STY				F
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	

IND,Y

[redacted]

OPCODE MAP (PAGE 3) (1Axx)

		ACCA				ACCB			
		IMM	DIR	IND,X	EXT			IND,X	
MSB	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
LSB	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0000	0															0
0001	1															1
0010	2															2
0011	3									CPD						3
0100	4															4
0101	5															5
0110	6															6
0111	7															7
1000	8															8
1001	9															9
1010	A															A
1011	B															B
1100	C										CPY					C
1101	D															D
1110	E														LDY	E
1111	F														STY	F
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

OPCODE MAP (PAGE 4)(CDxx)

									ACCA				ACCB				
											IND,Y				IND,Y		
MSB		0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111	
LSB		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0000	0																	0
0001	1																	1
0010	2																	2
0011	3											CPD						3
0100	4																	4
0101	5																	5
0110	6																	6
0111	7																	7
1000	8																	8
1001	9																	9
1010	A																	A
1011	B																	B
1100	C											CPX						C
1101	D																	D
1110	E															LDX		E
1111	F															STX		F
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	

SIMPLE BRANCHES

Mnemonic	Opcode	Cycles
BRA	20	3
BRN	21	3
BSR	8D	7

SIMPLE CONDITIONAL BRANCHES

Test	True	Opcode	False	Opcode
N = 1	BMI	2B	BPL	2A
Z = 1	BEQ	27	BNE	26
V = 1	BVS	29	BVC	28
C = 1	BCS	25	BCC	24

SIGNED CONDITIONAL BRANCHES

Test	True	Opcode	False	Opcode
r>m	BGT	2E	BLE	2F
r≥m	BGE	2C	BLT	2D
r = m	BEQ	27	BNE	26
r≤m	BLE	2F	BGT	2E
r<m	BLT	2D	BGE	2C

UNSIGNED CONDITIONAL BRANCHES

Test	True	Opcode	False	Opcode
r>m	BHI	22	BLS	23
r≥m	BHS/BCC	24	BLO/BCS	25
r = m	BEQ	27	BNE	26
r≤m	BLS	23	BHI	22
r<m	BLO/BCS	25	BHS/BCC	24

BIT MANIPULATION BRANCHES

BRCLR — Branch if all selected bits are clear
(opcode) (operand addr) (mask) (rel offset).
M•mm = 0? M = operand in memory; mm — mask

BRSET — Branch if all selected bits are set (opcode)
(operand addr) (mask) (rel offset).
($\overline{M}$)•mm = 0? M = operand in memory; mm mask

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
00		TEST	INH	—
01		NOP	INH	2
02		IDIV	INH	41
03		FDIV	INH	41
04		LSRD	INH	3
05		ASLD/LSLD	INH	3
06		TAP	INH	2
07		TPA	INH	2
08		INX	INH	3
09		DEX	INH	3
0A		CLV	INH	2
0B		SEV	INH	2
0C		CLC	INH	2
0D		SEC	INH	2
0E		CLI	INH	2
0F		SEI	INH	2
10		SBA	INH	2
11		CBA	INH	2
12	dd mm rr	BRSET (opr) (msk) (rel)	DIR	6
13	dd mm rr	BRCLR (opr) (msk) (rel)	DIR	6
14	dd mm	BSET (opr) (msk)	DIR	6
15	dd mm	BCLR (opr) (msk)	DIR	6
16		TAB	INH	2
17		TBA	INH	2
18		(Page 2 Switch)		
19		DAA	INH	2
1A		(Page 3 Switch)		
1B		ABA	INH	2
1C	ff mm	BSET (opr) (msk)	IND,X	7
1D	ff mm	BCLR (opr) (msk)	IND,X	7
1E	ff mm rr	BRSET (opr) (msk) (rel)	IND,X	7
1F	ff mm rr	BRCLR (opr) (msk) (rel)	IND,X	7

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
20	rr	BRA (rel)	REL	3
21	rr	BRN (rel)	REL	3
22	rr	BHI (rel)	REL	3
23	rr	BLS (rel)	REL	3
24	rr	BCC/BHS (rel)	REL	3
25	rr	BCS/BLO (rel)	REL	3
26	rr	BNE (rel)	REL	3
27	rr	BEQ (rel)	REL	3
28	rr	BVC (rel)	REL	3
29	rr	BVS (rel)	REL	3
2A	rr	BPL (rel)	REL	3
2B	rr	BMI (rel)	REL	3
2C	rr	BGE (rel)	REL	3
2D	rr	BLT (rel)	REL	3
2E	rr	BGT (rel)	REL	3
2F	rr	BLE (rel)	REL	3
30		TSX	INH	3
31		INS	INH	3
32		PULA	INH	4
33		PULB	INH	4
34		DES	INH	3
35		TXS	INH	3
36		PSHA	INH	3
37		PSHB	INH	3
38		PULX	INH	5
39		RTS	INH	5
3A		ABX	INH	3
3B		RTI	INH	12
3C		PSHX	INH	4
3D		MUL	INH	10
3E		WAI	INH	14
3F		SWI	INH	14
40		NEGA	INH	2
43		COMA	INH	2
44		LSRA	INH	2
46		RORA	INH	2
47		ASRA	INH	2
48		ASLA/LSLA	INH	2
49		ROLA	INH	2
4A		DECA	INH	2
4C		INCA	INH	2
4D		TSTA	INH	2
4F		CLRA	INH	2
50		NEGB	INH	2

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
53		COMB	INH	2
54		LSRB	INH	2
56		RORB	INH	2
57		ASRB/ASLB	INH	2
58		LSLB	INH	2
59		ROLB	INH	2
5A		DECB	INH	2
5C		iNCB	INH	2
5D		TSTB	INH	2
5F		CLRB	INH	2
60	ff	NEG (opr)	IND,X	6
63	ff	COM (opr)	IND,X	6
64	ff	LSR (opr)	IND,X	6
66	ff	ROR (opr)	IND,X	6
67	ff	ASR (opr)	IND,X	6
68	ff	ASL/LSL (opr)	IND,X	6
69	ff	ROL (opr)	IND,X	6
6A	ff	DEC (opr)	IND,X	6
6C	ff	INC (opr)	IND,X	6
6D	ff	TST (opr)	IND,X	6
6E	ff	JMP (opr)	IND,X	3
6F	ff	CLR (opr)	IND,X	6
70	hh ll	NEG (opr)	EXT	6
73	hh ll	COM (opr)	EXT	6
74	hh ll	LSR (opr)	EXT	6
76	hh ll	ROR (opr)	EXT	6
77	hh ll	ASR (opr)	EXT	6
78	hh ll	ASL/LSL (opr)	EXT	6
79	hh ll	ROL (opr)	EXT	6
7A	hh ll	DEC (opr)	EXT	6
7C	hh ll	INC (opr)	EXT	6
7D	hh ll	TST (opr)	EXT	6
7E	hh ll	JMP (opr)	EXT	3
7F	hh ll	CLR (opr)	EXT	6
80	ii	SUBA (opr)	IMM	2
81	ii	CMPA (opr)	IMM	2
82	ii	SBCA (opr)	IMM	2
83	jj kk	SUBD (opr)	IMM	4
84	ii	ANDA (opr)	IMM	2
85	ii	BITA (opr)	IMM	2
86	ii	LDAA (opr)	IMM	2
88	ii	EORA (opr)	IMM	2
89	ii	ADCA (opr)	IMM	2
8A	ii	ORAA (opr)	IMM	2

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
8B	ii	ADDA (opr)	IMM	2
8C	jj kk	CPX (opr)	IMM	4
8D	rr	BSR (rel)	REL	6
8E	jj kk	LDS (opr)	IMM	3
8F		XGDX	INH	3
90	dd	SUBA (opr)	DIR	3
91	dd	CMPA (opr)	DIR	3
92	dd	SBCA (opr)	DIR	3
93	dd	SUBD (opr)	DIR	5
94	dd	ANDA (opr)	DIR	3
95	dd	BITA (opr)	DIR	3
96	dd	LDAA (opr)	DIR	3
97	dd	STAA (opr)	DIR	3
98	dd	EORA (opr)	DIR	3
99	dd	ADCA (opr)	DIR	3
9A	dd	ORAA (opr)	DIR	3
9B	dd	ADDA (opr)	DIR	3
9C	dd	CPX (opr)	DIR	5
9D	dd	JSR (opr)	DIR	5
9E	dd	LDS (opr)	DIR	4
9F	dd	STS (opr)	DIR	4
A0	ff	SUBA (opr)	IND,X	4
A1	ff	CMPA (opr)	IND,X	4
A2	ff	SBCA (opr)	IND,X	4
A3	ff	SUBD (opr)	IND,X	6
A4	ff	ANDA (opr)	IND,X	4
A5	ff	BITA (opr)	IND,X	4
A6	ff	LDAA (opr)	IND,X	4
A7	ff	STAA (opr)	IND,X	4
A8	ff	EORA (opr)	IND,X	4
A9	ff	ADCA (opr)	IND,X	4
AA	ff	ORAA (opr)	IND,X	4
AB	ff	ADDA (opr)	IND,X	4
AC	ff	CPX (opr)	IND,X	6
AD	ff	JSR (opr)	IND,X	6
AE	ff	LDS (opr)	IND,X	5
AF	ff	STS (opr)	IND,X	5
B0	hh ll	SUBA (opr)	EXT	4
B1	hh ll	CMPA (opr)	EXT	4
B2	hh ll	SBCA (opr)	EXT	4
B3	hh ll	SUBD (opr)	EXT	6
B4	hh ll	ANDA (opr)	EXT	4
B5	hh ll	BITA (opr)	EXT	4
B6	hh ll	LDAA (opr)	EXT	4

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
B7	hh ll	STAA (opr)	EXT	4
B8	hh ll	EORA (opr)	EXT	4
B9	hh ll	ADCA (opr)	EXT	4
BA	hh ll	ORAA (opr)	EXT	4
BB	hh ll	ADDA (opr)	EXT	4
BC	hh ll	CPX (opr)	EXT	6
BD	hh ll	JSR (opr)	EXT	6
BE	hh ll	LDS (opr)	EXT	5
BF	hh ll	STS (opr)	EXT	5
C0	ii	SUBB (opr)	IMM	2
C1	ii	CMPB (opr)	IMM	2
C2	ii	SBCB (opr)	IMM	2
C3	jj kk	ADDD (opr)	IMM	4
C4	ii	ANDB (opr)	IMM	2
C5	ii	BITB (opr)	IMM	2
C6	ii	LDAB (opr)	IMM	2
C8	ii	EORB (opr)	IMM	2
C9	ii	ADCB (opr)	IMM	2
CA	ii	ORAB (opr)	IMM	2
CB	ii	ADDB (opr)	IMM	2
CC	jj kk	LDD (opr)	IMM	3
CD		(Page 4 Switch)		
CE	jj kk	LDX (opr)	IMM	3
CF		STOP	INH	2
D0	dd	SUBB (opr)	DIR	3
D1	dd	CMPB (opr)	DIR	3
D2	dd	SBCB (opr)	DIR	3
D3	dd	ADDD (opr)	DIR	5
D4	dd	ANDB (opr)	DIR	3
D5	dd	BITB (opr)	DIR	3
D6	dd	LDAB (opr)	DIR	3
D7	dd	STAB (opr)	DIR	3
D8	dd	EORB (opr)	DIR	3
D9	dd	ADCB (opr)	DIR	3
DA	dd	ORAB (opr)	DIR	3
DB	dd	ADDB (opr)	DIR	3
DC	dd	LDD (opr)	DIR	4
DD	dd	STD (opr)	DIR	4
DE	dd	LDX (opr)	DIR	4
DF	dd	STX (opr)	DIR	4
E0	ff	SUBB (opr)	IND,X	4
E1	ff	CMPB (opr)	IND,X	4
E2	ff	SBCB (opr)	IND,X	4
E3	ff	ADDD (opr)	IND,X	6

