

- MC9S12 Assembler Directives
- A Summary of MC9S12 Instructions
- Disassembly of MC9S12 op codes
  - Number of cycles and time taken to execute an MC9S12 program
  - A label is a name assigned to the address of the location counter where the label is defined
  - Use of assembler directives
  - A summary of MC9S12 instruction
  - How to disassemble an MC9S12 instruction sequence

### Summary of HCS12 addressing modes

Na	me	Example	Op Code	Effective Address
INH	Inherent	ABA	18 06	None
IMM	Immediate	LDAA #\$35	86 35	PC + 1
DIR	Direct	LDAA \$35	96 35	0x0035
EXT	Extended	LDAA \$2035	B6 20 35	0x2035
IDX IDX1 IDX2	Indexed	LDAA 3,X LDAA 30,X LDAA 300,X	A6 03 A6 E0 13 A6 E2 01 2C	X + 3 X + 30 X + 300
IDX	Indexed Postincrement	LDAA 3, X+	A6 32	x (x+3 -> x)
IDX	Indexed Preincrement	ldaa 3,+x	A6 22	X+3 (X+3 -> X)
IDX	Indexed Postdecrement	LDAA 3, X-	A6 3D	x (x-3 -> x)
IDX	Indexed Predecrement	LDAA 3,-X	A6 2D	x-3 (x-3 -> x)
REL	Relative	BRA \$1050 LBRA \$1F00	20 23 18 20 OE CF	PC + 2 + Offset PC + 4 + Offset

### ADDRESSING MODES



### A few instructions have two effective addresses:

• MOVB #\$AA,\$1C00	Move byte 0xAA (IMM) to address \$1C00 (EXT)
• MOVW 0,X,0,Y	Move word from address pointed to by X (IDX) to address
	pointed to by Y (IDX)

### A few instructions have three effective addresses:

• **BRSET FOO,#\$03,LABEL** Branch to LABEL (REL) if bits #\$03 (IMM) of variable FOO (EXT) are set.



### Using X and Y as Pointers

• Registers X and Y are often used to point to data.

• To initialize pointer use

### ldx #table

not

### ldx table

• For example, the following loads the address of table (\$1000) into X; i.e., X will point to table:

**ldx #table** ; *Address of table*  $\Rightarrow$  *X* 

The following puts the first two bytes of table (\$0C7A) into X. X will **not** point to table:

**ldx table** ; *First two bytes of table*  $\Rightarrow X$ 

• To step through table, need to increment pointer after use

ldaa 0,x inx

or

ldaa 1,x+

table

00
7A
D5
00
61
62
63
64

table: dc.b 12,122,-43,0 dc.b 'a','b','c','d'



### Which branch instruction should you use?

Branch if A > BIs 0xFF > 0x00?

If unsigned, 0xFF = 255 and 0x00 = 0, so 0xFF > 0x00

If signed, 0xFF = -1 and 0x00 = 0, so 0xFF < 0x00

Using unsigned numbers: **BHI** (checks C bit of CCR)

Using signed numbers: **BGT** (checks V bit of CCR)

For unsigned numbers, use branch instructions which check C bit For signed numbers, use branch instructions which check V bit



### Hand Assembling a Program

To hand-assemble a program, do the following:

**1**. Start with the org statement, which shows where the first byte of the program will go into memory.

(e.g., **org \$2000** will put the first instruction at address **\$2000**.)

**2**. Look at the first instruction. Determine the addressing mode used. (e.g., **ldab #10** uses IMM mode.)

**3**. Look up the instruction in the **MC9S12 S12CPUV2 Reference Manual**, find the appropriate Addressing Mode, and the Object Code for that addressing mode. (e.g., **Idab IMM** has object code **C6 ii**.)

• **Table A.1 of the S12CPUV2 Reference Manual** has a concise summary of the instructions, addressing modes, op-codes, and cycles.

**4**. Put in the object code for the instruction, and put in the appropriate operand. Be careful to convert decimal operands to hex operands if necessary. (e.g., **Idab #10** becomes **C6 0A**.)

5. Add the number of bytes of this instruction to the address of the instruction to determine the address of the next instruction. (e.g., 2000 + 2 = 2002 will be the starting address of the next instruction.)

org \$2000 ldab #10 loop: clra dbne b,loop swi



Source Form	Operation	Addr. Mode	Machine Coding (hex)	Acces HCS12	s Detall M68HC12	SXHI	NZVC
LBGT re/16	Long Branch If Greater Than (If $Z + (N \oplus V) = 0$ ) (signed)	REL	18 2E qq rr	OPPP/OP01	OPPP/OPO1		
LBHI ref16	Long Branch If Higher (If C + Z = 0) (unsigned)	REL	18 22 qq rr	OPPP/OP01	OPPP/OP01		
LBHS ref 16	Long Branch If Higher or Same (If C = 0) (unsigned) same function as LBCC	REL	18 24 qq rr	OPPP/OPO <sup>1</sup>	OPPP/OPO1		
LBLE rel16	Long Branch If Less Than or Equal (If $Z + (N \oplus V) = 1$ ) (signed)	REL	18 2F qq rr	OPPP/OP01	ODDD/ODO7		
LBLO rel 16	Long Branch If Lower (If C = 1) (unsigned) same function as LBCS	REL	18 25 qq rr	OPPP/OPO <sup>1</sup>	OPPP/OPO1		
LBLS ref 16	Long Branch If Lower or Same (If C + Z = 1) (unsigned)	REL	18 23 qq rr	OPPP/OPO1	OPPP/OPO1		
LBLT ref16	Long Branch If Less Than (If N ⊕ V = 1) (signed)	REL	18 2D qq rr	OPPP/OP01	OPPP/OPO <sup>1</sup>		
LBMI ref16	Long Branch If Minus (If N = 1)	REL	18 2B qq rr	OPPP/OPO1	OPPP/OPO1		
LBNE rel 16	Long Branch If Not Equal (If Z = 0)	REL	18 26 qq rr	OPPP/OPO <sup>1</sup>	OPPP/OPO1		
LBPL ref 16	Long Branch if Plus (if N = 0)	REL	18 2A qq rr	OPPP/OPO1	OPPP/OPO1		
LBRA ref 16	Long Branch Always (f 1-1)	REL	18 20 qq rr	OPPP	OPPP		
LBRN ref16	Long Branch Never (If 1 = 0)	REL	18 21 qq rr	090	OPO		
LBVC rel 16	Long Branch If Overflow Bit Clear (If V=0)	REL	18 28 qq rr	OPPP/OP01	OPPP/OP01		
LBVS rel 16	Long Branch If Overflow Bt Set (If V = 1)	REL	18 29 qq rr	OPPP/OP01	OPPP/OP01		
LDAA ±opr8 LDAA qor8a LDAA qor8a LDAA qor03ysp LDAA qor03ysp LDAA qor16ysp LDAA [oysp] LDAA [oysp]	(M) — A Loed Accumulator A	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	86 11 96 dd 86 hh 11 A6 xb A6 xb ff A6 xb ee ff A6 xb ee ff A6 xb ee ff	p rPf rP0 rPf rP0 frPp flfrPf flPrPf	p rtP rtP rtP rPO trP trP tfprtP		ΔΔ0-
LDAB #opr8 LDAB qor8a LDAB qor16a LDAB qor0_xysp LDAB qor0_xysp LDAB qor16_xysp LDAB [qor16_xysp] LDAB [qor16_xysp]	(M) → B Load Accumulator B	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	C6 11 D6 dd F6 hh 11 E6 xb E6 xb ff E6 xb aa ff E6 xb aa ff E6 xb aa ff	p rPf rP0 rPf frP0 frPp flfrPf flPrPf	p rfP rfD rfD rfD frPD ffff ffff fffff		ΔΔ0-
LDD #opri8i LDD #opri8a LDD #pri8a LDD #pri80_xysp LDD #pri8_xysp LDD #pri8_xysp LDD #pri8_xysp LDD [pri85] LDD [pri85]	(M:M-1) → A:B Load Double Accumulator D (A:B)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX0 [D,DX0]	CC jj kk DC dd FC hh 11 EC xb EC xb ff EC xb ee ff EC xb ee ff	PO RPf RPO RPf RPO fRPP flfRPf flPRPf	QD RfP RQP RfP RfP ffRfP fffRfP fffRfP		ΔΔ0-
	this instruction takes four cycles to refill the instruction queue		-				
DS appr1 <i>8</i> DS gpr18a DS gpr18a DS gpr00 ypsp DS gpr01 ypsp DS gpr16 ypsp DS [D ypsp] DS [D ypsp] DS [D ypsp]	(M:M+1) → SP Load Stack Pointer	DIR EXT IDX IDX1 IDX2 [D,IDX]	CF jj kk DF dd FF hh 11 EF xb EF xb ff EF xb ee ff EF xb ee ff EF xb ee ff	PO RPf RPO RPO fRPO fIRPP fIfRPf fIPRPf	QD RfP ROP RfP RPO fRPP fIfRfP fIPRfP		ΔΔ0-
DX. sopri 6 DX. opri 6a DX. opri 16a DX. opri 16a DX. opri 16a DX. opri 16a DX. opri 16a DX. [D, nj sp] DX. [D, nj sp]	$(M:M+1) \rightarrow X$ Load Index Register X	DIR EXT IDX IDX1 IDX2 [D,IDX]	CE jj kk DE dd FE hh 11 EE xb EE xb Gf EE xb GG ff EE xb GG ff EE xb GG ff	PO RDf RPO RPf RPO fRPP fIIRPf fIPRPf	QD R1P R0P RPO fIRP fIRP fIRP fIRP	,	ΔΔ0-

### Table A-1. Instruction Set Summary (Sheet 7 of 14)





Branch If Lower or Same (f C + Z = 1) (unsigned) Branch If Less Than (f N ⊕ V = 1) (signed) Branch If Minus (f N = 1) Branch If Not Equal (if Z = 0) Branch If Plus (f N = 0)	REL REL REL	23 rr 2D rr	עסעע <sup>ג</sup> ע/סעע 100 אין	p1	
(f N ⊕ V = 1) (signed) Branch If Minus (f N = 1) Branch If Not Equal (f Z = 0)		2D TT	TATION AND A TATION AND AND AND AND AND AND AND AND AND AN		
Branch if Not Equal (if Z = 0)	REL		verir veri	p1	
		2B rr	PPP/P <sup>1</sup> PPP/	p1	
Branch If Plus (If N = 0)	REL	26 rr	ppp/pl ppp/	p1	
	REL	2A rr	ppp/p1 ppp/	p1	
Branch Always (f 1 = 1)	REL	20 rr	ppp pi	·	
Branch If (M) • (mm) = 0 (If All Selected Bit(s) Clear)	DIR	4F dd mm rr 1F hh 11 mm rr	rfppp rfp	PP .	
10 - 140700 - 4070707004	IDX1 IDX2	OF xb ff mm rr	rfppp rffp	PIP .	
Branch Never (If 1 = 0)	REL	21 rr	P	P	
Branch ff (10) • (mm) = 0 (ff All Selected Bit(s) Set)	DIR EXT IDX IDX1 IDX2	4E dd mm rr 1E hh 11 mm rr 0E xb mm rr 0E xb ff mm rr 0E xb ee ff mm rr	rfPPP rfP rPPP rPP rfPPP rffP	99 99 99	
(M) + (mm) → M Set Bit(s) in Memory	DIR EXT IDX IDX1 IDX2	4C dd mm 1C hh 11 mm 0C xb mm 0C xb ff mm 0C xb ee ff mm	rPwP rP rPwO rP rPwP rP	N N D	ΔΔ0-
$\begin{array}{l} (SP)-2 \rightarrow SP; \mbox{RTN}_{H} \oplus RTN_{L} \rightarrow M_{(SP)} \cdot M_{(SP+1)} \\ \mbox{Subroutine address} \rightarrow PC \\ \mbox{Branch to Subroutine} \end{array}$	REL	07 rr	SDPP PD	×	
Branch If Overflow Bit Clear (If V = 0)	REL	28 rr	ppp/p1 ppp/	p <sup>1</sup>	
Branch If Overflow Bit Set (If V = 1)	REL	29 rr	PPP/P <sup>1</sup> PPP/	p1	
(SP) – 2 → SP; RTN <sub>4</sub> +RTN <sub>4</sub> → M <sub>SP</sub> ; (SP) – 1 → SP; (PPG) → M <sub>SP</sub> ; pg → PPAGE register; Program address → PC Call subroutine in extended memory (Program may be located on another expansion memory page.) Indirect modes get program address and new pg value based on pointer.	EXT IDX IDX1 IDX2 [D,IDX2 [IDX2]	4A hh 11 pg 4B xb pg 4B xb ff pg 4B xb ee ff pg 4B xb 4B xb ee ff	gnSsPPP gnfSsPJ gnSsPPP gnfSsPJ fgnSsPPP fgnfSsPJ flignSsPPP flignSsPJ	90 90 90 90	
(A) – (B) Compare 8-Bit Accumulators	NH	18 17	00 (	×0	
0 → C Translates to ANDCC #\$FE	IMM	10 FE	P	p	0
0 → I Translates to ANDCC #\$EF (enables i-bit interrupts)	IMM	10 EF	P	p0	
D → M Clear Memory Location D → A Clear Accumulator A D → B Clear Accumulator B	[D,IDX]	69 xb 69 xb ff 69 xb aa ff 69 xb aa ff 69 xb aa ff 87	DW         DW         DW           DwO         Dwd         Dwd           DwF         Dwd         Dwd           DFW         DFFW         DFFW           DFW         DFFW         D	e 0 0 0	0100
0 → V Translatesto ANDCC #\$FD	IMM	10 FD	P 1		0-
ction takes three cycles to refill the instruction queue if the bran	nch is taken	and one program fetch cyc	ie if the branch is not taken.		
A) – (M) Compare Accumulator A with Memory	EXT IDX IDX1 IDX2 [D,IDX]	B1 hh 11 Al xb Al xb ff Al xb ge ff Al xb	11         147           07         070           07         071           17         171           17         071           17         071           17         071           17         171           17         171           17         171           17         171           17         171	2	ΔΔΔΔ
	(f All Selected Bit(s) Clear) Branch Never (f 1 = 0) Branch If (M) • (mm) = 0 (f All Selected Bit(s) Set) (M) + (mm) → M Set Bit(s) in Memory (SP) - 2 → SP; RTN <sub>4</sub> +RTN <sub>1</sub> → M <sub>(SP)</sub> :M <sub>(SP+1</sub> ) Subroutine address → PC Branch If Overflow Bit Set (f V = 0) Branch If Overflow Bit Set (f V = 1) (SP) - 2 → SP; RTN <sub>4</sub> +RTN <sub>1</sub> → M <sub>(SP)</sub> :M <sub>(SP+1</sub> ) (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 1 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; RTN <sub>4</sub> +RTN <sub>1</sub> → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PPG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PGG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PGG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PGG) → M <sub>(SP)</sub> : (SP) - 2 → SP; (PGG) → M <sub>(SP)</sub> : (SP)	(f AJ Selected Bit(s) Clear)       EXT IDX IDX1 IDX2         Branch Never (ff 1 = 0)       REL         Branch If (M) + (mm) = 0 (ff AJ Selected Bit(s) Set)       DIR EXT IDX1 IDX2         (M) + (mm) → M Set Bit(s) in Memory       DIR EXT IDX1 IDX2         (M) + (mm) → M Set Bit(s) in Memory       DIR EXT IDX1 IDX2         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1) Eranch to Subroutine Branch if Overflow Bit Clear (ff V = 0)       REL         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1) (SP) - 1 → SP; (PC) → M(sP;-M(sP+1))       REL         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1))       REL         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1))       REL         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1))       REL         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1))       REL         (SP) - 1 → SP; (PC) → M(sP;-M(sP+1))       IDX         (SP) - 2 → SP; RTN <sub>4</sub> ; RTN <sub>4</sub> → M(sP;-M(sP+1))       IDX         (Call subroutine in extended memory (Program may be located on another expansion memory page.)       IDX1 IDX2         (A) - (B)       INH         Call subroutine in extended memory (Program may be located on pointer.       IMM         (A) - (B)       INH         Call subroutine in extended memory (Program may be located on pointer.       INM         (A) - (B)       INM         Call subroutine in extended memory (P	(f AI Selected Bit(s) Clear)       EXT       1P that 11 mm rr         DX       DF xb mm rr       DDX       DF xb mm rr         DX       DF xb mm rr       DDX       DF xb mm rr         DX       DF xb mm rr       DDX       DF xb mm rr         DX       DF xb mm rr       DDX       DF xb mm rr         DX       DF xb mm rr       DDX       DF xb mm rr         DX       DF xb mm rr       DDX       DE xb mm rr         DX       DE xb mm rr       DDX       DE xb mm rr         DX       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DE xb mm rr         DX1       DE xb mm rr       DDX       DX       Mm rr         DX1       DE xb mm rr       DX       Mm rr       DX         DX1       DE xb mm rr       DX       Mm rr       DX       Mm rr<	(If Al Selected Bit(s) Clear)       EXT       1P th 11 mm rr       rTDPp       rTDPp       rTPPp         IDX1       0P xb cm m rr       rTDPp       rTPPp       rTPPp       rTPPp         Branch Never (If 1 = 0)       REL       21 rr       P         Branch I (M) = (mm) = 0       DIR       4E dd mm rr       rTDPp       rTPPp         If Al Selected Bit(s) Set)       DIR       4E dd mm rr       rTDPp       rTPPp         (M) + (mm) → M       Set Dif fm nr       rTPP p       rTPPp       rTPPp         (M) + (mm) → M       DIR       4E dd mm rr       rTDP p       rTPP         (DX       0E xb ff mm rr       rPP prtPPp       frPPp rPP       rPP         (DX       0E xb ff mm rr       rPP prtPPp       frPPp rPP       rPP         (DX       0E xb ff mm rr       rPP prtPP       rPP       rPP         (DX       0E xb mm rr       rPP prtPP       rPP       rPP         (DX       0E xb ff mm rr       rPP prtPP       rPP       rPP         (DX       0E xb m nr       rr       rPP       rPP       rPP         (DX       0E xb ff mm rr       rPP       rPP       rPP       rPP         (SP) - 2 = SP, RTN_sFRTN_s + M(m) + M(mP, M(mP,	(f Al Selected Bit(s) Clear)         EXT         1F hh 11 mm rr. TOTO         r trop         <

### Table A-1. Instruction Set Summary (Sheet 3 of 14)



Source Form	Operation	Addr. Mode	Machine Coding (hex)	Access Det HCS12	all M68HC12	SXHI	NZVC
CMPB sopr8/ CMPB spr8a CMPB spr8a CMPB spr0.ysp CMPB spr0.ysp CMPB spr0.ysp CMPB (pysp) CMPB [oprx16.ysp]	(B) – (M) Compare Accumulator B with Memory	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	Cl 11 Dl dd Fl hh 11 El xb El xb ff El xb ge ff El xb ge ff El xb ge ff	p rpr rp0 rp1 rp0 frpp flfrpf flfrpf flprpf	p rtP rOP rtD rPO frPP flfrtP flPrtP		ΔΔΔΔ
COM oprifie COM opn0, xysp COM opn3, xysp COM ignrifixysp COM [oprifixysp] COM [oprifixysp] COM [oprifixysp] COMA COMA	<ul> <li>(M) → M equivalent b SFF - (M) → M</li> <li>1's Complement Memory Location</li> <li>(A) → A Complement Accumulator A</li> <li>(B) → B Complement Accumulator B</li> </ul>	EXT IDX IDX1 IDX2 [D,IDX] [IDX2] INH INH	71 hh 11 61 xb 61 xb ff 61 xb ee ff 61 xb ee ff 61 xb ee ff 41 51	rPw0 rPw rPw0 frPwP fifrPw fiPrPw 0 0	rOPw rPow rPOw frPDw fIfrPw fIPrPw 0 0		ΔΔ01
CPD soprifi CPD oprifie CPD oprifie CPD oprifie CPD oprifie CPD oprifie Spannifie CPD [Dupps] CPD [oprifie,sysp]	(A:B) – (M:M+1) Compare D to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	8C jj kk 9C dd BC hh 11 AC xb AC xb ff AC xb ee ff AC xb ee ff	PO HPT HPO HPT HPO HPP fHRPP fIIRPT fIPRPT	QD Q1R QQR RIP RIP QQR TITRIP TITRIP		ΔΔΔΔ
CPS #apr18 CPS opr8a CPS opr8a CPS opr78a CPS opr78.ysp CPS opr78.ysp CPS (p.rysp) CPS [0,rysp] CPS [0,rr16.ysp]	(SP) – (M:M+1) Compare SP to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [D,IDX2]	8F jj kk 9F dd BF hh 11 AF xb AF xb ff AF xb cc ff AF xb AF xb cc ff	OQ HPI HPI HPO HPI HRP fITRPI fITRPI	QD R1P ROP R1P RPO 1RPO 11R1P 11R1P		
CPX.eqprf8 CPX.opr8a CPX.opr8a CPX.opr0.opsp CPX.oprx9.opsp CPX.oprx16.opsp CPX.(oprx16.opsp) CPX.[oprnf6.opsp]	(X) – (M-M+1) Compare X to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	BE jj kk 9E dd BE hh 11 AE xb AE xb ff AE xb ce ff AE xb AE xb ce ff	PO RPT RPO RPT RPO fRPP fITRPT fITRPT	QD R1P R0P R1P R1P R00 f1R1P f11R1P f11R1P		ΔΔΔΔ
CPY #opr18 CPY opr8a CPY opr8a CPY opr8. CPY opr8.ysp CPY opr8.ysp CPY (opr16.ysp) CPY [opr16.ysp]	(Y) – (M-M+1) Compare Y to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	BD jj kk 9D dd BD hh 11 AD xb AD xb ff AD xb gg ff AD xb gg ff AD xb gg ff	PO HPT HPO HPT HPO HPO TRPP fIIRPT fIPRPT	QD R1P ROP R1P RDO RDP t1R1P f1IR1P f1IR1P		
DAA	Adjust Sum to BCD Decimal Adjust Accumulator A	NH	18 07	010	010		ΔΔ?Δ
DBEQ abdrys, rel9	(critr) = 1> critr if (critr) = 0, then Branch else Continue to next instruction Decrement Counter and Branch if = 0 (critr = A, B, D, X, Y, or SP)	REL (9-bit)	04 lb rr	PPP (branch) PPO (no branch)	ppp		
DBNE abdxys, ral9	$(cntr) - 1 \rightarrow cntr$ If (cntr) not = 0, then Branch, else Continue to next instruction Decrement Counter and Branch If $\neq 0$ (cntr = A, B, D, X, Y, or SP)	REL (9-bit)	04 1b rr	PPP (branch) PPO (no branch)	PPP		