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
E4	ff	ANDB (opr)	IND,X	4
E5	ff	BITB (opr)	IND,X	4
E6	ff	LDAB (opr)	IND,X	4
E7	ff	STAB (opr)	IND,X	4
E8	ff	EORB (opr)	IND,X	4
E9	ff	ADCB (opr)	IND,X	4
EA	ff	ORAB (opr)	IND,X	4
EB	ff	ADDB (opr)	IND,X	4
EC	ff	LDD (opr)	IND,X	5
ED	ff	STD (opr)	IND,X	5
EE	ff	LDX (opr)	IND,X	5
EF	ff	STX (opr)	IND,X	5
F0	hh ll	SUBB (opr)	EXT	4
F1	hh ll	CMPB (opr)	EXT	4
F2	hh ll	SBCB (opr)	EXT	4
F3	hh ll	ADDD (opr)	EXT	6
F4	hh ll	ANDB (opr)	EXT	4
F5	hh ll	BITB (opr)	EXT	4
F6	hh ll	LDAB (opr)	EXT	4
F7	hh ll	STAB (opr)	EXT	4
F8	hh ll	EORB (opr)	EXT	4
F9	hh ll	ADCB (opr)	EXT	4
FA	hh ll	ORAB (opr)	EXT	4
FB	hh ll	ADDB (opr)	EXT	4
FC	hh ll	LDD (opr)	EXT	5
FD	hh ll	STD (opr)	EXT	5
FE	hh ll	LDX (opr)	EXT	5
FF	hh ll	STX(opr)	EXT	5
18 08		INY	INH	4
18 09		DEY	INH	4
18 1C	ff mm	BSET (opr) (msk)	IND,Y	8
18 1D	ff mm	BCLR (opr) (msk)	IND,Y	8
18 1E	ff mm rr	BRSET (opr) (msk) (rel)	IND,Y	8
18 1F	ff mm rr	BRCLR (opr) (msk) (rel)	IND,Y	8
18 30		TSY	INH	4
18 35		TYS	INH	4
18 38		PULY	INH	6
18 3A		ABY	INH	4

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
18 3C		PSHY	INH	5
18 60	ff	NEG (opr)	IND,Y	7
18 63	ff	COM (opr)	IND,Y	7
18 64	ff	LSR (opr)	IND,Y	7
18 66	ff	ROR (opr)	IND,Y	7
18 67	ff	ASR (opr)	IND,Y	7
18 68	ff	ASL/LSL (opr)	IND,Y	7
18 69	ff	ROL (opr)	IND,Y	7
18 6A	ff	DEC (opr)	IND,Y	7
18 6C	ff	INC (opr)	IND,Y	7
18 6D	ff	TST (opr)	IND,Y	7
18 6E	ff	JMP (opr)	IND,Y	4
18 6F	ff	CLR (opr)	IND,Y	7
18 8C	jj kk	CPY (opr)	IMM	5
18 8F		XGDY	INH	4
18 9C	dd	CPY (opr)	DIR	6
18 A0	ff	SUBA (opr)	IND,Y	5
18 A1	ff	CMPA (opr)	IND,Y	5
18 A2	ff	SBCA (opr)	IND,Y	5
18 A3	ff	SUBD (opr)	IND,Y	7
18 A4	ff	ANDA (opr)	IND,Y	5
18 A5	ff	BITA (opr)	IND,Y	5
18 A6	ff	LDAA (opr)	IND,Y	5
18 A7	ff	STAA (opr)	IND,Y	5
18 A8	ff	EORA (opr)	IND,Y	5
18 A9	ff	ADCA (opr)	IND,Y	5
18 AA	ff	ORAA (opr)	IND,Y	5
18 AB	ff	ADDA (opr)	IND,Y	5
18 AC	ff	CPY (opr)	IND,Y	7
18 AD	ff	JSR (opr)	IND,Y	7
18 AE	ff	LDS (opr)	IND,Y	6
18 AF	ff	STS (opr)	IND,Y	6
18 BC	hh ll	CPY (opr)	EXT	7
18 CE	jj kk	LDY (opr)	IMM	4
18 DE	dd	LDY (opr)	DIR	5
18 DF	dd	STY (opr)	DIR	5
18 E0	ff	SUBB (opr)	IND,Y	5
18 E1	ff	CMPB (opr)	IND,Y	5
18 E2	ff	SBCB (opr)	IND,Y	5
18 E3	ff	ADDD (opr)	IND,Y	5
18 E4	ff	ANDB (opr)	IND,Y	5
18 E5	ff	BITB (opr)	IND,Y	5
18 E6	ff	LDAB (opr)	IND,Y	5
18 E7	ff	STAB (opr)	IND,Y	5

Opcode vs Instruction Cross Reference

Opcode	Operands	Instruction	ADDR Mode	Cycle
18 E8	ff	EORB (opr)	IND,Y	5
18 E9	ff	ADCB (opr)	IND,Y	5
18 EA	ff	ORAB (opr)	IND,Y	5
18 EB	ff	ADDB (opr)	IND,Y	5
18 EC	ff	LDD (opr)	IND,Y	6
18 ED	ff	STD (opr)	IND,Y	6
18 EE	ff	LDY (opr)	IND,Y	6
18 EF	ff	STY (opr)	IND,Y	6
18 FE	hh ll	LDY (opr)	EXT	6
18 FF	hh ll	STY (opr)	EXT	6
1A 83	jj kk	CPD (opr)	IMM	5
1A 93	dd	CPD (opr)	DIR	6
1A A3	ff	CPD (opr)	IND,X	7
1A AC	ff	CPY (opr)	IND,X	7
1A B3	hh ll	CPD (opr)	EXT	7
1A EE	ff	LDY (opr)	IND,X	6
1A EF	ff	STY (opr)	IND,X	6
CD A3	ff	CPD (opr)	IND,Y	7
CD AC	ff	CPX (opr)	IND,Y	7
CD EE	ff	LDX (opr)	IND,Y	6
CD EF	ff	STX (opr)	IND,Y	6

NOTES:

Operands:

- dd = 8-bit direct address $0000–$00FF. (High byte assumed to be $00).
- ff = 8-bit positive offset $00 (0) to $FF (255) added to index.
- hh = High-order byte of 16-bit extended address
- ii = One byte of immediate data.
- jj = High-order byte of 16-bit immediate data.
- kk = Low-order byte of 16-bit immediate data.
- ll = Low-order by te of 16-bit extended address.
- mm = 8-bit mask (set bits to be effective).
- rr = Signed relative offset $80 (128) to $7F (127). Offset relative to the address following the machine code offset byte.

INSTRUCTIONS, ADDRESSING MODES, AND EXECUTION TIMES

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
ABA	Add Accumulators	A + B ⇨ A	INH	1B		1	2	— — ↕ — ↕ ↕ ↕ ↕
ABX	Add B to X	IX + 00:B ⇨ IX	INH	3A		1	3	— — — — — — — —
ABY	Add B to Y	IY + 00:B ⇨ IY	INH	18 3A		2	4	— — — — — — — —
ADCA (opr)	Add with Carry to A	A + M + C ⇨ A	A IMM	89	ii	2	2	— — ↕ — ↕ ↕ ↕ ↕
			A DIR	99	dd	2	3	
			A EXT	B9	hh ll	3	4	
			A IND,X	A9	ff	2	4	
			A IND,Y	18 A9	ff	3	5	
ADCB (opr)	Add with Carry to B	B + M + C ⇨ B	B IMM	C9	ii	2	2	— — ↕ — ↕ ↕ ↕ ↕
			B DIR	D9	dd	2	3	
			B EXT	F9	hh ll	3	4	
			B IND,X	E9	ff	2	4	
			B IND,Y	18 E9	ff	3	5	

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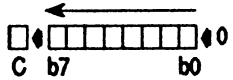
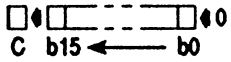
Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes							
				Opcode	Operand(s)			S	X	H	I	N	Z	V	C
ADDA (opr)	Add Memory to A	A + M ⧫ A	A IMM	8B	ii	2	2	—	—	↕	—	↕	↕	↕	↕
			A DIR	9B	dd	2	3								
			A EXT	BB	hh ll	3	4								
			A IND,X	AB	ff	2	4								
			A IND,Y	18 AB	ff	3	5								
ADDB (opr)	Add Memory to B	B + M ⧫ B	B IMM	CB	ii	2	2	—	—	↕	—	↕	↕	↕	↕
			B DIR	DB	dd	2	3								
			B EXT	FB	hh ll	3	4								
			B IND,X	EB	ff	2	4								
			B IND,Y	18 EB	ff	3	5								
ADDD (opr)	Add 16-Bit to D	D + M:M + 1 ⧫ D	IMM	C3	jj kk	3	4	—	—	—	—	↕	↕	↕	↕
			DIR	D3	dd	2	5								
			EXT	F3	hh ll	3	6								
			IND,X	E3	ff	2	6								
			IND,Y	18 E3	ff	3	7								

ANDA (opr)	AND A with Memory	A • M ⇨ A	A IMM A DIR A EXT A IND,X A IND,Y	84 94 B4 A4 18 A4	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ 0 —
ANDB (opr)	AND B with Memory	B • M ⇨ B	B IMM B DIR B EXT B IND,X B IND,Y	C4 D4 F4 E4 18 E4	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ 0 —
ASL (opr) ASLA ASLB	Arithmetic Shift Left		EXT IND,X IND,Y A INH B INH	78 68 18 68 48 58	hh ll ff ff	3 2 3 1 1	6 6 7 2 2	— — — — ↕ ↕ ↕ ↕
ASLD	Arithmetic Shift Left Double		INH	05		1	3	— — — — ↕ ↕ ↕ ↕

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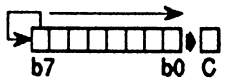
Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
ASR (opr)	Arithmetic Shift Right		EXT	77	hh ll	3	6	— — — — ↕ ↕ ↕ ↕
			IND,X	67	ff	2	6	
			IND,Y	18 67	ff	3	7	
ASRA			A INH	47		1	2	
ASRB			B INH	57		1	2	
BCC (rel)	Branch if Carry Clear	? C = 0	REL	24	rr	2	3	— — — — — — — —
BCLR (opr) (msk)	Clear Bit(s)	M • ($\overline{mm}$) ⇩ M	DIR	15	dd mm	3	6	— — — — ↕ ↕ 0 —
			IND,X	1D	ff mm	3	7	
			IND,Y	18 1D	ff mm	4	8	
BCS (rel)	Branch if Carry Clear	? C = 1	REL	25	rr	2	3	— — — — — — — —
BEQ (rel)	Branch if = Zero	? Z = 1	REL	27	rr	2	3	— — — — — — — —
BGE (rel)	Branch if ≥ Zero	? N ⊕ V = 0	REL	2C	rr	2	3	— — — — — — — —
BGT (rel)	Branch if > Zero	? Z + (N ⊕ V) = 0	REL	2E	rr	2	3	— — — — — — — —
BHI (rel)	Branch if Higher	? C + Z = 0	REL	22	rr	2	3	— — — — — — — —

BHS (rel)	Branch if Higher or Same	? C = 0	REL	24	rr	2	3	— — — — — — — —
BITA (opr)	Bit(s) Test A with Memory	A • M	A IMM A DIR A EXT A IND,X A IND,Y	85 95 B5 A5 18 A5	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ 0 —
BITB (opr)	Bit(s) Test B with Memory	B • M	B IMM B DIR B EXT B IND,X B IND,Y	C5 D5 F5 E5 18 E5	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ 0 —
BLE (rel)	Branch if ≤ Zero	? Z + (N ⊕ V) = 1	REL	2F	rr	2	3	— — — — — — — —
BLO (rel)	Branch if Lower	? C = 1	REL	25	rr	2	3	— — — — — — — —
BLS (rel)	Branch if Lower or Same	? C + Z = 1	REL	23	rr	2	3	— — — — — — — —
BLT (rel)	Branch If < Zero	? N ⊕ V = 1	REL	2D	rr	2	3	— — — — — — — —
BMI (rel)	Branch if Minus	? N = 1	REL	2B	rr	2	3	— — — — — — — —
BNE (rel)	Branch if Not = Zero	? Z = 0	REL	26	rr	2	3	— — — — — — — —
BPL (rel)	Branch if Plus	? N = 0	REL	2A	rr	2	3	— — — — — — — —