### Table A-1. Instruction Set Summary (Sheet 4 of 14)



Source Form	Operation	Address Mode	Machine Coding (Hex)	Access Detall	SXHINZVC
STY opr8a	Store Y	DIR	spdd	PW	
STY opr16a	$(Y_H;Y_L) \Rightarrow M:M+1$	EXT	70 hh 11	FWO	
STY oprx0_xysppc		IDX .	en xp	<b>EW</b>	
STY oprx9,xysppc		IDX1	an xb ff	FWO	
STY oprx16,xysppc		IDX2	ff eedx da	PWP	
STY [D, xysppd]		[XQLQ]	en xb	PITW	
STY [oprx16, xysppc]		[IDX2]	sp xbee ff	PIPM	
SUBA#opr8/	Subtract from A	IMM	8011	2	
SUBA opr8a	(A)–(M)⇒A	DIR	50 dd	TPT	
SUBA opr16a	or (A)-imm A	EXT	no hh 11	TPO	
SUBA oprx0_xysppc	C1000000000000000000000000000000000000	IDX .	AU XD	TPT	
SUBA oprx9,xysppc		IDX1	AD XD II	TPO	
SUBA oprix16,xysppc		IDX2	AD XD ee ff	frpp	
SUBA [D.xysopc]		ID.IDXI	AD XD	fifrpf	
SUBA [oprx16,xysppc]		[DX2]	AD XD GG ff	fiprpf	
SUBB #oor8/	Subtract from B	IMM	co 11	2	
SUBB oorSa	(B)−(M)⇒B	DIR	po dd	TPE	
SUBB opr16a	or (B)-imm B	EXT	rohh 11	TPO	
SUBB oprid_xysppc	or (b) minuse	DX	no xb	TPE	
SUBB opression		DX1	noxbff	IPO	1
SUBB oprx16,xysppc		DX2	no xbee ff	frpp	
SUBB [D, xysppc]		[D,IDX]	no xb	fifrpf	
SUBB [oprx16,xysppc]		[DX2]	no xbee ff	fiprpf	1
SUBD #opr16/	Subtract from D	IMM	83 11 kk	PO	
SUBD opr8a	(A:B)-(M:M+1)⇒A:B	DIR	93 dd	RPE	
SUBD opr/6a	or (A:B)−imm⇒A:B	EXT	#3 hh 11	820	
SUBD oprx0_xysppc	or year minister	DX	AS XD	RPE	
SUBD oprx9,xysppc		DX1	AS XD II	RPO	
		DX2	A3 xbee ff	fapp	
SUBD oprx16,xysppc SUBD (D,xysppc)		DJDX1	AS XDEE II	fifspf	
SUBD (oprx16.xysppc)		1DX21	A3 XDee ff	fipspf	
				TIPRPI	
SWI	Software Interrupt; (SP)-2⇒SP	INH	38	VSPSSPSSP*	1
	RTN <sub>H</sub> :RTN <sub>L</sub> =Msp:Msp+1				
	$(SP)$ -2 $\Rightarrow$ SP; $(Y_H, Y_L)$ $\Rightarrow$ Mgp:Mgp+1	1		1	
	$(SP)$ -2 $\Rightarrow$ SP; $(X_H, X_L) \Rightarrow M_{SP}, M_{SP+1}$	1		1	
	(SP)-2⇒SP; (B:A)⇒Mgp:Mgp+1	1		1	
	(SP)-1⇒SP; (CCR)⇒M <sub>sp</sub> ;1⇒I	1		1	
		1		1	
	(SWI vector)⇒PC	-	ormani i		
	P for hardware interrupts and unimplement			š	2
TAB	Transfer A to B; (A)⇒B	INH	18 08	00	
TAP	Transfer Ato CCR; (A)⇒CCR	INH	87 02	2	A . A A A A A A
	Assembled as TFR A, CCR				
TBA	Transfer B to A; (B)⇒A	INH	18 05	00	
TBEQ abditysp.rel9	Test and branch if equal to 0	REL	04 lbrr	PPP (branch)	
	If (counter)=0, then (PC)+2+rel⇒PC	(9-bit)		PPO (no branch)	
TBL oprx0_xysppc	Table lookup and interpolate, 8-bit	DX	18 3D XD	ORIFIP	
	(M)+[(B)×((M+1)−(M))]⇒A	6308	1000000000	00000000	
TBNE abdxysp,rel9	Test and branch if not equal to 0	REL	04 lbrr	PPP (branch)	
	If (counter)≠0, then (PC)+2+rel⇒PC	(9-bit)		PPO (no branch)	[===========
TFR abcdxysp,abcdxysp	Transfer from register to register	INH	B7 eb	P	
	(r1)⇒r2r1 and r2 same size			1	
	\$00:(r1)=r2r1=8-bit;r2=16-bit			1	or
	(r1, )=r2r1=16-bit;r2=8-bit			1	A 3 A A A A A A
2-10	Transfer CCR to A: (CCR) A	INH	87.20	2	
TPASame as TFR CCR A					



DBNE

# DBNE Decrement and Branch if Not Equal to Zero

Operation  $(counter) - 1 \Rightarrow counter$ 

If (counter) not = 0, then (PC) +  $0003 + rel \Rightarrow PC$ 

Subtracts one from the counter register A, B, D, X, Y, or SP. Branches to a relative destination if the counter register does not reach zero. Rel is a 9-bit two's complement offset for branching forward or backward in memory. Branching range is \$100 to \$0FF (-256 to +255) from the address following the last byte of object code in the instruction.

CCR Effects

			Т				
-	-	-	-	-	-	-	-

Code and CPU

Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
DBNE abdxysp, rel9	REL (9-bit)		PPP (branch) PPO (no branch)

	Loop Primitive Postbyte (1b) Coding							
Source Form	Postbyte <sup>1</sup>	Object Code	Counter Register	Offset				
DBNE A, rel9 DBNE B, rel9 DBNE D, rel9 DBNE X, rel9 DBNE Y, rel9 DBNE SP, rel9	0010 X000 0010 X001 0010 X100 0010 X101 0010 X110 0010 X110	04 20 rr 04 21 rr 04 24 rr 04 25 rr 04 26 rr 04 27 rr	A B D X Y P	Positive				
DBNE A, rel9 DBNE B, rel9 DBNE D, rel9 DBNE X, rel9 DBNE X, rel9 DBNE Y, rel9 DBNE SP, rel9	0011 X000 0011 X001 0011 X100 0011 X100 0011 X101 0011 X110 0011 X111	04 30 rr 04 31 rr 04 34 rr 04 35 rr 04 36 rr 04 37 rr	A B D X Y P	Negative				

NOTES:

 Bits 7:6:5 select DBEQ or DBNE; bit 4 is the offset sign bit: bit 3 is not used; bits 2:1:0 select the counter register.



### MC9S12 Cycles

- MC9S12 works on 48 MHz clock
- A processor cycle takes 2 clock cycles P clock is 24 MHz
- Each processor cycle takes **41.7** ns  $(1/24 \ \mu s)$  to execute
- An instruction takes from 1 to 12 processor cycles to execute

• You can determine how many cycles an instruction takes by looking up the CPU cycles for that instruction in the Reference Manual.

- For example, **LDAA** using the **IMM** addressing mode shows one CPU cycle (of type P).

LDAA using the EXT addressing mode shows three CPU cycles (of type rPO).
 Section 6.6 of the S12CPUV2 Reference Manual explains what the HCS12 is doing during each of the different types of CPU cycles.

2000			org \$2000	; Inst	Mode Cycles
2000	C6 0A		ldab #10	; <i>LDAB</i>	(IMM) 1
2002	87	loop:	clra	; CLRA	(INH) 1
2003	04 31 FC		dbne b,loop	; DBNE	(REL) 3
2006	3F		swi	; <i>SWI</i>	9

The program executes the **ldab #10** instruction **once** (which takes one cycle). It then goes through the loop **10 times** (which has two instructions, one with one cycle and one with three cycles), and finishes with the swi instruction (which takes 9 cycles).

Total number of cycles:

 $1 + 10 \times (1 + 3) + 9 = 50$ 

 $50 \text{ cycles} = 50 \times 41.7 \text{ ns/cycle} = 2.08 \text{ }\mu\text{s}$ 



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# LDAB

Load B

# LDAB

(m) ⇒ r or

 $imm \Rightarrow B$ 

Loads B with either the value in M or an immediate value.

#### CCR Effects

s	х	н	1	Ν	z	v	С
-	-	-	-	Δ	Δ	0	-

N: Set If MSB of result is set; cleared otherwise

Z: Set if result is \$00; cleared otherwise

V: Cleared

Code and

CPU

сy	С	les	

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
LDAB #opr8/ LDAB opr8a LDAB opr76a LDAB oprx0_xysppc LDAB oprx16,xysppc LDAB oprx16,xysppc LDAB [D,xysppc] LDAB [oprx16,xysppc]	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [D,IDX]	E6 xb E6 xb ff E6 xb ee ff E6 xb	P rPf rPO rPf frPP fIfrPf fIPrPf



### **Assembler Directives**

• In order to write an assembly language program it is necessary to use assembler directives.

• These are not instructions which the HC12 executes but are directives to the assembler program about such things as where to put code and data into memory.

• We will use only a few of these directives. (Note: In the following table, [] means an optional argument.) Here are the ones we will need:

Directive Name	Description	Example
equ	Give a value to a symbol	len: equ 100
org	Set starting value of location counter where code or data will go	org \$1000
dc.b	Allocate and initialize storage for 8-bit variables. Place the bytes in successive memory locations	var: dc.b 2,18 name: dc.b "Jane"
dc.w	Allocate and initialize storage for 16-bit variables. Place the bytes in successive memory locations	var: dc.w \$ABCD
ds.b	Allocate specified number of 8-bit storage places	Table: ds.b 10
ds.w	Allocate specified number of 16-bit storage spaces	table: ds.w 50
dcb.b	Fill memory with a given value The first value is the number of bytes to fill. The second number is the value to put into memory	init_data: dc.b 100,0



### Using labels in assembly programs

A **label** is defined by a name followed by a colon as the first thing on a line. When the label is referred to in the program, it has the numerical value of the location counter when the label was defined.

Here is a code fragment using labels and the assembler directives dc and ds:

org \$2000 table1:dc.b \$23,\$17,\$f2,\$a3,\$56 table2: ds.b 5 var: dc.w \$43af

The CodeWarrior assembler produces a listing file (**.lst**). Here is the listing file from the assembler:

		2-Assen reescale	nbler 1987-2009			
Àbs.	Rel.		Obj. code	Source	line	
1	1				org	\$2000
2	2 a002	000 231	7 F2A3	table1:	dc.b	\$23,\$17,\$f2,\$a3,\$56
	0020	04 56				
3	3 a002	005		table2:	ds.b	5
4	4 a002	00A 43A	١F	var:	dc.w	\$43af
5	5					

Note that **table1** is a name with the value of \$2000, the value of the location counter defined in the **org** directive. Five bytes of data are defined by the **dc.b** directive, so the location counter is increased from \$2000 to \$2005.