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
BRA (rel)	Branch Always	? 1 = 1	REL	20	rr	2	3	— — — — — — — —
BRCLR(opr) (msk) (rel)	Branch if Bit(s) Clear	? M • mm = 0	DIR IND,X IND,Y	13 1F 18 1F	dd mm rr ff mm rr ff mm rr	4 4 5	6 7 8	— — — — — — — —
BRN (rel)	Branch Never	? 1 = 0	REL	21	rr	2	3	— — — — — — — —
BRSET(opr) (msk) (rel)	Branch if Bit(s) Set	? ($\overline{M}$) • mm = 0	DIR IND,X IND,Y	12 1E 18 1E	dd mm rr ff mm rr ff mm rr	4 4 5	6 7 8	— — — — — — — —
BSET (opr) (msk)	Set Bit(s)	M + mm ⇳ M	DIR IND,X IND,Y	14 1C 18 1C	dd mm ff mm ff mm	3 3 4	6 7 8	— — — — ↕ ↕ 0 —
BSR (rel)	Branch to Subroutine	See Special Ops	REL	8D	rr	2	6	— — — — — — — —
BVC (rel)	Branch if Overflow Clear	? V = 0	REL	28	rr	2	3	— — — — — — — —
BVS (rel)	Branch if Overflow Set	? V = 1	REL	29	rr	2	3	— — — — — — — —

CBA	Compare A to B	A − B	INH	11		1	2	— — — — ↕ ↕ ↕ ↕
CLC	Clear Carry Bit	0 ⇞ C	INH	0C		1	2	— — — — — — — — 0
CLI	Clear Interrupt Mask	0 ⇞ I	INH	0E		1	2	— — — 0 — — — —
CLR (opr)	Clear Memory Byte	0 ⇞ M	EXT IND,X IND,Y	7F 6F 18 6F	hh ll ff ff	3 2 3	6 6 7	— — — — 0 1 0 0
CLRA	Clear Accumulator A	0 ⇞ A	A INH	4F		1	2	— — — — 0 1 0 0
CLRB	Clear Accumulator B	0 ⇞ B	B INH	5F		1	2	— — — — 0 1 0 0
CLV	Clear Overflow Flag	0 ⇞ V	INH	0A		1	2	— — — — — — 0 —
CMPA (opr)	Compare A to Memory	A − M	A IMM A DIR A EXT A IND,X A IND,Y	81 91 B1 A1 18 A1	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ ↕ ↕

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Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
CMPB (opr)	Compare B to Memory	B–M	B IMM	C1	ii	2	2	— — — — ↕ ↕ ↕ ↕
			B DIR	D1	dd	2	3	
			B EXT	F1	hh ll	3	4	
			B IND,X	E1	ff	2	4	
			B IND,Y	18 E1	ff	3	5	
COM (opr)	Ones Complement Memory Byte	$FF–M ⇩ M	EXT	73	hh ll	3	6	— — — — ↕ ↕ 0 1
			IND,X	63	ff	2	6	
			IND,Y	18 63	ff	3	7	
COMA	Ones Complement A	$FF–A ⇩ A	A INH	43		1	2	— — — — ↕ ↕ 0 1
COMB	Ones Complement B	$FF–B ⇩ B	B INH	53		1	2	— — — — ↕ ↕ 0 1
CPD (opr)	Compare D to Memory 16-Bit	D – M:M + 1	IMM	1A 83	jj kk	4	5	— — — — ↕ ↕ ↕ ↕
			DIR	1A 93	dd	3	6	
			EXT	1A B3	hh ll	4	7	
			IND,X	1A A3	ff	3	7	
			IND,Y	CD A3	ff	3	7	

CPX (opr)	Compare X to Memory 16-Bit	IX – M:M + 1	IMM DIR EXT IND,X IND,Y	 CD	8C 9C BC AC AC	jj kk dd hh ll ff ff	3 2 3 2 3	4 5 6 6 7	— — — — ↕ ↕ ↕ ↕
CPY (opr)	Compare Y to Memory 16-Bit	IY – M:M + 1	IMM DIR EXT IND,X IND,Y	18 18 18 1A 18	8C 9C BC AC AC	jj kk dd hh ll ff ff	4 3 4 3 3	5 6 7 7 7	— — — — ↕ ↕ ↕ ↕
DAA	Decimal Adjust A	Adjust Sum to BCD	INH		19		1	2	— — — — ↕ ↕ ↕ ↕
DEC (opr)	Decrement Memory Byte	M – 1 ⇩ M	EXT IND,X IND,Y	 18	7A 6A 6A	hh ll ff ff	3 2 3	6 6 7	— — — — ↕ ↕ ↕ —
DECA	Decrement Accumulator A	A – 1 ⇩ A	A INH		4A		1	2	— — — — ↕ ↕ ↕ —
DECB	Decrement Accumulator B	B – 1 ⇩ B	B INH		5A		1	2	— — — — ↕ ↕ ↕ —
DES	Decrement Stack Pointer	SP – 1 ⇩ SP	INH		34		1	3	— — — — — — — —

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Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes							
				Opcode	Operand(s)			S	X	H	I	N	Z	V	C
DEX	Decrement Index Register X	IX – 1 ⇩ IX	INH	09		1	3	—	—	—	—	—	↕	—	—
DEY	Decrement Index Register Y	IY – 1 ⇩ IY	INH	18 09		2	4	—	—	—	—	—	↕	—	—
EORA (opr)	Exclusive OR A with Memory	A ⊕ M ⇩ A	A IMM	88	ii	2	2	—	—	—	—	↕	↕	0	—
			A DIR	98	dd	2	3								
			A EXT	B8	hh ll	3	4								
			A IND,X	A8	ff	2	4								
			A IND,Y	18 A8	ff	3	5								
EORB (opr)	Exclusive OR B with Memory	B ⊕ M ⇩ B	B IMM	C8	ii	2	2	—	—	—	—	↕	↕	0	—
			B DIR	D8	dd	2	3								
			B EXT	F8	hh ll	3	4								
			B IND,X	E8	ff	2	4								
			B IND,Y	18 E8	ff	3	5								
FDIV	Fractional Divide 16 by 16	D/IX ⇩ IX; r ⇩ D	INH	03		1	41	—	—	—	—	—	↕	↕	↕
IDIV	Integer Divide 16 by 16	D/IX ⇩ IX; r ⇩ D	INH	02		1	41	—	—	—	—	—	↕	0	↕

INC (opr)	Increment Memory Byte	M + 1 ⇨ M	EXT IND,X IND,Y	7C 6C 18 6C	hh ll ff ff	3 2 3	6 6 7	— — — — ↕ ↕ ↕ —
INCA	Increment Accumulator A	A + 1 ⇨ A	A INH	4C		1	2	— — — — ↕ ↕ ↕ —
INCB	Increment Accumulator B	B + 1 ⇨ B	B INH	5C		1	2	— — — — ↕ ↕ ↕ —
INS	Increment Stack Pointer	SP + 1 ⇨ SP	INH	31		1	3	— — — — — — — —
INX	Increment Index Register X	IX + 1 ⇨ IX	INH	08		1	3	— — — — — ↕ — —
INY	Increment Index Register Y	IY + 1 ⇨ IY	INH	18 08		2	4	— — — — — ↕ — —
JMP (opr)	Jump	See Special Ops	EXT IND,X IND,Y	7E 6E 18 6E	hh ll ff ff	3 2 3	3 3 4	— — — — — — — —
JSR (opr)	Jump to Subroutine	See Special Ops	DIR EXT IND,X IND,Y	9D BD AD 18 AD	dd hh ll ff ff	2 3 2 3	5 6 6 7	— — — — — — — —

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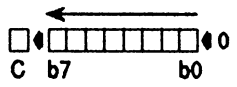
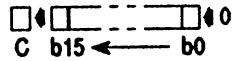
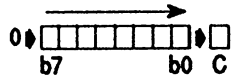
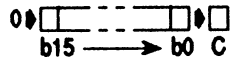
Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes							
				Opcode	Operand(s)			S	X	H	I	N	Z	V	C
LDAA (opr)	Load Accumulator A	M ⇨ A	A IMM	86	ii	2	2	—	—	—	—	↕	↕	0	—
			A DIR	96	dd	2	3								
			A EXT	B6	hh ll	3	4								
			A IND,X	A6	ff	2	4								
			A IND,Y	18 A6	ff	3	5								
LDAB (opr)	Load Accumulator B	M ⇨ B	B IMM	C6	ii	2	2	—	—	—	—	↕	↕	0	—
			B DIR	D6	dd	2	3								
			B EXT	F6	hh ll	3	4								
			B IND,X	E6	ff	2	4								
			B IND,Y	18 E6	ff	3	5								
LDD (opr)	Load Double Accumulator D	M ⇨ A,M+1 ⇨ B	IMM	CC	jj kk	3	3	—	—	—	—	↕	↕	0	—
			DIR	DC	dd	2	4								
			EXT	FC	hh ll	3	5								
			IND,X	EC	ff	2	5								
			IND,Y	18 EC	ff	3	6								

LDS (opr)	Load Stack Pointer	M:M+1 ⇨ SP	IMM		8E	jj kk	3	3	— — — — ↕ ↕ 0 —
			DIR		9E	dd	2	4	
			EXT		BE	hh ll	3	5	
			IND,X		AE	ff	2	5	
			IND,Y	18	AE	ff	3	6	
LDX (opr)	Load Index Register X	M:M+1 ⇨ IX	IMM		CE	jj kk	3	3	— — — — ↕ ↕ 0 —
			DIR		DE	dd	2	4	
			EXT		FE	hh ll	3	5	
			IND,X		EE	ff	2	5	
			IND,Y	CD	EE	ff	3	6	
LDY (opr)	Load Index Register Y	M:M+1 ⇨ IY	IMM	18	CE	jj kk	4	4	— — — — ↕ ↕ 0 —
			DIR	18	DE	dd	3	5	
			EXT	18	FE	hh ll	4	6	
			IND,X	1A	EE	ff	3	6	
			IND,Y	18	EE	ff	3	6	
LSL (opr)	Logical Shift Left		EXT		78	hh ll	3	6	— — — — ↕ ↕ ↕ ↕
			IND,X		68	ff	2	6	
			IND,Y	18	68	ff	3	7	
LSLA			A INH		48		1	2	
LSLB			B INH		58		1	2	

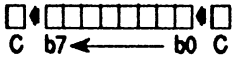
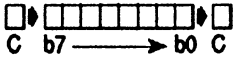
[redacted]

[redacted]

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
LSLD	Logical Shift Left Double		INH	05		1	3	— — — — ↕ ↕ ↕ ↕
LSR (opr)	Logical Shift Right		EXT	74	hh ll	3	6	— — — — 0 ↕ ↕ ↕
			IND,X	64	ff	2	6	
			IND,Y	18 64	ff	3	7	
LSRA			A INH	44		1	2	
LSRB			B INH	54		1	2	
LSRD	Logical Shift Right Double		INH	04		1	3	— — — — 0 ↕ ↕ ↕
MUL	Multiply 8 by 8	A × B ⇕ D	INH	3D		1	10	— — — — — — — ↕
NEG (opr)	Twos Complement Memory Byte	0 − M ⇕ M	EXT	70	hh ll	3	6	— — — — ↕ ↕ ↕ ↕
			IND,X	60	ff	2	6	
			IND,Y	18 60	ff	3	7	
NEGA	Twos Complement A	0 − A ⇕ A	A INH	40		1	2	— — — — ↕ ↕ ↕ ↕
NEGB	Twos Complement B	0 − B ⇕ B	B INH	50		1	2	— — — — ↕ ↕ ↕ ↕

NOP	No Operation	No Operation	INH	01		1	2	— — — — — — — —
ORAA (opr)	OR Accumulator A (Inclusive)	A + M ⧫ A	A IMM A DIR A EXT A IND,X A IND,Y	8A 9A BA AA 18 AA	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ⇕ ⇕ 0 —
ORAB (opr)	OR Accumulator B (Inclusive)	B + M ⧫ B	B IMM B DIR B EXT B IND,X B IND,Y	CA DA FA EA 18 EA	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ⇕ ⇕ 0 —
PSHA	Push A onto Stack	A ⧫ Stk,SP = SP − 1	A INH	36		1	3	— — — — — — — —
PSHB	Push B onto Stack	B ⧫ Stk,SP = SP − 1	B INH	37		1	3	— — — — — — — —
PSHX	Push X onto Stack (Lo First)	IX ⧫ Stk,SP = SP − 2	INH	3C		1	4	— — — — — — — —
PSHY	Push Y onto Stack (Lo First)	IY ⧫ Stk,SP = SP − 2	INH	18 3C		2	5	— — — — — — — —
PULA	Pull A from Stack	SP = SP + 1,A ⧪ Stk	A INH	32		1	4	— — — — — — — —
PULB	Pull B from Stack	SP = SP + 1,B ⧪ Stk	B INH	33		1	4	— — — — — — — —