Note that **table2** is a name with the value of \$2005. Five bytes of data are set aside for table2 by the **ds.b 5** directive. The as12 assembler initialized these five bytes of data to all zeros. **var** is a name with the value of \$200a, the first location after table2.



### **HC12 Instructions**

1. Data Transfer and Manipulation Instructions — instructions which move and manipulate data (S12CPUV2 Reference Manual, Sections 5.3, 5.4, and 5.5).

• Load and Store — load copy of memory contents into a register; store copy of register contents into memory.

LDAA \$2000 ; Copy contents of addr \$2000 into A STD 0,X ; Copy contents of D to addrs X and X+1

• Transfer — copy contents of one register to another.

TBA	; Copy B to A
TFR X,Y	; Copy X to Y

• Exhange — exchange contents of two registers.

XGDX	; Exchange contents of D and X
EXG A,B	; Exchange contents of A and B

 Move — copy contents of one memory location to another. MOVB \$2000,\$20A0 ; Copy byte at \$2000 to \$20A0 MOVW 2,X+,2,Y+ ; Copy two bytes from address held ; in X to address held in Y ; Add 2 to X and Y

2. Arithmetic Instructions — addition, subtraction, multiplication, divison (S12CPUV2 Reference Manual, Sections 5.6, 5.8 and 5.12).

ABA	; Add B to A; results in A
SUBD \$20A1	; Subtract contents of \$20A1 from D
INX	; Increment X by 1
MUL	; Multiply A by B; results in D

3. Logic and Bit Instructions — perform logical operations (**S12CPUV2 Reference Manual**, Sections 5.9, 5.10, 5.11, 5.13 and 5.14).

• Logic Instructions

ANDA \$2000; Logical AND of A with contents of \$2000EORB 2,X; Exclusive OR B with contents of address (X+2)

• Clear, Complement and Negate Instructions

NEG -2,X	; Negate (2's comp) contents of address (X-2)
CLRA	; Clear Acc A





 Bit manipulate and test instructions — work with one bit of a register or memory. BITA #\$08 ; Check to see if Bit 3 of A is set BSET \$0002,#\$18 ; Set bits 3 and 4 of address \$002

• Shift and rotate instructions

LSLA ; Logical shift left A ASR \$1000 ; Arithmetic shift right value at address \$1000

4. Compare and test instructions — test contents of a register or memory (to see if zero, negative, etc.), or compare contents of a register to memory (to see if bigger than, etc.) (S12CPUV2 Reference Manual, Section 5.9).

TSTA ; (A)-0 -- set flags accordingly CPX #\$8000 ; (X) - \$8000 -- set flags accordingly

5. Jump and Branch Instructions — Change flow of program (e.g., goto, it-then-else, switch-case) (**S12CPUV2 Reference Manual**, Sections 5.19, 5.20 and 5.21).

JMP L1	; Start executing code at address label L1
BEQ L2	; If Z bit set, go to label L2
DBNE X,L3	; Decrement X; if X not 0 then goto L3
BRCLR \$1A,#\$80,L4	; If bit 7 of addr \$1A clear, go to label L4
JSR sub1	; Jump to subroutine sub1
RTS	; Return from subroutine

6. Interrupt Instructions — Initiate or terminate an interrupt call (**S12CPUV2 Reference Manual**, Section 5.22).

• Interrupt instructions

SWI ; Initiate software interrupt

RTI ; Return from interrupt

7. Index Manipulation Instructions — Put address into X, Y or SP, manipulate X, Y or SP (**S12CPUV2 Reference Manual**, Section 5.23).

ABX ; Add (B) to (X) LEAX 5,Y ; Put address (Y) + 5 into X

8. Condition Code Instructions — change bits in Condition Code Register (S12CPUV2 Reference Manual, Section 5.26).

ANDCC #\$f0 ; Clear N, Z, C and V bits of CCR SEV ; Set V bit of CCR

9. Stacking Instructions — push data onto and pull data off of stack (S12CPUV2 Reference Manual, Section 5.24).

PSHA ; Push contents of A onto stack PULX ; Pull two top bytes of stack, put into X





10. Stop and Wait Instructions — put MC9S12 into low power mode (S12CPUV2 Reference Manual, Section 5.27).

**STOP** ; Put into lowest power mode

WAI ; Put into low power mode until next interrupt

11. Null Instructions

NOP ; No operation

BRN ; Branch never

12. Instructions we won't discuss or use — BCD arithmetic, fuzzy logic, minimum and maximum, multiply-accumulate, table interpolation (**S12CPUV2 Reference Manual**, Sections 5.7, 5.16, 5.17, and 5.18).



### **Disassembly of an HC12 Program**

• It is sometimes useful to be able to convert *HC12 op codes* into *mnemonics*.

For example, consider the hex code:

### ADDR DATA

1000 C6 05 CE 20 00 E6 01 18 06 04 35 EE 3F

• To determine the instructions, use Table A-2 of the HCS12 Core Users Guide.

- If the first byte of the instruction is anything other than **\$18**, use Sheet 1 of Table A.2. From this table, determine the number of bytes of the instruction and the addressing mode. For example, **\$C6** is a two-byte instruction, the mnemonic is **LDAB**, and it uses the **IMM** addressing mode. Thus, the two bytes **C6 05** is the op code for the instruction **LDAB #\$05**.

– If the first byte is **\$18**, use Sheet 2 of Table A.2, and do the same thing. For example, **18 06** is a two byte instruction, the mnemonic is **ABA**, and it uses the **INH** addressing mode, so there is no operand. Thus, the two bytes **18 06** is the op code for the instruction **ABA**.

– Indexed addressing mode is fairly complicated to disassemble. You need to use Table A.3 to determine the operand. For example, the op code \$E6 indicates LDAB indexed, and may use two to four bytes (one to three bytes in addition to the op code). The postbyte 01 indicates that the operand is 0,1, which is 5-bit constant offset, which takes only one additional byte. All 5-bit constant offset, pre and post increment and decrement, and register offset instructions use one additional byte. All 9-bit constant offset instructions use two additional bytes, with the second byte holding 8 bits of the 9 bit offset. (The 9th bit is a direction bit, which is held in the first postbyte.) All 16-bit constant offset instructions use three postbytes, with the 2nd and 3rd holding the 16-bit unsigned offset.

- Transfer (**TFR**) and exchange (**EXG**) instructions all have the op code **\$B7**. Use Table A.5 to determine whether it is **TFR** or an **EXG**, and to determine which registers are being used. If the most significant bit of the postbyte is **0**, the instruction is a transfer instruction.

– Loop instructions (Decrement and Branch, Increment and Branch, and Test and Branch) all have the op code **\$04**. To determine which instruction the op code **\$04** implies, and whether the branch is <u>positive</u> (forward) or <u>negative</u> (backward), use Table A.6. For example, in the sequence **04 35 EE**, the 04 indicates a loop



instruction. The 35 indicates it is a **DBNE X** instruction (decrement register X and branch if result is not equal to zero), and the direction is backward (negative). The **EE** indicates a branch of -18 bytes.

• Use up all the bytes for one instruction, then go on to the next instruction.

C6 05 CE 20 00 E6 01	⇒ LDAA #\$05 ⇒ LDX #\$2000 ⇒ LDAB 1,X	two-byte LDAA, IMM addressing mode three-byte LDX, IMM addressing mode two to four-byte LDAB, IDX addressing
		mode. Operand $01 \Rightarrow 1, X$ , a 5b constant offset which uses only one postbyte
18 06	$\Rightarrow ABA$	two-byte ABA, INH addressing mode
04 35 EE	$\Rightarrow$ DBNE X,(-18)	three-byte loop instruction Postbyte 35 indicates DBNE X, negative
3F	$\Rightarrow$ SWI	one-byte SWI, INH addressing mode



				14			2 000		p (one	erior	<b>2</b> )				
00 †5						60 3-6		80 1		AD 3-6		C0 1		E0 3-6	
BGND	ANDCC	BRA	PULX	NEGA	NEGB	NEG	NEG	SUBA	SUBA	SUBA	SUBA	SUBB	SUBB	SUBB	SUBB
IH 1	IM 2	RL 2	IH 1	⊪ 1	IH 1	ID 2-4	EX 3		DI 2	ID 2-4	EX 3	IM 2			EX 3
01 5 MEM	11 11 EDIV	21 1 BRN	31 3 PULY	41 1 COMA	51 1 COMB	61 3-6 COM	71 4 COM	81 1 CMPA	91 3 CMPA	A1 3-6 CMPA	B1 3 CMPA	C1 1 CMPB	D1 3 CMPB	E1 3-6 CMPB	F1 3 CMPB
IH 1	IH 1	RL 2	IH 1	IH 1	IH 1		EX 3	IM 2	DI 2	ID 2-4	EX 3	IM 2	DI 2	ID 2-4	EX 3
02 1		22 3/1	32 3		52 1	62 3-6		82 1		A2 3-6	B2 3	C2 1	D2 3		F2 3
INY	MUL	BHI	PULA	INCA	INCB	INC	INC	SBCA	SBCA	SBCA	SBCA	SBCB	SBCB	SBCB	SBCB
IH 1	IH 1		IH 1	IH 1	IH 1		EX 3		DI 2	ID 2-4	EX 3	IM 2			EX 3
03 1 DEY	13 3 EMUL	23 3/1 BLS	33 3 PULB	43 1 DECA	53 1 DECB	63 3-6 DEC	73 4 DEC	83 2 SUBD	93 3 SUBD	A3 3-6 SUBD	B3 3 SUBD	C3 2 ADDD	D3 3 ADDD	E3 3-6 ADDD	F3 3 ADDD
IH 1	IH 1	RL 2	IH 1	IH 1	IH 1	ID 2-4	EX 3	IM 3	DI 2	ID 2-4	EX 3	IM 3	DI 2	ID 2-4	EX 3
04 , 3	14 1	24 3/1			54 1	64 3-6				A4 3-6	B4 3		D4 3		F4 3
loop	ORCC	BCC	PSHX	LSRA	LSRB	LSR	LSR	ANDA	ANDA	ANDA	ANDA	ANDB	ANDB	ANDB	ANDB
RL 3	IM 2		IH 1	IH 1	IH 1		EX 3		DI 2		EX 3	IM 2			EX 3
05 3-6		25 3/1			55 1 POLP	65 3-6				A5 3-6				E5 3-6	
JMP	JSR	BCS	PSHY	ROLA	ROLB	ROL	ROL	BITA	BITA	BITA	BITA	BITB	BITB	BITB	BITB
ID 2-4 06 3	ID 2-4	RL 2 26 3/1	IH 1 36 2		IH 1	ID 2-4 66 3-6	EX 3	IM 2	DI 2	ID 2-4 A6 3-6	EX 3 B6 3	IM 2	DI 2 D6 3		EX 3 F6 3
06 3 JMP	16 4 JSR	20 3/1 BNE	PSHA	RORA	56 1 RORB	80R 80R	76 4 ROR	86 1 LDAA	96 3 LDAA	LDAA	LDAA	C6 1 LDAB	LDAB	LDAB	LDAB
EX 3			IH 1	IH 1	IH 1		EX 3		DI 2	ID 2-4	EX 3	IM 2			EX 3
07 4	17 4	27 3/1			57 1	67 3-6		87 1	97 1		B7 1	C7 1	D7 1	E7 3-6	F7 3
BSR	JSR	BEQ	PSHB	ASRA	ASRB	ASR	ASR	CLRA	TSTA	NOP	TFR/EXG	CLRB	TSTB	TST	TST
RL 2	DI 2		IH 1		IH 1	ID 2-4		IH 1	IH 1	IH 1	IH 2	IH 1		ID 2-4	EX 3
08 1	18 -	28 3/1	38 3		58 1	68 3-6	78 4	88 1		A8 3-6	B8 3	C8 1	D8 3		F8 3
INX	Page 2	BVC	PULC	ASLA	ASLB	ASL	ASL	EORA	EORA	EORA	EORA	EORB	EORB	EORB	EORB
IH 1		RL 2	IH 1	IH 1	IH 1		EX 3		DI 2		EX 3	IM 2			EX 3
09 1	19 2	29 3/1				69 <b>‡</b> 2-4				A9 3-6	B9 3		D9 3		F9 3
DEX	LEAY	BVS	PSHC	LSRD	ASLD	CLR	CLR	ADCA	ADCA	ADCA	ADCA	ADCB	ADCB	ADCB	ADCB
IH 1 0A ±7	ID 2-4	RL 2 2A 3/1	IH 1 3A 3		IH 1 5A 2	ID 2-4 6A ±2-4	EX 3 7A 3	IM 2	DI 2 9A 3	ID 2-4 AA 3-6	EX 3 BA 3	IM 2 CA 1	DI 2 DA 3		EX 3 FA 3
RTC <sup>1</sup>	LEAX	BPL	PULD	CALL	STAA	STAA	STAA	8A 1 ORAA	ORAA	ORAA	ORAA	ORAB	ORAB	ORAB	ORAB
IH 1		RL 2	IH 1				EX 3		DI 2	ID 2-4	EX 3	IM 2			EX 3
0B †8	1B 2	2B 3/1		4B ±7-10		6B ±2-4				AB 3-6	BB 3		DB 3		FB 3
RTI	LEAS	BMI	PSHD	CALL	STAB	STAB	STAB	ADDA	ADDA	ADDA	ADDA	ADDB	ADDB	ADDB	ADDB
IH 1 0C 4-6	ID 2-4 1C 4	2C 3/1			5C 2		EX 3 7C 3	8C 2	9C 3	AC 3-6	EX 3 BC 3		DC 3	EC 3-6	EX 3 FC 3
BSET	BSET	BGE	wavr	BSET	STD	STĎ	STD	CPD	CPD	CPD	CPD	LDD	LDD	LDD	LDD
ID 3-5	EX 4	RL 2	SP 1						DI 2			IM 3			EX 3
0D 4-6 BCLR	1D 4 BCLR	2D 3/1 BLT	3D 5 RTS	4D 4 BCLR	5D 2 STY	6D ±2-4 STY	7D 3 STY	8D 2 CPY	9D 3 CPY	AD 3-6 CPY	BD 3 CPY	CD 2 LDY	DD 3 LDY	ED 3-6 LDY	FD 3 LDY
ID 3-5	EX 4		IH 1	DI 3		ID 2-4	EX 3	IM 3	DI 2		EX 3	IM 3	DI 2	ID 2-4	EX 3
0E ±4-6 BRSET	1E 5 BRSET	2E 3/1 BGT	3E ‡†7 WAI	4E 4 BRSET	5E 2 STX	6E ‡2-4 STX	7E 3 STX	8E 2 CPX	9E 3 CPX	AE 3-6 CPX	BE 3 CPX	CE 2 LDX	DE 3 LDX	EE 3-6 LDX	FE 3 LDX
ID 4-6	EX 5		IH 1						DI 2			IM 3			EX 3
0F ±4-6	1F 5		3F 9			6F ±2-4		8F 2		AF 3-6	BF 3			EF 3-6	
BRCLR	BRCLR	BLE	SWI	BRCLR	STS	STS	STS	CPS	CPS	CPS	CPS	LDS	LDS	LDS	LDS
ID 4-6	EX 5	RL 2	IH 1	DI 4	DI 2	ID 2-4	EX 3	IM 3	DI 2	ID 2-4	EX 3	IM 3	DI 2	ID 2-4	EX 3

### Table A-2. CPU12 Opcode Map (Sheet 1 of 2)

Key to Table A-2 Opcode Mnemonic Address Mode

Number of HCS12 cycles (‡ indicates HC12 different)