[redacted]

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes
				Opcode	Operand(s)			S X H I N Z V C
PULX	Pull X from Stack (Hi First)	SP = SP + 2,IX ⇐ Stk	INH	38		1	5	— — — — — — — —
PULY	Pull Y from Stack (Hi First)	SP = SP + 2,IY ⇐ Stk	INH	18 38		2	6	— — — — — — — —
ROL (opr)	Rotate Left		EXT	79	hh ll	3	6	— — — — ↕ ↕ ↕ ↕
			IND,X	69	ff	2	6	
			IND,Y	18 69	ff	3	7	
ROLA			A INH	49		1	2	
ROLB			B INH	59		1	2	
ROR (opr)	Rotate Right		EXT	76	hh ll	3	6	— — — — ↕ ↕ ↕ ↕
			IND,X	66	ff	2	6	
			IND,Y	18 66	ff	3	7	
RORA			A INH	46		1	2	
RORB			B INH	56		1	2	
RTI	Return from Interrupt	See Special Ops	INH	3B		1	12	↕ — ↕ ↕ ↕ ↕ ↕ ↕
RTS	Return from Subroutine	See Special Ops	INH	39		1	5	— — — — — — — —
SBA	Subtract B from A	A − B ⇐ A	INH	10		1	2	— — — — ↕ ↕ ↕ ↕

SBCA (opr)	Subtract with Carry from A	A – M – C ⇨ A	A IMM A DIR A EXT A IND,X A IND,Y	 18	82 92 B2 A2 A2	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ ↕ ↕
SBCB (opr)	Subtract with Carry from B	B – M – C ⇨ B	B IMM B DIR B EXT B IND,X B IND,Y	 18	C2 D2 F2 E2 E2	ii dd hh ll ff ff	2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ ↕ ↕
SEC	Set Carry	1 ⇨ C	INH		OD		1	2	— — — — — — — 1
SEI	Set Interrupt Mask	1 ⇨ I	INH		OF		1	2	— — — 1 — — — —
SEV	Set Overflow Flag	1 ⇨ V	INH		OB		1	2	— — — — — — 1 —
STAA (opr)	Store Accumulator A	A ⇨ M	A DIR A EXT A IND,X A IND,Y	 18	97 B7 A7 A7	dd hh ll ff ff	2 3 2 3	3 4 4 5	— — — — ↕ ↕ 0 —

[redacted]

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes							
				Opcode	Operand(s)			S	X	H	I	N	Z	V	C
STAB (opr)	Store Accumulator B	B ⇨ M	B DIR	D7	dd	2	3	—	—	—	—	↕	↕	0	—
			B EXT	F7	hh ll	3	4								
			B IND,X	E7	ff	2	4								
			B IND,Y	18 E7	ff	3	5								
STD (opr)	Store Accumulator D	A ⇨ M,B ⇨ M + 1	DIR	DD	dd	2	4	—	—	—	—	↕	↕	0	—
			EXT	FD	hh ll	3	5								
			IND,X	ED	ff	2	5								
			IND,Y	18 ED	ff	3	6								
STOP	Stop Internal Clocks		INH	CF		1	2	—	—	—	—	—	—	—	—
STS (opr)	Store Stack Pointer	SP ⇨ M:M + 1	DIR	9F	dd	2	4	—	—	—	—	↕	↕	0	—
			EXT	BF	hh ll	3	5								
			IND,X	AF	ff	2	5								
			IND,Y	18 AF	ff	3	6								
STX (opr)	Store Index Register X	IX ⇨ M:M + 1	DIR	DF	dd	2	4	—	—	—	—	↕	↕	0	—
			EXT	FF	hh ll	3	5								
			IND,X	EF	ff	2	5								
			IND,Y	CD EF	ff	3	6								

STY (opr)	Store Index Register Y	IY ⇨ M:M+1	DIR EXT IND,X IND,Y	18 DF 18 FF 1A EF 18 EF	dd hh ll ff ff		3 4 3 3	5 6 6 6	— — — — ↕ ↕ 0 —
SUBA (opr)	Subtract Memory from A	A − M ⇨ A	A IMM A DIR A EXT A IND,X A IND,Y	80 90 B0 A0 18 A0	ii dd hh ll ff ff		2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ ↕ ↕
SUBB (opr)	Subtract Memory from B	B − M ⇨ B	B IMM B DIR B EXT B IND,X B IND,Y	C0 D0 F0 E0 18 E0	ii dd hh ll ff ff		2 2 3 2 3	2 3 4 4 5	— — — — ↕ ↕ ↕ ↕
SUBD (opr)	Subtract Memory from D	D − M:M+1 ⇨ D	IMM DIR EXT IND,X IND,Y	83 93 B3 A3 18 A3	jj kk dd hh ll ff ff		3 2 3 2 3	4 5 6 6 7	— — — — ↕ ↕ ↕ ↕
SWI	Software Interrupt	See Special Ops	INH	3F			1	14	— — — 1 — — — —
TAB	Transfer A to B	A ⇨ B	INH	16			1	2	— — — — ↕ ↕ 0 —

[redacted]

Source Form(s)	Operation	Boolean Expression	Addressing Mode for Operand	Machine Coding (Hexadecimal)		Bytes	Cycles	Condition Codes							
				Opcode	Operand(s)			S	X	H	I	N	Z	V	C
TAP	Transfer A to CC Register	A ⇨ CCR	INH	06		1	2	↕	–	↕	↕	↕	↕	↕	↕
TBA	Transfer B to A	B ⇨ A	INH	17		1	2	—	—	—	—	↕	↕	0	—
TEST	TEST (Only in Test Modes)	Address Bus Counts	INH	00		1	*	—	—	—	—	—	—	—	—
TPA	Transfer CC Register to A	CCR ⇨ A	INH	07		1	2	—	—	—	—	—	—	—	—
TST (opr)	Test for Zero or Minus	M – 0	EXT	7D	hh ll	3	6	—	—	—	—	↕	↕	0	0
			IND,X	6D	ff	2	6								
			IND,Y	18 6D	ff	3	7								
TSTA		A – 0	A INH	4D		1	2	—	—	—	—	↕	↕	0	0
TSTB		B – 0	B INH	5D		1	2	—	—	—	—	↕	↕	0	0
TSX	Transfer Stack Pointer to X	SP + 1 ⇨ IX	INH	30		1	3	—	—	—	—	—	—	—	—
TSY	Transfer Stack Pointer to Y	SP + 1 ⇨ IY	INH	18 30		2	4	—	—	—	—	—	—	—	—
TXS	Transfer X to Stack Pointer	IX – 1 ⇨ SP	INH	35		1	3	—	—	—	—	—	—	—	—

TYS	Transfer Y to Stack Pointer	IY − 1 ⇨ SP	INH	18 35		2	4	— — — — — — — —
WAI	Wait for Interrupt	Stack Regs & WAIT	INH	3E		1	**	— — — — — — — —
XGDX	Exchange D with X	IX ⇨ D, D ⇨ IX	INH	8F		1	3	— — — — — — — —
XGDY	Exchange D with Y	IY ⇨ D, D ⇨ IY	INH	18 8F		2	4	— — — — — — — —

NOTES:

*Infinity or until reset occurs

**12 cycles are used beginning with the opcode fetch. A wait state is entered which remains in effect for an integer number of MPU E-clock cycles (n) until an interrupt is recognized. Finally, two additional cycles are used to fetch the appropriate interrupt vector (14 + n total).

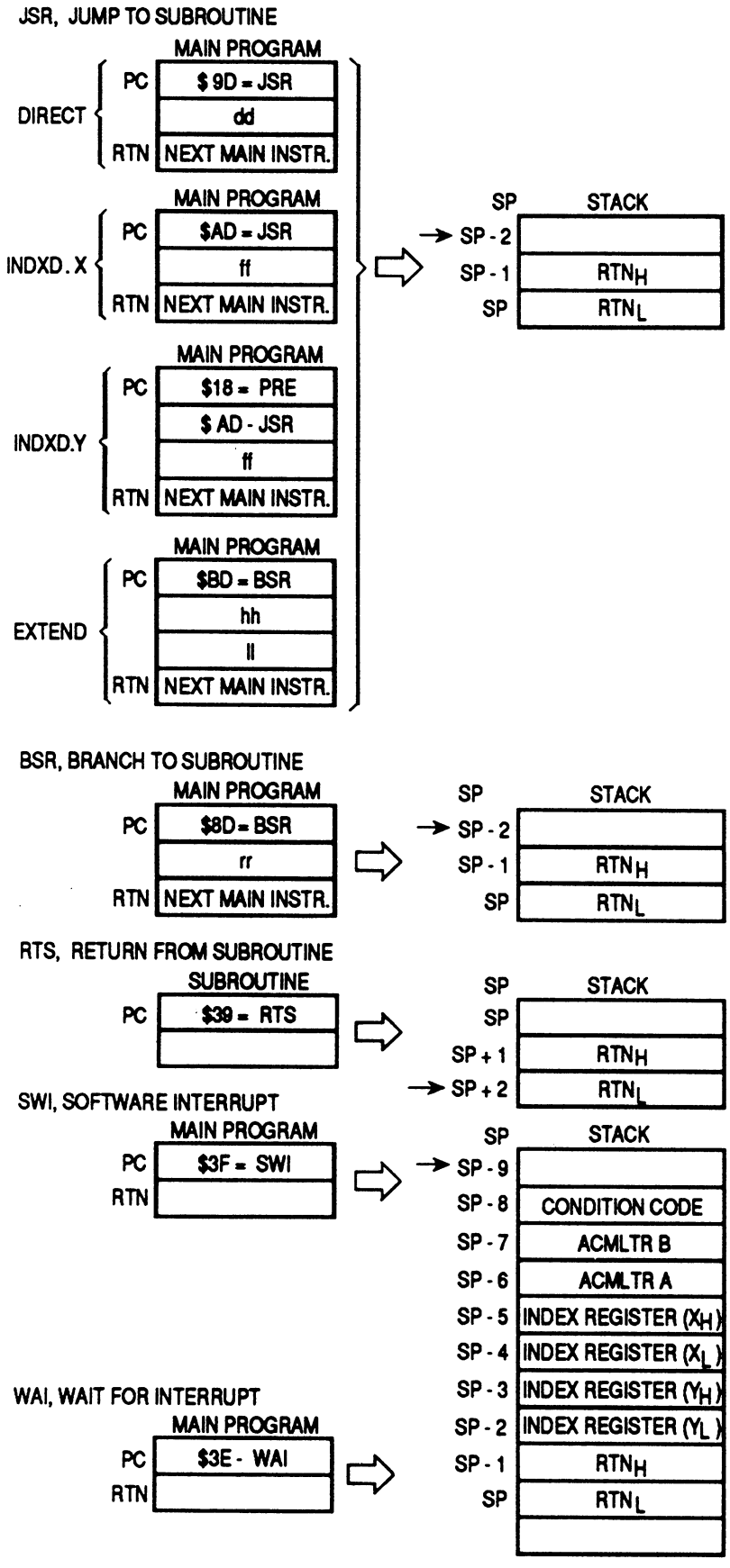
Operands

dd	8-Bit Direct Address ($000–$00FF) (High Byte Assumed to be $00)
ff	8-Bit Positive offset $00 (0) to $FF (255) (Is Added to Index)
hh	High-Order Byte of 16-Bit Extended Address
ii	One Byte of Immediate Data
jj	High-Order Byte of 16-Bit Immediate Data
kk	Low-Order Byte of 16-Bit Immediate Data
ll	Low-Order byte of 16-Bit Extended Address
mm	8-Bit Mask (Set Bits to be Affected)
rr	Signed Relative offset $80 (128) to $7F (127) (Offset Relative to the Address Following the Machine Code Offset Byte)