- Number of bytes

5



1					1										
00 4 MOVW	10 12 IDIV	20 4 LBRA	30 10 TRAP	40 10 TRAP	50 10 TRAP	60 10 TRAP	70 10 TRAP	80 10 TRAP	90 10 TRAP	A0 10 TRAP	80 10 TRAP	C0 10 TRAP	D0 10 TRAP	E0 10 TRAP	F0 10 TRAP
IM-ID 5	IH 2	RL 4	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2
01 5				41 10				81 10				C1 10			F1 10
MOVW	FDIV	LBRN	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
EX-ID 5	IH 2	RL 4	IH 2		IH 2	IH 2	IH 2	IH 2	IH 2		IH 2	IH 2	IH 2	IH 2	IH 2
MOVW S	12 13 EMACS	22 4/3 LBHI	32 10 TRAP	42 10 TRAP	52 10 TRAP	62 10 TRAP	72 10 TRAP	82 10 TRAP	92 10 TRAP	A2 10 TRAP	82 10 TRAP	C2 10 TRAP	D2 10 TRAP	E2 10 TRAP	TRAP
ID-ID 4	SP 4	RL 4	IH 2		IH 2	IH 2	IH 2	IH 2	IH 2					IH 2	IH 2
03 5 MOVW	13 3 EMULS	23 4/3 LBLS	33 10 TRAP	43 10 TRAP	53 10 TRAP	63 10 TRAP	73 10 TRAP	83 10 TRAP	93 10 TRAP	A3 10 TRAP	B3 10 TRAP	C3 10 TRAP	D3 10 TRAP	E3 10 TRAP	F3 10 TRAP
IM-EX 6	IH 2	1.	IH 2	13130	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2		IH 2	IH 2	IH 2	IH 2
04 6	14 12				54 10							C4 10	D4 10		F4 10
MOVW	EDIVS	LBCC	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
EX-EX 6	IH 2	RL 4	IH 2		IH 2	IH 2	IH 2	IH 2	IH 2			IH 2	IH 2	IH 2	IH 2
05 5 MOVW	15 12 IDIVS	25 4/3 LBCS	35 10 TRAP	45 10 TRAP	55 10 TRAP	65 10 TRAP	75 10 TRAP	85 10 TRAP	95 10 TRAP	A5 10 TRAP	85 10 TRAP	C5 10 TRAP	D5 10 TRAP	E5 10 TRAP	F5 10 TRAP
ID-EX 5	IH 2	RL 4	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2
06 2	16 2		36 10			66 10			96 10	A6 10	B6 10	C6 10		E6 10	F6 10
ABA	SBA	LBNE	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
IH 2	IH 2		IH 2		IH 2	IH 2	IH 2	IH 2	IH 2					IH 2	IH 2
07 3 DAA		27 4/3			57 10 TPAD									E7 10	
UAA IH 2	CBA	LBEQ RL 4	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
09 4	19 4.7	28 4/3			58 10			88 10	98 10			C8 10	D8 10		E9 10
MOVB	MAXA	LBVC	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
IM-ID 4	ID 3-5		IH 2		IH 2	IH 2	IH 2	IH 2	IH 2	IH 2		IH 2	IH 2	IH 2	IH 2
09 5	19 4-7	29 4/3		49 10 TRAP	59 10			89 10		A9 10		C9 10	D9 10	E9 10	F9 10
MOVB	MINA	LBVS										TOID			
EX-ID 5			TRAP		TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP	TRAP
0.4	ID 3-5	RL 4	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	IH 2	TRAP IH 2	TRAP IH 2	IH 2
0A 5 MOVB			IH 2	IH 2		IH 2	IH 2	IH 2		IH 2	IH 2	IH 2	TRAP	TRAP IH 2	
	1A 4-7	RL 4 2A 4/3 LBPL	IH         2           3A         †3n           REV           SP         2	IH 2 4A 10 TRAP IH 2	1H 2 5A 10 TRAP 1H 2	IH 2 6A 10 TRAP IH 2	IH 2 7A 10 TRAP IH 2	IH 2 8A 10 TRAP IH 2	IH 2 9A 10 TRAP IH 2	IH 2 AA 10 TRAP IH 2	IH 2 BA 10 TRAP IH 2	IH 2 CA 10 TRAP IH 2	TRAP 1H 2 DA 10 TRAP	TRAP IH 2 EA 10	IH 2 FA 10
MOVB	1A 4-7 EMAXD	RL 4 2A 4/3 LBPL	IH 2 3A †3n REV	IH 2 4A 10 TRAP IH 2	1H 2 5A 10 TRAP	1H 2 6A 10 TRAP	1H 2 7A 10 TRAP	IH 2 8A 10 TRAP IH 2 8B 10	1H 2 9A 10 TRAP	IH 2 AA 10 TRAP IH 2	IH 2 BA 10 TRAP	IH 2 CA 10 TRAP	TRAP 1H 2 DA 10 TRAP	TRAP IH 2 EA 10 TRAP IH 2	IH 2 FA 10 TRAP
MOVB ID-ID 4 0B 4	1A 4-7 EMAXD ID 3-5 1B 4-7	RL 4 2A 4/3 LBPL RL 4 2B 4/3 LBMI	IH         2           3A         †3n           REV           SP         2           3B †5n/3n	IH 2 4A 10 TRAP IH 2 4B 10	IH         2           5A         10           TRAP         11           IH         2           5B         10	IH         2           6A         10           TRAP           IH         2           6B         10	IH         2           7A         10           TRAP           IH         2           7B         10	IH 2 8A 10 TRAP IH 2	IH         2           9A         10           TRAP         11           IH         2           9B         10	IH         2           AA         10           TRAP           IH         2           AB         10	IH         2           BA         10           TRAP           IH         2           BB         10	IH         2           CA         10           TRAP           IH         2           CB         10	TRAP IH 2 DA 10 TRAP IH 2 DB 10	TRAP IH 2 EA 10 TRAP IH 2 EB 10	IH         2           FA         10           TRAP         IH           IH         2           FB         10
MOVB ID-ID 4 08 4 MOVB IM-EX 5 0C 6	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5 1C 4-7	RL         4           2A         4/3           LBPL         4           2B         4/3           LBMI         4           2C         4/3	IH         2           3A         †3n           REV         3           SP         2           3B         †5n/3n           REVW         3P           3C         ‡7B	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2           4B         10           TRAP           IH         2           4C         10	IH         2           5A         10           TRAP         11           IH         2           5B         10           TRAP           IH         2           5C         10	IH         2           6A         10           TRAP         11           IH         2           6B         10           TRAP         11           IH         2           6B         10           TRAP         11           IH         2           6C         10	IH         2           7A         10           TRAP           IH         2           7B         10           TRAP           IH         2           7B         10           TRAP           IH         2           7C         10	IH         2           8A         10           TRAP           IH         2           8B         10           TRAP           IH         2           8B         10           TRAP           IH         2           8C         10	IH         2           9A         10           TRAP           IH         2           9B         10           TRAP           IH         2           9B         10           TRAP           IH         2           9C         10	IH         2           AA         10           TRAP           IH         2           AB         10           TRAP           IH         2           AB         10           TRAP           IH         2           AC         10	IH         2           BA         10           TRAP           IH         2           BB         10           TRAP           IH         2           BB         10           TRAP           IH         2           BC         10	IH         2           CA         10           TRAP           IH         2           CB         10           TRAP           IH         2           CB         10           TRAP           IH         2           CC         10	TRAP           IH         2           DA         10           TRAP         IH           IH         2           DB         10           TRAP         IH           IH         2           DB         10           TRAP         IH           IH         2           DC         10	TRAP           IH         2           EA         10           TRAP         IH           IH         2           EB         10           TRAP         IH           IH         2           EB         10           TRAP         IH           IH         2           EC         10	IH         2           FA         10           TRAP         11           IH         2           FB         10           TRAP         11           IH         2           FB         10           TRAP         11           IH         2           FC         10
MOVB ID-ID 4 0B 4 MOVB IM-EX 5	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5	RL         4           2A         4/3           LBPL         4           2B         4/3           LBMI         4           2C         4/3           LBGE         4	IH         2           3A         †3n           REV         3           SP         2           3B         †5n/3n           REVW         SP	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2	IH         2           5A         10           TRAP         11           IH         2           5B         10           TRAP         11           IH         2           IH         2           IH         2	IH         2           6A         10           TRAP         11           IH         2           6B         10           TRAP         11           IH         2           IH         2           IH         2	IH         2           7A         10           TRAP           IH         2           7B         10           TRAP           IH         2           IH         2           IH         2	IH         2           8A         10           TRAP           IH         2           8B         10           TRAP           IH         2	IH         2           9A         10           TRAP         11           IH         2           9B         10           TRAP         11           IH         2           IH         2           IH         10           TRAP         11           IH         2	IH         2           AA         10           TRAP         IH           IH         2           AB         10           TRAP         IH           IH         2	IH         2           BA         10           TRAP           IH         2           BB         10           TRAP           IH         2	IH         2           CA         10           TRAP           IH         2           CB         10           TRAP           IH         2	TRAP IH 2 DA 10 TRAP IH 2 DB 10 TRAP IH 2	TRAP IH 2 EA 10 TRAP IH 2 EB 10 TRAP IH 2	IH         2           FA         10           TRAP         11           IH         2           FB         10           TRAP         11           IH         2           IH         10           TRAP         10           IH         2
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5 1C 4-7 MAXM	RL         4           2A         4/3           LBPL         RL           RL         4           2B         4/3           LBMI         RL           RL         4           2C         4/3           LBGE         RL           RL         4	IH         2           3A         †3n           REV         SP           3B         †5n/3n           REVW         SP           3C         ‡7B           WAV         SP           SP         2	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4C         10           TRAP           IH         2	IH         2           5A         10           TRAP           IH         2           5B         10           TRAP           IH         2           5C         10           TRAP           IH         2	IH         2           6A         10           TRAP         IH           IH         2           6B         10           TRAP         IH           IH         2           6C         10           TRAP         IH           IH         2           IH         2           IH         2	IH         2           7A         10           TRAP           IH         2           7B         10           TRAP           IH         2           7C         10           TRAP           TRAP	IH         2           8A         10           TRAP           IH         2           8B         10           TRAP           IH         2           8C         10           TRAP           IH         2           8C         10           TRAP           IH         2           8D         10	IH         2           9A         10           TRAP           IH         2           9B         10           TRAP           IH         2           9C         10           TRAP           IH         2           9C         10           TRAP           IH         2	IH         2           AA         10           TRAP           IH         2           AB         10           TRAP           IH         2           AC         10           TRAP           IH         2           AC         10           TRAP           IH         2	IH         2           BA         10           TRAP           IH         2           BB         10           TRAP           IH         2           BC         10           TRAP	IH         2           CA         10           TRAP           IH         2           CB         10           TRAP           IH         2           CCB         10           TRAP           IH         2           CC         10           TRAP	TRAP           IH         2           DA         10           TRAP         IH           IH         2           DB         10           TRAP           IH         2           DC         10           TRAP           IH         2           DC         10           TRAP           IH         2	TRAP IH 2 EA 10 TRAP IH 2 EB 10 TRAP IH 2 EC 10 TRAP IH 2 IH 2	IH         2           FA         10           TRAP         11           IH         2           FB         10           TRAP         11           IH         2           FC         10           TRAP         11
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB EX-EX 6 0D 5 MOVB	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5 1C 4-7 MAXM ID 3-5 1D D4-7 MINM	RL         4           2A         4/3           LBPL         4/3           2B         4/3           LBMI         4           2C         4/3           LBGE         RL           RL         4           2C         4/3           LBGE         RL           A         2D           LBLT         4/3	IH         2           3A         †3n           REV         2           3B         †5n/3n           REVW         2           3C         ‡78           WAV         SP           SP         2           3C         ‡78           WAV         SP           SD         ±6           TBL	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4C         10           TRAP           IH         2           4D         10           TRAP	IH         2           5A         10           TRAP         11           1H         2           5B         10           TRAP         11           5C         10           TRAP         11           1H         2           5C         10           TRAP         11           1H         2           5C         10           TRAP         10           TRAP         10	IH         2           6A         10           TRAP         11           0B         10           TRAP         11           0C         10           TRAP         11           0C         10           TRAP         11           0C         10           TRAP         11           1H         2           0C         10           TRAP         10           TRAP         10	IH         2           7A         10           TRAP         14           1H         2           7B         10           TRAP         14           1H         2           7C         10           TRAP         14           2         7C           1H         2           7C         10           TRAP         10           TRAP         10	IH         2           8A         10           TRAP           IH         2           8B         10           TRAP           IH         2           8C         100           TRAP           IH         2           8C         10           TRAP           IH         2           8C         10           TRAP           IH         2           8D         10           TRAP	IH         2           9A         10           TRAP           IH         2           9B         10           TRAP           IH         2           9C         100           TRAP           IH         2           9C         10           TRAP           IH         2           9D         10           TRAP	IH         2           AA         10           TRAP         IH           IH         2           AB         10           TRAP           IH         2           AC         100           TRAP           IH         2           AC         10           TRAP           IH         2           AC         10           TRAP           IH         2	IH         2           BA         10           TRAP           IH         2           BB         10           TRAP           IH         2           BC         100           TRAP           IH         2           BC         10           TRAP           IH         2           BD         10           TRAP	IH         2           CA         10           TRAP         11           IH         2           CB         10           TRAP         11           IH         2           CC         100           TRAP         11           IH         2           CC         100           TRAP         11           IH         2           CC         100           TRAP         10	TRAP           IH         2           DA         10           TRAP         11           IH         2           DB         10           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DD         10           TRAP         10	TRAP IH 2 EA 10 TRAP IH 2 EB 10 TRAP IH 2 EC 10 TRAP IH 2 EC 10 TRAP IH 2 ED 10 TRAP	IH         2           FA         10           TRAP         IH           IH         2           FB         10           TRAP           IH         2           FC         10           TRAP           IH         2           FC         10           TRAP           IH         2           FD         10           TRAP
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB EX-EX 6 0D 5 MOVB ID-EX 5	1A         4-7           EMAXD         ID         3-5           1B         4-7         EMIND           ID         3-5         10           ID         3-5         10         3-5           ID         3-5         10         04-7           MINM         ID         3-5	RL         4           2A         4/3           LBPL         RL           2B         4/3           LBMI         RL           2C         4/3           LBGE         RL           RL         4           2D         4/3           LBLT         RL           RL         4	IH         2           3A         †3n           REV         2           3B         †5n/3n           REVW         SP           3C         ‡7B           WAV         SP           3D         ‡6           TBL         ID	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4C         10           TRAP           IH         2           4D         10           TRAP           IH         2	IH         2           5A         10           TRAP         IH           IH         2           5B         10           TRAP         IH           IH         2           5C         10           TRAP         IH           IH         2           5C         10           TRAP         IH           IH         2           5D         10           TRAP         IH	IH         2           6A         10           TRAP         IH           IH         2           6B         10           TRAP         IH           IH         2           6C         10           TRAP         IH           IH         2           6D         10           TRAP         IH           IH         2           IH         2	IH         2           7A         10           TRAP         IH           IH         2           7B         10           TRAP           IH         2           7C         10           TRAP           IH         2           7C         10           TRAP           IH         2           7D         10           TRAP           IH         2	IH         2           8A         10           TRAP         IH           IH         2           8B         10           TRAP           IH         2           8C         10           TRAP           IH         2           8C         10           TRAP           IH         2           8D         10           TRAP           IH         2           IH         2	IH         2           9A         10           TRAP         IH         2           9B         10         TRAP           IH         2         9C         10           TRAP         IH         2         9C           IH         2         9C         10           TRAP         IH         2         9D           9D         10         TRAP           IH         2         IH         2	IH         2           AA         10           TRAP         IH         2           AB         10         TRAP           IH         2         AC         10           TRAP         IH         2         AC         10           TRAP         IH         2         AC         10           TRAP         IH         2         IN         10           TRAP         IH         2         IN         10	IH         2           BA         10           TRAP         IH           IH         2           BB         10           TRAP           IH         2           BC         10           TRAP           IH         2           BC         10           TRAP           IH         2           BD         10           TRAP           IH         2	IH         2           CA         10           TRAP         IH         2           CB         10         TRAP           IH         2         CC         10           TRAP         IH         2         CC           IH         2         CC         10         TRAP           IH         2         CD         10         TRAP           IH         2         III         2         III         2	TRAP           IH         2           DA         10           TRAP         11           DB         10           TRAP         11           DB         10           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DD         100           TRAP         11           IH         2           DD         TRAP           IH         2	TRAP IH 2 EA 10 TRAP IH 2 EB 10 TRAP IH 2 EC 10 TRAP IH 2 EC 10 TRAP IH 2 ED 10 TRAP IH 2 IH 2	IH         2           FA         10           TRAP         IH           IH         2           FB         10           TRAP         IH           IH         2           FC         10           TRAP         IH           IH         2           FD         10           TRAP         IH           IH         2