Condition Codes

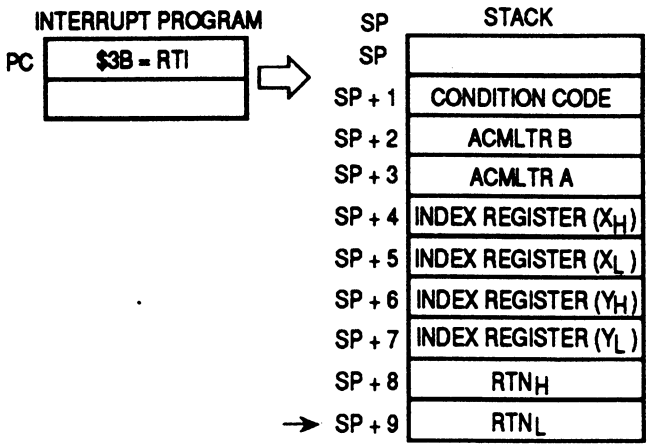
—	Bit not changed
0	Bit always cleared
1	Bit always set
⇕	Bit cleared or set, depending on operation
⇓	Bit can be cleared, cannot become set

SPECIAL OPERATIONS

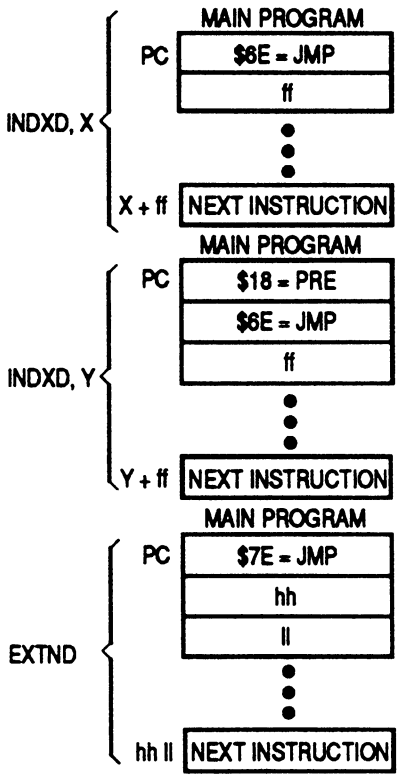


SPECIAL OPERATIONS

RTI, RETURN FROM INTERRUPT



JMP, JUMP



LEGEND:

RTN	Address of Next Instruction in Main Program To Be Executed upon Return from Subroutine
RTN_H	Most Significant Byte of Return Address
RTN_L	Least Significant Byte of Return Address
→	Stack Pointer after Execution
dd	8-Bit Direct Address ($0000-$00FF) (High Byte Assumed To Be $00)
ff	8-Bit Positive Offset $00 (0) to $FF (256) (Is Added to Index)
hh	High-Order Byte of 16-Bit Extended Address
ll	Low-Order Byte of 16-Bit Extended Address
rr	Signed-Relative Offset $80 (- 128) to $7F (+ 127) (Offset Relative to the Address Following the Machine Code Offset BYTE)

REGISTER AND CONTROL BIT SUMMARY

	Bit 7	6	5	4	3	2	1	Bit 0	
$0000	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0	PORTA
$0001									Reserved
$0002			CWOM						PIOC
$0003	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0	PORTC
$0004	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0	PORTB
$0005									Reserved
$0006	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	DDRB
$0007	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	DDRC
$0008	PD7	PB6	PD5	PD4	PD3	PD2	PD1	PD0	PORTD
$0009	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	DDRD
$000A									Reserved
$000B	FOC1	FOC2	FOC3	FOC4	FOC5	0	0	0	CFORC
$000C	OC1M7	OC1M6	OC1M5	OC1M4	OC1M3	0	0	0	OC1M
$000D	OC1D7	OC1D6	OC1D5	OC1D4	OC1D3	0	0	0	OC1D
$000E	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TCNT
$000F	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0010	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TIC1
$0011	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0012	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TIC2
$0013	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0014	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TIC3
$0015	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0016	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TOC1
$0017	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0018	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TOC2
$0019	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$001A	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TOC3
$001B	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$001C	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TOC4
$001D	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$001E	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	TI4O5
$001F	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
$0020	OM2	OL2	OM3	OL3	OM4	OL4	OM5	OL5	TCTL1

REGISTER AND CONTROL BIT SUMMARY

$0021	EDG4B	EDG4A	EDG1B	EDG1A	EDG2B	EDG2A	EDG3B	EDG3A	TCTL2
$0022	OC1I	OC2I	OC3I	OC4I	I405I	IC1I	IC2I	IC3I	TMSK1
$0023	OC1F	OC2F	OC3F	OC4F	I4O5F	IC1F	IC2F	IC3F	TFLG1
$0024	TOI	RTII	PAOVI	PAII	0	0	PR1	PR0	TMSK2
$0025	TOF	RTIF	PAOVF	PAIF	0	0	0	0	TFLG2
$0026	DDRA7	PAEN	PAMOD	PEDGE	DDRA3	I4/O5	RTR1	RTR0	PACTL
$0027	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	PACNT
$0028	SPIE	SPE	DWOM	MSTR	CPOL	CPHA	SPR1	SPR0	SPCR
$0029	SPIF	WCOL	0	MODF	0	0	0	0	SPSR
$002A	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	SPDR
$002B	TCLR	0	SCP1	SCP0	RCKB	SCR2	SCR1	SCR0	BAUD
$002C	R8	T8	0	M	WAKE	0	0	0	SCCR1
$002D	TIE	TCIE	RIE	ILIE	TE	RE	RWU	SBK	SCCR2
$002E	TDRE	TC	RDRF	IDLE	OR	NF	FE	0	SCSR
$002F	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	SCDR
$0030									Reserved
to $0038									Reserved
$0039	0	0	IRQE	DLY	CME	0	CR1	CR0	OPTION
$003A	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	COPRST
$003B	MBE	0	ELAT	EXCOL	EXROW	0	0	PGM	PPROG*
$003C	RBOOT	SMOD	MDA	IRVNE	PSEL3	PSEL2	PSEL1	PSEL0	HPRIO
$003D	RAM3	RAM2	RAM1	RAM0	REG3	REG2	REG1	REG0	INIT
$003E	TILOP	EPTST	OCCR	CBYP	DISR	FCM	FCOP	0	TEST1
$003F	0	0	0	0	0	NOCOP	EPON**	0	CONFIG

* — Not present in ROM-based MC68HC11D3
** — ROMON in MC68HC11D3

NOTE

The status and control register block is relocatable to any 4K boundary within the MC68HC711D3's 64K of addressable memory using the REG3–REG0 bits of the INIT register. Reset locates this block at $0000–003F. The default value is indicated by the use of a bold **0** at the beginning of the address of any relocatable register.

SCI Baud Rate Control Register

$002B	TCLR	0	SCP1	SCP0	RCKB	SCR2	SCR1	SCR0
RESET:	0	0	0	0	0	U	U	U

TCLR — Clear Baud Counter Chain (Test Only)
RCKB — SCI Baud Rate Clock Test (Test Only)

SCP1, SCP0 — Serial Prescaler Selects

SCP1	SCP0	Divide E By	Highest Baud Rate Xtal = 2^{23}	Highest Baud Rate Xtal = 8.0 MHz	Highest Baud Rate Xtal = 4.0 MHz
0	0	1	131.07 K	—	—
0	1	3	—	—	—
1	0	4	32.768 K	—	—
1	1	13	—	9600	4800
		E =	2.1 MHz	2.0 MHz	1.0 MHz

SCR2–SCR0 — SCI Rate Select Bit 2 Through Bit 0

SCR2	SCR1	SCR0	Prescaler Output Divide-By Factor	Highest Baud Rate 32.768 K	Highest Baud Rate 9600	Highest Baud Rate 4800
0	0	0	1	32.768 K	9600	4800
0	0	1	2	—	4800	2400
0	1	0	4	8.192 K	2400	1200
0	1	1	8	—	1200	600
1	0	0	16	2.048 K	600	300
1	0	1	32	—	300	—
1	1	0	64	512	—	—
1	1	1	128	—	—	—

Timer Compare Force Register

$000B	FOC1	FOC2	FOC3	FOC4	FOC5	0	0	0
RESET:	0	0	0	0	0	0	0	0

Write 1's to force compare(s).

Configuration Control Register

The configuration control register controls the presence of PROM in the memory map and enables the COP watchdog system.

$003F	0	0	0	0	0	NOCOP	EPONt	0
RESET:	0	0	0	0	0	*	*	0

Bits 7–3 and 0 — Not implemented; always read zero.

NOCOP — Computer Operating Properly System Disable
This bit is cleared out of reset in normal modes (single chip and expanded), enabling the COP system. It is writable only once after reset in these modes (SMOD = 0). In the special modes (test and bootstrap) (SMOD = 1), this bit comes out of reset set and is writable any time.
1 = COP system is disabled.
0 = COP system is enabled; reset is forced on timeout.

†EPON — PROM Enable (ROM Enable (ROMON) in the MC68HC11D3)
This is the EPON bit in the MC68HC711D3. In the MC68HC11D3, it is the ROMON bit. In either case, the functionality is the same. This bit is set out of reset, enabling the ROM or PROM in all modes. It is writable once in normal modes (SMOD = 0), but is writable at any time in special modes (SMOD = 1).
1 = PROM is present in the memory map.
0 = PROM is disabled from the memory map.

NOTE

In expanded mode out of reset, the ROM or PROM is located at $7000–$7FFF. In all other modes, the ROM or PROM resides at $F000–$FFFF.

COPRST

Arm/Reset COP Timer Circuitry

$003A	—	—	—	—	—	—	—	—

Write $55 and $AA to reset COP watchdog timer.

DDRB

Port B Data Direction Register

$0006	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0
RESET:	0	0	0	0	0	0	0	0

0 = Inputs 1 = Outputs

DDRC

Port C Data Direction Register

$0007	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0
RESET:	0	0	0	0	0	0	0	0

0 = Inputs 1 = Outputs

DDRD

Port D Data Direction Register

$0009	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0
RESET:	0	0	0	0	0	0	0	0

0 = Inputs 1 = Outputs

DDRD

Highest Priority Interrupt and Misc.

Four bits of this register (PSEL3–PSEL0) are used to select one of the I-bit-related interrupt sources and to elevate it to the highest I-bit-masked position of the priority resolution circuit. In addition, four miscellaneous system control bits are included in this register.

$003C	RBOOT	SMOD	MDA	IRVNE	PSEL3	PSEL2	PSEL1	PSEL0
RESET:	*	*	*	*	0	1	0	1

* = The reset condition of bits 7, 6, 5, and 4 depends on the mode selected at power-up initialization.

RBOOT — Read Bootstrap ROM

This bit can be read at any time. It can only be written in special modes (SMOD = 1). In special bootstrap mode, it is set during reset. Reset clears it in all other modes.

1 = Bootloader ROM is enabled in the memory map at $BF00–$BFFF.

0 = Bootloader ROM is disabled and is not in the memory map.

SMOD and MDA — Special Mode Select, Mode Select A

These two bits can be read at any time. They may only be written in special modes (SMOD = 1). MDA may be written once with SMOD = 0. These bits reflect the status of the MODA and MODB input pins at the rising edge of reset. SMOD cannot be written to a one after being cleared without an interim reset. An interpretation of the values of these two bits is shown in the following table:

Input Pins		Mode Description	Latched at Reset	
MODB	MODA		SMOD	MDA
1	0	(0) Single Chip	0	0
1	1	(1) Expanded Multiplexed	0	1
0	0	Special Bootstrap	1	0
0	1	Special Test	1	1

IRVNE — Internal Read Visibility Enable/Not E
This bit may be read at any time. It may only be written once. IRVNE is set during reset in special mode and is cleared by reset in all other modes.