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB EX-EX 6 0D 5 MOVB	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5 1C 4-7 MAXM ID 3-5 1D D4-7 MINM	RL         4           2A         4/3           LBPL         RL           2B         4/3           LBMI         RL           2C         4/3           LBGE         RL           RL         4           2C         4/3           LBGE         RL           A         2D           LBLT         A	IH         2           3A         †3n           REV         2           3B         †5n/3n           REVW         SP           3C         ‡7B           WAV         SP           3D         ‡6           TBL         ID	IH         2           4A         10           TRAP         IH           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4C         10           TRAP           IH         2           4D         10           TRAP           IH         2	IH         2           5A         10           TRAP         11           1H         2           5B         10           TRAP         11           5C         10           TRAP         11           1H         2           5C         10           TRAP         11           1H         2           5C         10           TRAP         10           TRAP         10	IH         2           6A         10           TRAP         IH           IH         2           6B         10           TRAP         IH           IH         2           6C         10           TRAP         IH           IH         2           6D         10           TRAP         IH           IH         2           IH         2	IH         2           7A         10           TRAP         IH           IH         2           7B         10           TRAP           IH         2           7C         10           TRAP           IH         2           7C         10           TRAP           IH         2           7D         10           TRAP           IH         2	IH         2           8A         10           TRAP           IH         2           8B         10           TRAP           IH         2           8C         100           TRAP           IH         2           8C         10           TRAP           IH         2           8C         10           TRAP           IH         2           8D         10           TRAP	IH         2           9A         10           TRAP         IH           9B         10           TRAP           IH         2           9C         10           TRAP           IH         2           9C         10           TRAP           IH         2           9D         10           TRAP           IH         2           IH         2	IH         2           AA         10           TRAP         IH         2           AB         10         TRAP           IH         2         AC         10           TRAP         IH         2         AC         10           TRAP         IH         2         AC         10           TRAP         IH         2         IN         10           TRAP         IH         2         IN         10	IH         2           BA         10           TRAP         IH           IH         2           BB         10           TRAP           IH         2           BC         10           TRAP           IH         2           BC         10           TRAP           IH         2           BD         10           TRAP           IH         2	IH         2           CA         10           TRAP         11           IH         2           CB         10           TRAP         11           IH         2           CC         100           TRAP         11           IH         2           CC         100           TRAP         11           IH         2           CC         100           TRAP         10	TRAP           IH         2           DA         10           TRAP         11           DB         10           TRAP         11           DB         10           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DD         100           TRAP         11           IH         2           DD         TRAP           IH         2	TRAP IH 2 EA 10 TRAP IH 2 EB 10 TRAP IH 2 EC 10 TRAP IH 2 EC 10 TRAP IH 2 ED 10 TRAP IH 2 IH 2	IH         2           FA         10           TRAP         IH           IH         2           FB         10           TRAP           IH         2           FC         10           TRAP           IH         2           FC         10           TRAP           IH         2           FD         10           TRAP
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB EX-EX 6 0D 5 MOVB ID-EX 5 0E 2	1A 4-7 EMAXD ID 3-5 1B 4-7 EMIND ID 3-5 1C 4-7 MAXM ID 3-5 1D D4-7 MINM ID 3-5 1E 4-7	RL         4           2A         4/3           LBPL         4/3           2B         4/3           LBMI         RL           RL         4           2C         4/3           LBGE         RL           RL         4           2D         4/3           LBLT         RL           RL         4           2D         4/3	IH         2           3A         †3n           REV         38           3B         †5n/3n           REVW         SP           3C         ‡78           WAV         SP           SP         2           3D         ‡6           TBL         10           3E         ‡8	IH         2           4A         10           TRAP           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4C         10           TRAP           IH         2           4D         10           TRAP           IH         2           4D         10           TRAP           IH         2	IH         2           5A         10           TRAP         11           16         58         10           TRAP         11         2           5E         10         TRAP           IH         2         5C         10           TRAP         11         2         5C           10         TRAP         11         2           5D         10         TRAP         11           2         5D         10         5E         10	IH         2           6A         10           TRAP         11           0B         10           TRAP         14           1H         2           6C         10           TRAP         14           1H         2           6C         10           TRAP         14           2         6D           10         TRAP           1H         2           6D         10           TRAP         14           0D         10           TRAP         10	IH         2           7A         10           TRAP         IH           IH         2           7B         10           TRAP           IH         2           7C         10           TRAP           IH         2           7C         10           TRAP           IH         2           7D         10           TRAP           IH         2           7D         10           TRAP           IH         2           7E         10	IH         2           8A         10           TRAP         IH           IH         2           8B         10           TRAP           IH         2           8C         10           TRAP           IH         2           8D         10           TRAP           IH         2           8D         10           TRAP           IH         2           8D         10           TRAP           IH         2           8E         10	IH         2           9A         10           TRAP         11           9B         10           TRAP         11           9C         10           TRAP         11           9C         10           TRAP         11           9D         10           TRAP         11           9D         10           TRAP         11           9D         10           TRAP         11           9E         10	IH         2           AA         10           TRAP         II           IH         2           AB         10           TRAP           IH         2           AC         10           TRAP           IH         2           AC         10           TRAP           IH         2           AD         10           TRAP           IH         2           AD         10           TRAP         IH           IH         2	IH         2           BA         10           TRAP         IH           IH         2           BB         10           TRAP           IH         2           BC         10           TRAP           IH         2           BD         10           TRAP           IH         2           BD         10           TRAP           IH         2           BD         10           TRAP           IH         2           BE         10	IH         2           CA         10           TRAP         IH           IH         2           CB         10           TRAP         IH           IH         2           CC         10           TRAP           IH         2           CC         10           TRAP           IH         2           CD         10           TRAP           IH         2           CD         10           TRAP           IH         2           CD         10           TRAP           IH         2           CE         10	TRAP           IH         2           DA         10           TRAP         10           IH         2           DB         10           TRAP         11           IH         2           DC         100           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DC         10           TRAP         11           IH         2           DD         10           TRAP         11	TRAP           IH         2           EA         10           TRAP         IH           IH         2           EB         10           TRAP         IH           IH         2           EC         10           TRAP         IH           IH         2           ED         10           TRAP         IH           IH         2           ED         10           TRAP         IH           IH         2           EE         10	IH         2           FA         10           TRAP         II           IH         2           FB         10           TRAP         II           IH         2           FC         10           TRAP         II           IH         2           FD         10           TRAP         II           IH         2           FD         10           TRAP         II           IH         2           FE         10
MOVB ID-ID 4 MOVB IM-EX 5 OC 6 MOVB IM-EX 6 OD 5 MOVB ID-EX 5 OE 2 IH 2 OF 2	1A         4-7           EMAXD         ID         3-5           1B         4-7         EMIND           ID         3-5         10         10           1D         3-5         10         4-7           MAXM         ID         3-5         10         04-7           MINM         ID         3-5         11E         4-7           ID         3-5         11E         4-7         EMAXM           ID         3-5         11E         4-7         EMAXM           ID         3-5         11E         4-7         EMAXM           ID         3-5         11E         4-7         11E         4-7	RL         4           2A         4/3           LBPL            LBPL            LBMI            RL         4           2D         4/3           LBGE         RL           4         2C           2C         4/3           LBGE         RL           RL         4           2D         4/3           LBGT         RL           LBGT         RL           LBGT         RL           4         2F           4/3         2F	IH         2           3A         +3n           REV         \$\$           3B         +5n/3n           REVW         \$\$           SP         2           3B         +5n/3n           REVW         \$\$           SP         2           3C         +178           WAV         \$\$           SD         ±6           TBL         3           STOP         IH           IH         2           3F         10	IH         2           4A         10           TRAP         II           IH         2           4B         10           TRAP         II           IH         2           4C         10           TRAP         II           IH         2           4D         10           TRAP         II           IH         2           4E         10	IH         2           5A         10           TRAP           IH         2           5B         10           TRAP           IH         2           5C         10           TRAP           IH         2           5D         10           TRAP           IH         2           5D         10           TRAP           IH         2           5E         10           TRAP           IH         2           5E         10           TRAP         11	IH         2           6A         10           TRAP         II           IH         2           08         10           TRAP         II           IH         2           06C         10           TRAP         II           IH         2           06C         10           TRAP         II           IH         2           06C         10           TRAP         II           IH         2           06E         10           TRAP         II           IH         2           06E         10           TRAP         II           IH         2           06E         10           TRAP         II           III         2           06F         10	IH         2           7A         10           TRAP         II           IH         2           7B         10           TRAP         IH           IH         2           7C         10           TRAP         IH           IH         2           7D         10           TRAP         IH           IH         2           7E         10           TRAP         IH           IH         2           7E         10           TRAP         IH	IH         2           8A         10           TRAP         II           IH         2           8B         10           TRAP         II           IH         2           8C         10           TRAP         II           IH         2           8D         10           TRAP         II           IH         2           8E         10           TRAP         II           IH         2           8E         10           TRAP         II           IH         2           8E         10           TRAP         II           IH         2           8F         10	IH         2           9A         10           TRAP         IH           IH         2           9B         10           TRAP         IH           IH         2           9C         10           TRAP         IH           IH         2           9D         10           TRAP         IH           IH         2           9E         10           TRAP         IH           IH         2           9F         10	IH         2           AA         10           TRAP           IH         2           AB         10           TRAP           IH         2           AC         10           TRAP           IH         2           AD         10           TRAP           IH         2           AD         10           TRAP           IH         2           AE         10           TRAP           IH         2           AE         10	IH         2           BA         10           TRAP         II           IH         2           BD         10           TRAP         IH           IH         2           BC         10           TRAP         IH           IH         2           BD         10           TRAP         IH           IH         2           BE         10           TRAP         IH           IH         2           BE         10           TRAP         IH           IH         2           BE         10           TRAP         IH           2         BE           IH         2           BF         10	IH         2           CA         10           TRAP         II           IH         2           CB         10           TRAP         IH           IH         2           CC         10           TRAP         IH           IH         2           CD         10           TRAP         IH           IH         2           CE         10           TRAP         IH           IH         2           CF         10	TRAP IH 2 DA 10 TRAP IH 2 DB 10 TRAP IH 2 DC 10 TRAP IH 2 DD 10 TRAP IH 2 DE 10 TRAP IH 2 DE 10 TRAP IH 2 DD 10 TRAP	TRAP           IH         2           EA         10           TRAP         IH           IH         2           EB         10           TRAP         IH           IH         2           EC         10           TRAP         IH           IH         2           EC         10           TRAP         IH           IH         2           EE         10	IH         2           FA         10           TRAP           IH         2           FB         10           TRAP           IH         2           FC         10           TRAP           IH         2           FD         10           TRAP           IH         2           FE         10           TRAP           IH         2           FE         10           TRAP           IH         2           FE         10
MOVB ID-ID 4 0B 4 MOVB IM-EX 5 0C 6 MOVB EX-EX 6 0D 5 MOVB ID-EX 5 0E 2	1A         4.7           EMAXD         ID           ID         3.5           1B         4.7           EMIND         ID           ID         3.6           1C         4.7           MAXM         ID           ID         3.6           1D         0.6           1D         3.6           1D         3.6           1E         4.7           MINM         ID           ID         3.6           1E         4.7           EMAXM         ID           ID         3.5           1F         4.7           EMINM	RL         4           2A         4/3           LBPL         LBPL           LBPL         LBMI           RL         4           2C         4/3           LBGE         RL           RL         4           2C         4/3           LBGE         RL           RL         4           2C         4/3           LBLT         RL           RL         4           2C         4/3           LBGT         RL           4         2F           4/3         LBLE	IH         2           3A         +3n           REV         SP           3B         +5n/3n           REVW         SP           SP         2           3C         ±17B           WAV         SP           SP         2           3D         ±6           TBL         ID           ID         3           3E         ±8           STOP         IH           2         3F           TBL         ETBL	IH         2           4A         10           TRAP         II           IH         2           4B         10           TRAP           IH         2           4C         10           TRAP           IH         2           4D         100           TRAP           IH         2           4D         100           TRAP           IH         2           4E         10           TRAP           IH         2	IH         2           5A         10           TRAP         II           IH         2           5B         10           TRAP         II           IH         2           5C         10           TRAP         II           IH         2           5D         10           TRAP         II           IH         2           5D         10           TRAP         II           IH         2           5E         10           TRAP         IH           IH         2	IH         2           6A         10           TRAP         10           IH         2           6B         10           TRAP         IH           IH         2           6C         10           TRAP         IH           IH         2           6D         10           TRAP         IH           IH         2           6D         10           TRAP         IH           IH         2           6E         10           TRAP         IH           IH         2	IH         2           7A         10           TRAP         10           IH         2           7B         10           TRAP         11           IH         2           7C         10           TRAP         11           IH         2           7D         10           TRAP         11           IH         2           7D         10           TRAP         11           IH         2           7E         10           TRAP         11           IH         2           7E         10           TRAP         11           IH         2           7E         10           TRAP         11           IH         2	IH         2           8A         10           TRAP         II           IH         2           8B         10           TRAP         II           IH         2           8C         10           TRAP         II           IH         2           8D         100           TRAP         II           IH         2           8D         100           TRAP         II           IH         2           8E         10           TRAP         IH           IH         2	IH         2           9A         10           TRAP         II           9B         10           TRAP         II           9C         10           TRAP         II           9C         10           TRAP         II           9C         10           TRAP         II           1H         2           9D         10           TRAP         II           1H         2           9E         10           TRAP         II           1H         2           9E         10           TRAP         II           1H         2	IH         2           AA         10           TRAP           IH         2           AB         10           TRAP           IH         2           AC         10           TRAP           IH         2           AD         10           TRAP           IH         2           AD         10           TRAP           IH         2           AE         10           TRAP           IH         2           AF         10           TRAP	IH         2           BA         10           TRAP           IH         2           BB         10           TRAP           IH         2           BC         10           TRAP           IH         2           BD         10           TRAP           IH         2           BC         10           TRAP           IH         2           BE         10           TRAP           IH         2           BE         10           TRAP	IH         2           CA         10           TRAP           IH         2           CB         10           TRAP           IH         2           CC         10           TRAP           IH         2           CC         10           TRAP           IH         2           CD         10           TRAP           IH         2           CE         10           TRAP           IH         2	TRAP           IH         2           DA         100           TRAP         IH           IH         2           DB         100           TRAP         IH           IH         2           DC         100           TRAP         IH           IH         2           DC         100           TRAP         IH           IH         2           DE         100           TRAP         IH           IH         2           DE         100           TRAP         IH           IF         10           TRAP         IH	TRAP         IH         2           IH         2         EA         10           TRAP         IH         2         EB           IF         2         EC         10           TRAP         IH         2         EC           IF         2         ED         10           TRAP         IH         2         EE           IH         2         EE         10           TRAP         IH         2         EE           IH         2         III         2	IH         2           FA         10           TRAP         II           IH         2           FB         10           TRAP         II           IH         2           FC         10           TRAP         II           IH         2           FD         10           TRAP         II           IH         2           FE         10           TRAP         II           IH         2           FE         10           TRAP         II           IH         2           IH         2           IH         2