Mode	IRVNE Out of Reset	E-Clock Out of Reset	IRV Out of Reset	IRVNE Affects Only
Single Chip	0	On	Off	E
Expanded	0	On	Off	IRV
Bootstrap	0	On	Off	E
Special Test	1	On	On	IRV

PSEL3–PSEL0 — Priority Select Bits 3–0
(May only be written if I bit in CCR = 1)

PSEL3	PSEL2	PSEL1	PSEL0	Interrupt Source Promoted
0	0	0	0	Timer Overflow
0	0	0	1	Pulse Accumulator Overflow
0	0	1	0	Pulse Accumulator Input Edge
0	0	1	1	SPI Serial Transfer Complete
0	1	0	0	SCI Serial System
0	1	0	1	Reserved (Default to IRQ)
0	1	1	0	IRQ
0	1	1	1	Real-Time Interrupt
1	0	0	0	Timer Input Capture 1
1	0	0	1	Timer Input Capture 2
1	0	1	0	Timer Input Capture 3
1	0	1	1	Timer Output Compare 1
1	1	0	0	Timer Output Compare 2
1	1	0	1	Timer Output Compare 3
1	1	1	0	Timer Output Compare 4
1	1	1	1	Timer Input Capture 4/Output Compare 5

RAM and I/O Mapping Register

$003D	RAM3	RAM2	RAM1	RAM0	REG3	REG2	REG1	REG0
RESET:	0	0	0	0	0	0	0	0

(Time protected)

RAM3–RAM0 — RAM Map Position

REG3–REG0 — 64-Byte Register Block Map Position

OC1D

Output Compare 1 Data Register

$000D	OC1D7	OC1D6	OC1D5	OC1D4	OC1D3	0	0	0
RESET:	0	0	0	0	0	0	0	0

If OC1Mx is set, data in OC1Dx is output to port A bit x on successful OC1 compares.

OC1M

Output Compare 1 Mask Register

$000C	OC1M7	OC1M6	OC1M5	OC1M4	OC1M3	0	0	0
RESET:	0	0	0	0	0	0	0	0
REF:	PAI/ OC1	OC2/ OC1	OC3/ OC1	OC4/ OC1	OC5/IC4 OC1			

Set bit(s) to enable OC1 to control corresponding pin(s) of port A.

OPTION

System Configuration Options

$0039	0	0	IRQE	DLY	CME	0	CR1	CR0
RESET:	0	0	0	1	0	0	0	0

Bits 7, 6, and 0 — Not implemented; always read zero.

IRQE — $\overline{\text{IRQ}}$ Select Edge Sensitive Only (Time Protected)
0 = $\overline{\text{IRQ}}$ configured for low-level sensitivity
1 = $\overline{\text{IRQ}}$ configured for falling edge sensitivity

DLY — Enable Oscillator Startup Delay (On Exit from STOP) (Time Protected)
0 = No startup delay
1 = A delay is imposed

CME — Clock Monitor Enable
0 = Disabled
1 = Slow or stopped clocks cause reset

CR1, CR0 — COP Timer Rate Select Bits (Time Protected)

CR1	CR0	E/2^{15} Divided By	Xtal = 2^{23} Timeout −0/+15.6 ms	Xtal = 8.0 MHz Timeout −0/+16.4 ms	Xtal = 4.0 MHz Timeout −0/+32.8 ms
0	0	1	15.625 ms	16.384 ms	32.768 ms
0	1	4	62.5 ms	65.536 ms	131.07 ms
1	0	16	250 ms	262.14 ms	524.29 ms
1	1	64	1 s	1.049 s	2.1 s
		E =	2.1 MHz	2.0 MHz	1.0 MHz

PACNT

Pulse Accumulator Count Register

$0027	PCNT7	PCNT6	PCNT5	PCNT4	PCNT3	PCNT2	PCNT1	PCNT0

(Readable and writable; unaffected by reset)

PACNT

Pulse Accumulator Control Register

$0026	0	PAEN	PAMOD	PEDGE	DDRA3	I4/O5	RTR1	RTR0
RESET:	0	0	0	0	0	0	0	0

PAEN — Pulse Accumulator System Enable
0 = Disabled
1 = Enabled

PAMOD — Pulse Accumulator Mode
0 = Event counter
1 = Gated time accumulation

PEDGE — Pulse Accumulator Edge Control
0 = Falling edges, high level enables accumulation
1 = Rising edges, low level enables accumulation

DDRA3 — Data Direction Control for Port A Bit 3
1 = PA3 is an output.
0 = PA3 is an input only.

I4/O5 — Input Capture 4/Output Compare 5
0 = Output compare 5 function enable (no IC4)
1 = Input capture 4 function enable (no OC5)

RTR1, RTR0 — RTI Interrupt Rate

RTR1	RTR0	Divide E By	Xtal = 2^{23}	Xtal = 8.0 MHz	Xtal = 4.0 MHz
0	0	2^{13}	3.91 ms	4.10 ms	8.19 ms
0	1	2^{14}	7.81 ms	8.19 ms	16.38 ms
1	0	2^{15}	15.62 ms	16.38 ms	32.77 ms
1	1	2^{16}	31.25 ms	32.77 ms	65.54 ms
		E =	2.1 MHz	2.0 MHz	1.0 MHz

PIOC

Parallel I/O Control Register

$0002	0	0	CWOM	0	0	0	0	0
RESET:	0	0	0	0	0	0	0	0

CWOM — Port C Wired-OR Mode Option Bit
1 = All port C outputs act as open-drain ouputs.
0 = All port C outputs are normal CMOS outputs.

Bits 7, 6, 4–0 are not used in this register.

PORTA

Port A Data Register

$0000	PA7	PA6*	PA5	PA4*	PA3	PA2	PA1	PA0
RESET:	HiZ	0	0	0	HiZ	HiZ	HiZ	HiZ
REF.	PAI/ OC1	OC2/ OC1	OC3/ OC1	OC4/ OC1	OC5/IC4 OC1	IC1	IC2	IC3

*Not bonded on 40-pin DIP.

PORTB

Port B Data Register

$0004	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0
MODE 0 or BOOT	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0
	(RESET to HiZ inputs)							
MODE 1 or TEST	A15	A14	A13	A12	A11	A10	A9	A8
	(ADDRESS outputs during RESET)							

PORTB

Port C Data Register

$0003	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0

MODE 0 or BOOT	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
	(RESET to HiZ inputs)							
MODE 1 or TEST	A7/ D7	A6/ D6	A5/ D5	A4/ D4	A3/ D3	A2/ D2	A1/ D1	A0/ D0
	(Multiplexed address/data outputs during RESET)							

Port D Data Register

$0008	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0

MODE 0 or BOOT	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
	(RESET to HiZ inputs)							
MODE 1 or TEST	R/$\overline{W}$	AS	PD5	PD4	PD3	PD2	PD1	PD0
	Outputs		(RESET to HiZ inputs)					
REF.			$\overline{SS}$	SCK	MOSI	MISO	TxD	RxD

EPROM Programming Control Register

This register is used to control the programming of the PROM. PPROG is cleared on reset so that the PROM is configured for normal read.

$003B	MBE	0	ELAT	EXCOL	EXROW	0	0	PGM
RESET:	0	0	0	0	0	0	0	0

MBE — Multiple Byte Program Enable
This bit is reserved for testing.

Bits 6, 2, and 1 — Not implemented; always read zero.

ELAT — EPROM (OTPROM) Latch Control
1 = PROM address and data bus are configured for programming. Writes to PROM cause address and data to be latched. The PROM cannot be read.
0 = PROM address and data bus configured for normal reads. PROM cannot be programmed.

EXCOL — Select Extra Columns
This bit is reserved for testing.

EXROW — Select Extra Row
This bit is reserved for testing.

PGM — EPROM (OTPROM) Program Command
This bit may be written only when ELAT = 1.
1 = Programming power is switched on to PROM array.
0 = Programming power is switched off.

NOTE

This is an unused location in the ROM-based MC68HC11D3.

SCI Control Register 1

$002C	R8	T8	0	M	WAKE	0	0	0
RESET:	U	U	0	0	0	0	0	0

R8 — Receive Bit 8

T8 — Transmit Bit 8

M — Mode (Select Character Format)
0 = 1 start, 8 data, 1 stop bit
1 = 1 start, 8 data, ninth data, 1 stop bit

WAKE — Wakeup (By Address Mark/Idle)
0 = Wakeup by idle line
1 = Wakeup by address mark

SCI Control Register 2

$002D	TIE	TCIE	RIE	ILIE	TE	RE	RWU	SBK
RESET:	0	0	0	0	0	0	0	0

TIE — Transmit Interrupt Enable

TCIE — Transmit Complete Interrupt Enable

RIE — Receiver Interrupt Enable

ILIE — Idle-Line Interrupt Enable
0 = Inhibit interrupts
1 = Enable interrupts

TE — Transmitter Enable
(Toggle to queue idle character.)

RE — Receiver Enable
0 = Off
1 = On

RWU — Receiver Wakeup Control
0 = Normal
1 = Receiver asleep

SBK — Send Break

SCDR

SCI Data Register

$002F	R7/T7	R6/T6	R5/T5	R4/T4	R3/T3	R2/T2	R1/T1	R0/T0

(Receive and transmit double buffered)

SCSR

SCI Status Register

$002E	TDRE	TC	RDRF	IDLE	OR	NF	FE	0
RESET:	1	1	0	0	0	0	0	0

TDRE — Transmit Data Register Empty Flag

TC — Transmit Complete Flag

RDRF — Receive Data Register Full Flag

IDLE — Idle Line Detected Flag

OR — Overrun Error Flag

NF — Noise Error Flag

FE — Framing Error Flag

SCSR

SPI Control Register

$0028	SPIE	SPE	DWOM	MSTR	CPOL	CPHA	SPR1	SPR0
RESET:	0	0	0	0	0	1	U	U

SPIE — SPI Interrupt Enable

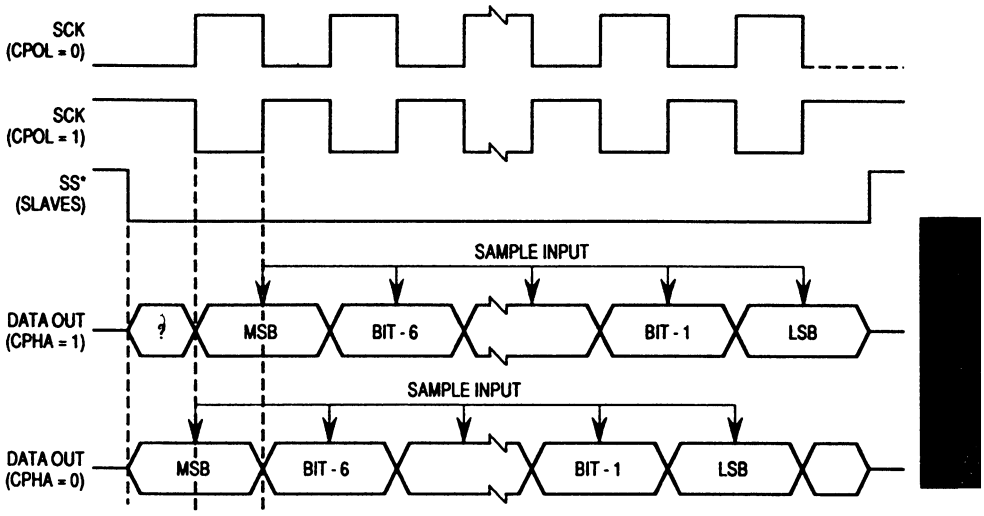
SPE — SPI System Enable

DWOM — Port D Wired-OR Mode
0 = Port D output normal
1 = Open drain (Bits 5–0 only)

MSTR — Master/Slave Mode Select
0 = Slave mode
1 = Master mode

CPOL — Clock Polarity

CPHA — Clock Phase



SPR1, SPR0 — SPI Clock (SCK)
Rate Select Bits

SPR1	SPR0	E-Clock Divided By
0	0	2
0	1	4
1	0	16
1	1	32

SPDR

SPI Data Register

$002A	SPD7	SPD6	SPD5	SPD4	SPD3	SPD2	SPD1	SPD0

(Double buffered in, single buffered out)

SPSR

SPI Status Register

$0029	SPIF	WCOL	0	MODF	0	0	0	0
RESET:	0	0	0	0	0	0	0	0

SPIF — SPI Interrupt Request

WCOL — Write Collision Status Flag

MODF — SPI Mode Error Interrupt Status Flag

TCNT

Timer Count Register

	B7			TCNT (HIGH)				B0
$000E	CNT15	CNT14	CNT13	CNT12	CNT11	CNT10	CNT9	CNT8

	B7			TCNT (LOW)				B0
$000F	CNT7	CNT6	CNT5	CNT4	CNT3	CNT2	CNT1	CNT0

RESET: $0000 (Readable, not writable)

TCNT

Timer Control Register 1

$0020	OM2	OL2	OM3	OL3	OM4	OL4	OM5	OL5
RESET:	0	0	0	0	0	0	0	0

OMx	OLx	Action Taken Upon Successful Compare
0	0	Timer Disconnected from Output Pin Logic
0	1	Toggle OCx Output Line
1	0	Clear OCx Output Line to Zero
1	1	Set OCx Output Line to One

Timer Control Register 2

$0021	EDG4B	EDG4A	EDG1B	EDG1A	EDG2B	EDG2A	EDG3B	EDG3A
RESET:	0	0	0	0	0	0	0	0

Timer input capture edge specifications:

EDGxB	EDGxA	Configuration
0	0	Capture Disabled
0	1	Capture on Rising Edges Only
1	0	Capture on Falling Edges Only
1	1	Capture on Any Edge (Rising or Falling)

TFLG1

Main Timer Interrupt Flag Reg. 1

$0023	OC1F	OC2F	OC3F	OC4F	I4O5F	IC1F	IC2F	IC3F
RESET:	0	0	0	0	0	0	0	0

OC1F–OC4F — Output Compare "x" Flag

I4O5F — Input Capture 4 or Output Compare 5 Flag

IC1F–IC3F — Input Capture "x" Flag

(To clear flag(s), write with corresponding bit(s) set.)

1

TFLG2

Misc. Timer Interrupt Flag Reg. 2

$0025	TOF	RTIF	PAOVF	PAIF	0	0	0	0
RESET:	0	0	0	0	0	0	0	0

TOF — Timer Overflow Flag

RTIF — Real-Time (Periodic) Interrupt Flag

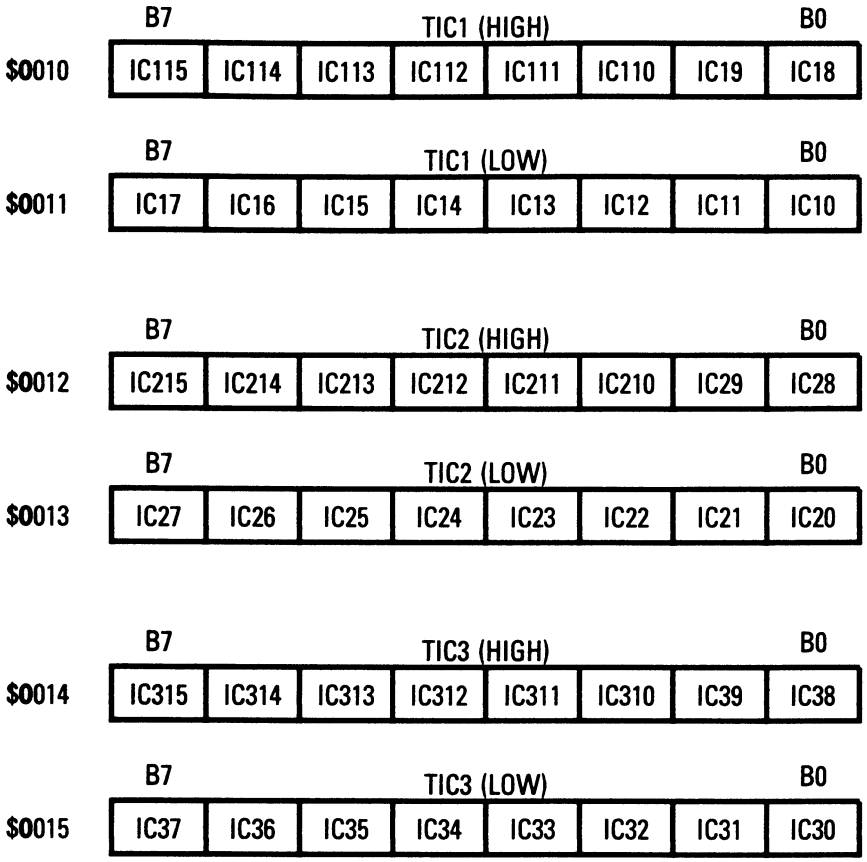
PAOVF — Pulse Accumulator Overflow Flag

PAIF — Pulse Accumulator Input Edge Flag

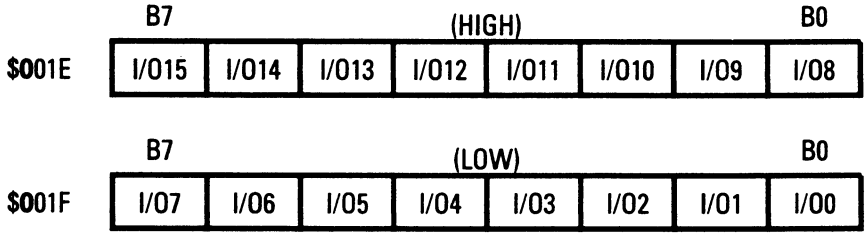
(To clear flag(s), write with corresponding bit(s) set.)

TFLG2

Timer Input Capture Registers



Timer Input Capture 4 or Output Compare 5 Register



TMSK1

Main Timer Interrupt Mask Reg. 1

$0022	OC1I	OC2I	OC3I	OC4I	I4O5I	IC1I	IC2I	IC3I
RESET:	0	0	0	0	0	0	0	0

OC1I–OC4I — Output Compare "x" Interrupt Enable

I4O5I — Input Capture 4 or Output Compare 5 Interrupt

IC1I–IC3I — Input Capture "x" Interrupt Enable
0 = Interrupt inhibited
1 = Interrupt requested if flag set

TMSK2

Misc. Timer Interrupt Mask Reg. 2

$0024	TOI	RTII	PAOVI	PAII	0	0	PR1	PR0
RESET:	0	0	0	0	0	0	0	0

TOI — Timer Overflow Interrupt Enable

RTII — RTI Interrupt Enable

PAOVI — Pulse Accumulator Overflow Interrupt Enable

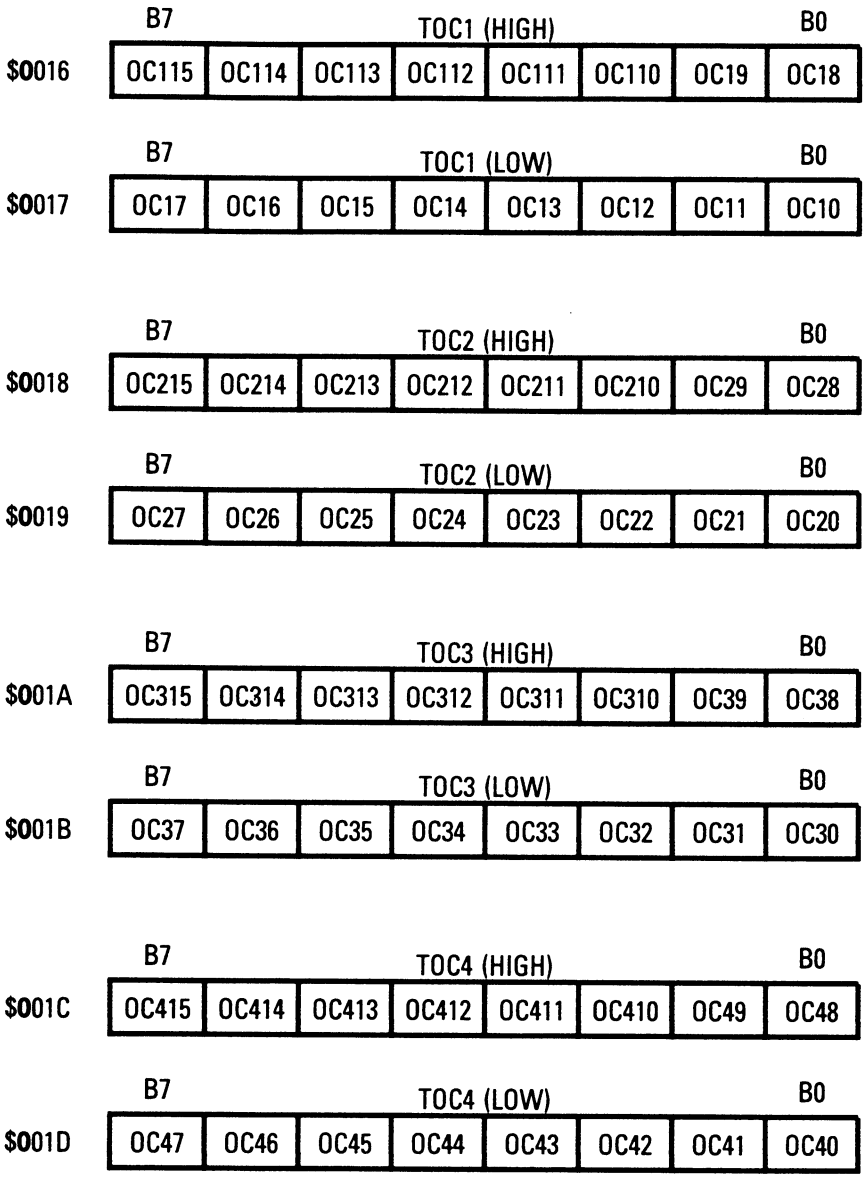
PAII — Pulse Accumulator Input Interrupt Enable
0 = Interrupt inhibited
1 = Interrupt requested if flag set

PR1, PR0 — Timer Prescaler Select (Time Protected)

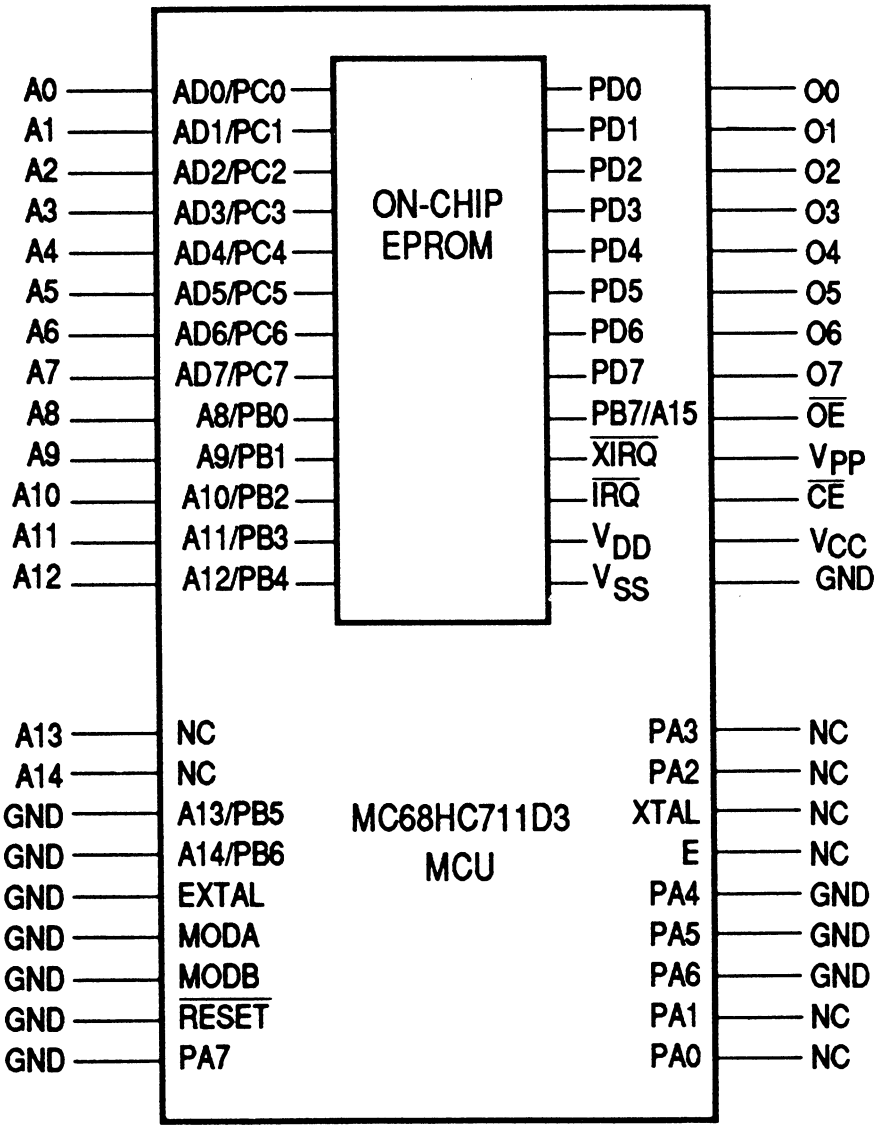
PR1	PR0	Prescale Factor
0	0	1
0	1	4
1	0	8
1	1	16

TMSK2

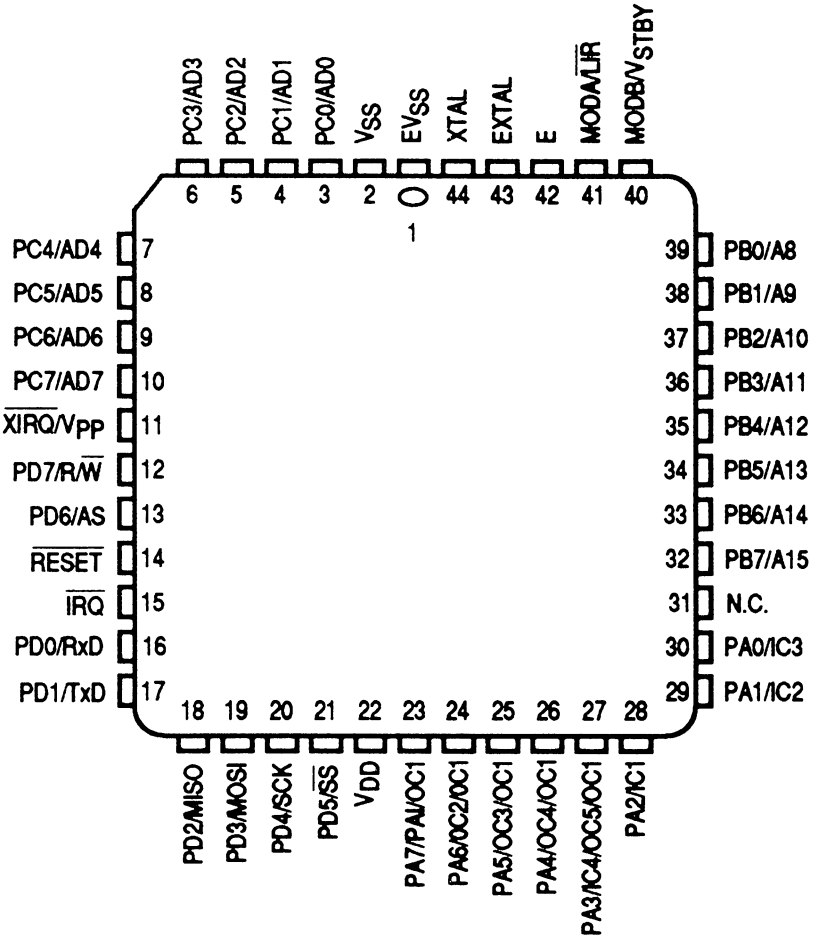
Timer Output Compare Registers



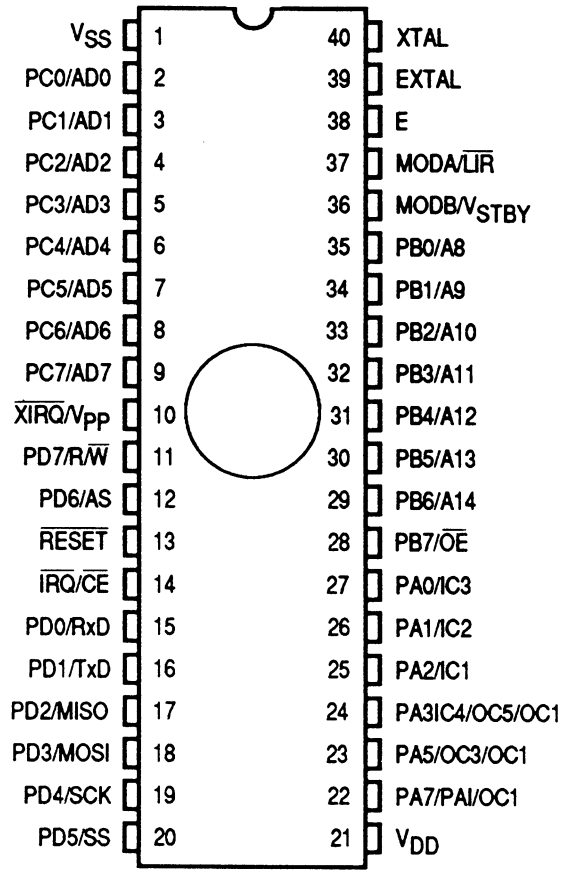
PIN FUNCTIONS FOR EPROM EMULATION MODE



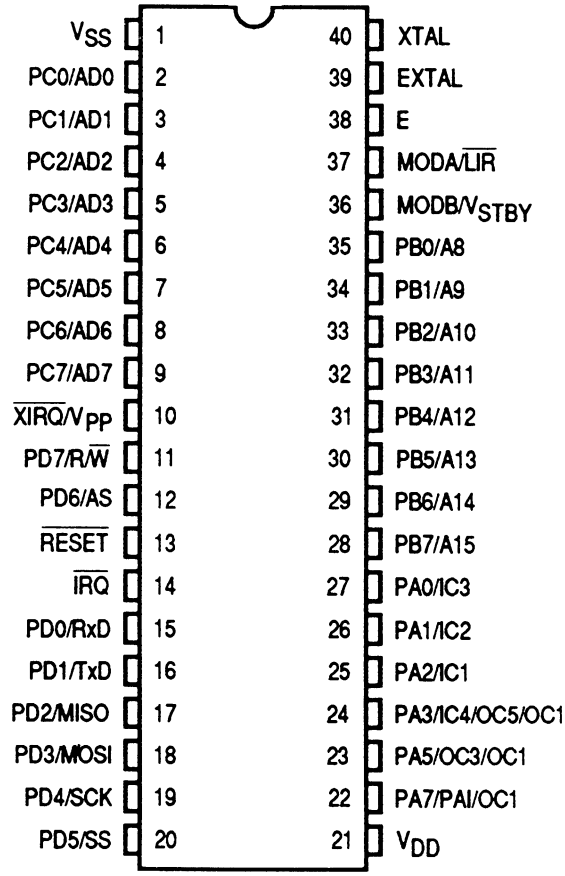
MC68HC11D3FN or MC68HC711D3FN (OTPROM)



MC68HC711D3S (EPROM)



MC68HC11D3P or MC68HC711D3P (OTPROM)



ASCII CHART

ASCII CHARACTER SET (7-Bit Code)								
MS Dig. / LS Dig.	0	1	2	3	4	5	6	7
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

[redacted]

HEXADECIMAL AND DECIMAL CONVERSION

How to use:

Conversion to Decimal: Find the decimal weights for corresponding hexadecimal characters beginning with the least significant character. The sum of the decimal weights is the decimal value of the hexadecimal number.

Conversion to Hexadecimal: Find the highest decimal value in the table which is lower than or equal to the decimal number to be converted. The corresponding hexadecimal character is the most significant. Subtract the decimal value found from the decimal number to be converted. With the difference repeat the process to find subsequent hexadecimal characters.

15	Byte		12	Byte		11	Byte		8	Byte		7	Byte		4	Byte		3	Byte		0
15	Char		12	Dec		11	Hex		8	Dec		7	Hex		4	Dec		3	Hex		0
Hex	Char		Dec	Dec		Hex	Char		Dec	Dec		Hex	Char		Dec	Dec		Hex	Char		Dec
0			0	0		0			0	0		0			0	0		0			0
1			4,096	4,096		1			256	256		1			16	16		1			1
2			8,192	8,192		2			512	512		2			32	32		2			2
3			12,228	12,228		3			768	768		3			48	48		3			3
4			16,384	16,384		4			1,024	1,024		4			64	64		4			4
5			20,480	20,480		5			1,280	1,280		5			80	80		5			5
6			24,576	24,576		6			1,536	1,536		6			96	96		6			6
7			28,672	28,672		7			1,792	1,792		7			112	112		7			7
8			32,768	32,768		8			2,048	2,048		8			128	128		8			8
9			36,864	36,864		9			2,304	2,304		9			144	144		9			9
A			40,960	40,960		A			2,560	2,560		A			160	160		A			10
B			45,056	45,056		B			2,816	2,816		B			176	176		B			11
C			49,152	49,152		C			3,072	3,072		C			192	192		C			12
D			53,248	53,248		D			3,328	3,328		D			208	208		D			13
E			57,344	57,344		E			3,584	3,584		E			224	224		E			14
F			61,440	61,440		F			3,840	3,840		F			240	240		F			15

NOTES

NOTES

PROGRAMMING MODEL
CRYSTAL DEPENDENT TIMING
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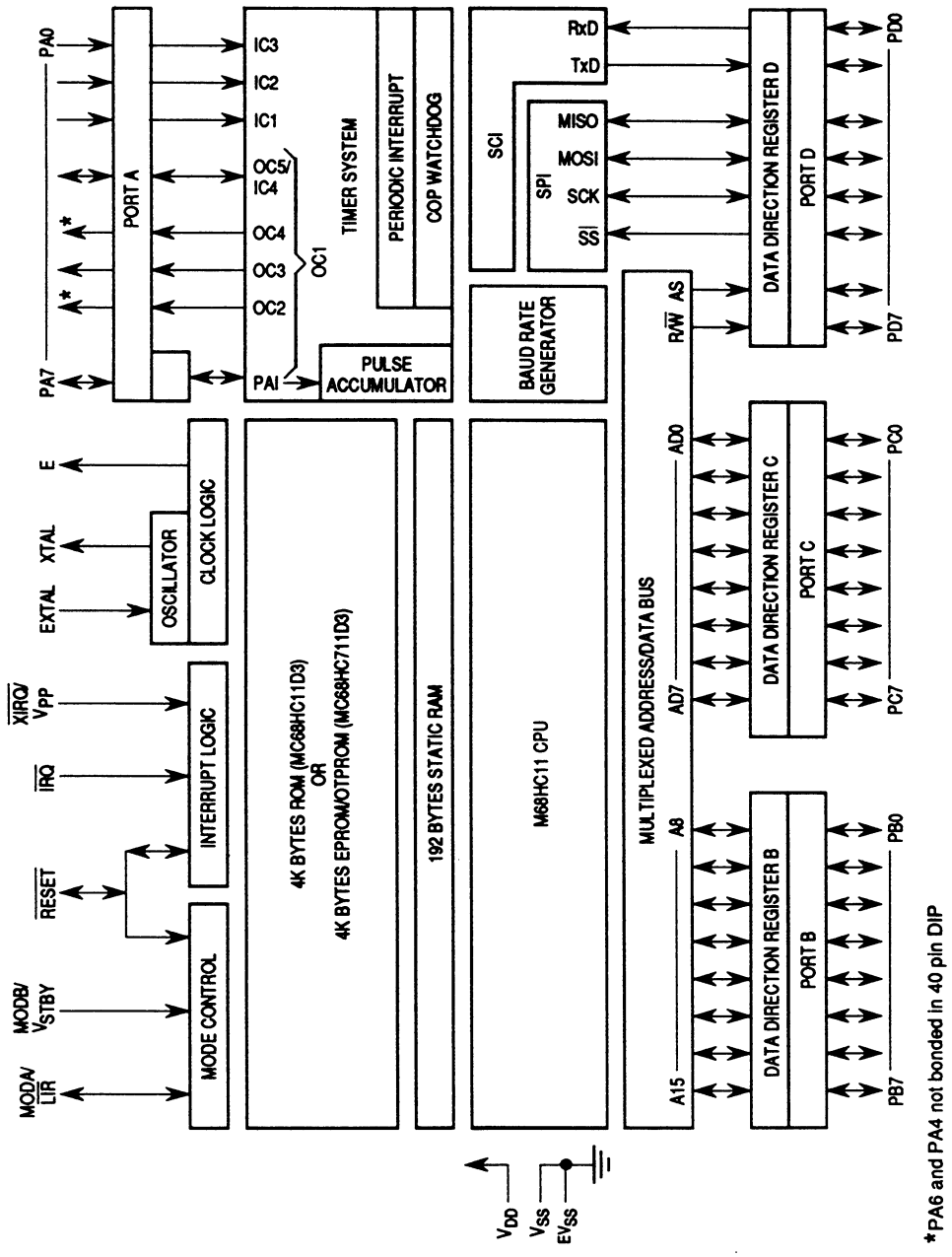
BLOCK DIAGRAM



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