### Table A-2. CPU12 Opcode Map (Sheet 2 of 2)

 III
 2 III
 3 5 RL
 4 IID
 3 III
 2 IIII
 2 III
 2 IIII
 2 III
 2 III
 <t

Refer to instruction summary for different HC12 cycle count.
 Page 2: When the CPU encounters a page 2 opcode (\$18 on page 1 of the opcode map), it treats the next byte of object code as a page 2 instruction opcode.



00	10	20	30	40	50	60	70	80	90	AD	80	CO	DO	EO	FO
0,X 5b const	-16,X 5b const	1,+X pre-inc	1,X+ post-inc	0,Y 5b const	-16,Y 5b const	1,+Y pre-inc	1,Y+ post-inc	0,SP 5b const	-16,SP 5b const	1,+SP pre-inc	1,SP+ post-inc	0,PC 5b const	-16,PC 5b const	n,X 9b const	n,SP 9b const
01	11 00 const	21	31	41	50 const	61	post-inc	81	91	A1	B1	C1	D1	E1	F1
1.X	-15.X	21 2.+X	2.X+	1.Y	-15.Y	2.+Y	2.Y+	1.SP	-15.SP	2.+SP	2.SP+	1.PC	-15.PC	-n.X	-n,SP
5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	9b const	9b const
02	12	22	32	42	52	62	72	82	92	A2	B2	C2	D2	E2	F2
2,X	-14,X	3,+X	3,X+	2,Y	-14,Y	3,+Y	3,Y+	2,SP	-14,SP	3,+SP	3,SP+	2,PC	-14,PC	n,X	n,SP
5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	16b const	16b const
03	13	23	33	43	53	63	73	83	93	A3	B3	C3	D3	E3	F3
3,X	-13,X 5b const	4,+X	4,X+	3,Y	-13,Y	4,+Y	4,Y+	3,SP 5b const	-13,SP	4,+SP	4,SP+	3,PC 5b const	-13,PC	[n,X] 16b indr	[n,SP]
5b const 04	14	pre-inc 24	post-inc 34	5b const 44	5b const 54	pre-inc 64	post-inc 74	SD CONST 84	5b const 94	pre-inc A4	post-inc B4	C4	5b const D4	E4	16b indr F4
4.X	-12.X	24 5.+X	5.X+	44 4.Y	=12.Y	5.+Y	5.Y+	4.SP	-12.SP	5.+SP	5.SP+	4.PC	-12.PC	A.X	A.SP
5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	A offset	A offset
05	15	25	35	45	55	85	75	85	95	A5	B5	C5	D5	E5	F5
5,X	-11,X	6,+X	6,X+	5,Y	-11,Y	6,+Y	6,Y+	5,SP	-11,SP	6,+SP	6,SP+	5,PC	-11.PC	B,X	B,SP
5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	B offset	B offset
06	16	26	36	46	56	66	76	86	96	A6	B6	C6	D6	E6	F6
6,X	-10,X	7.+X	7,X+	6,Y	-10,Y	7.+Y	7,Y+	6,SP	-10,SP	7,+SP	7,SP+	6,PC	-10,PC	D,X	D,SP
5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	pre-inc	post-inc	5b const	5b const	D offset	D offset
07	17 -9.X	27	37	47 7.Y	57	67 8.+Y	77	87 7.SP	97 -9.SP	A7 8,+SP	87 8,SP+	C7 7.PC	D7 -9.PC	E7	F7 [D.SP]
7,X 5b const	-⊎,∧ 5b const	8,+X pre-inc	8,X+ post-inc	5b const	-9,Y 5b const	pre-inc	8,Y+ post-inc	5b const	5b const	o,+or pre-inc	post-inc	5b const	5b const	[D,X] D indirect	D indirect
08	18	28	38	48	58	68	78	88	98	A8	B8	C8	D8	E8	E8
8.X	-8.X	8X	8.X-	8.Y	-8.Y	8Y	8.Y-	8.SP	-8.SP	8SP	8.SP-	8.PC	-8.PC	n.Y	n.PC
5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	9b const	9b const
09	19	29	39	49	59	69	79	89	99	A9	B9	C9	D9	E9	F9
9,X	-7,X	7,-X	7,X-	9,Y	-7.Y	7Y	7,Y-	9,SP	-7,SP	7SP	7,SP-	9,PC	-7.PC	-n,Y	-n,PC
5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	9b const	9b const
OA XO X	1A	2A	3A	4A	5A	6A	7A	8A	9A	AA	BA	CA	DA	EA	FA
10,X 5b const	-6,X 5b const	6,-X pre-dec	6,X- post-dec	10,Y 5b const	-6,Y 5b const	6,-Y pre-dec	6,Y- post-dec	10,SP 5b const	-6,SP 5b const	6,-SP pre-dec	6,SP- post-dec	10,PC 5b const	-6,PC 5b const	n,Y 16b const	n,PC 16b const
0B	1B	2B	3B	4B	5B	6B	7B	8B	9B	AB	BB	CB	DB	EB	FB
11.X	-5.X	5X	5.X-	11.Y	-5.Y	5Y	5.Y-	11.SP	-5.SP	5SP	5.SP-	11.PC	-5.PC	[n,Y]	In.PC1
5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	16b indr	16b indr
0C	10	2C	30	4C	5C	6C	7C	8C	9C	AC	BC	CC	DC	EC	FC
								10.00	4.00	1 00	4.SP-	12.PC	-4.PC	A.Y	A.PC
12,X	-4,X	4,-X	4,X-	12,Y	-4.Y	4,-Y	4,Y-	12,SP	-4,SP	4SP	4,00-	12,PC	-+,FU	M, 1	A.FU
5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	pre-dec	post-dec	5b const	5b const	A offset	A offset
5b const 0D	5b const 1D	pre-dec 2D	post-dec 3D	5b const 4D	5b const 5D	pre-dec 6D	post-dec 7D	5b const 8D	5b const 9D	pre-dec AD	post-dec BD	5b const CD	5b const DD	A offset ED	A offset FD
5b const 0D 13,X	5b const 1D -3,X	pre-dec 2D 3,-X	3D 3,X-	5b const 4D 13,Y	5b const 5D -3,Y	pre-dec 6D 3,-Y	post-dec 7D 3,Y-	5b const 8D 13,SP	5b const 9D _3,SP	pre-dec AD 3,-SP	post-dec BD 3,SP-	5b const CD 13,PC	5b const DD -3,PC	A offset ED B,Y	A offset FD B,PC
5b const 0D 13,X 5b const	5b const 1D -3,X 5b const	pre-dec 2D 3,-X pre-dec	post-dec 3D 3,X- post-dec	5b const 4D 13,Y 5b const	5b const 5D -3,Y 5b const	pre-dec 6D 3,-Y pre-dec	post-dec 7D 3,Y- post-dec	5b const 8D 13,SP 5b const	5b const 9D -3,SP 5b const	pre-dec AD 3,-SP pre-dec	post-dec BD 3,SP- post-dec	5b const CD 13,PC 5b const	5b const DD -3,PC 5b const	A offset ED B.Y B offset	A offset FD B,PC B offset
5b const 0D 13,X 5b const 0E	5b const 1D -3,X 5b const 1E	pre-dec 2D 3,-X pre-dec 2E	post-dec 3D 3,X- post-dec 3E	5b const 4D 13,Y 5b const 4E	5b const 5D -3,Y 5b const 5E	pre-dec 6D 3,-Y pre-dec 6E	post-dec 7D 3,Y- post-dec 7E	5b const 8D 13,SP 5b const 8E	5b const 9D -3,SP 5b const 9E	pre-dec AD 3,-SP pre-dec AE	post-dec BD 3,SP- post-dec BE	5b const CD 13,PC 5b const CE	5b const DD -3,PC 5b const DE	A offset ED B,Y B offset EE	A offset FD B,PC B offset FE
5b const 0D 13,X 5b const 0E 14,X	5b const 1D -3,X 5b const 1E -2,X	pre-dec 2D 3,-X pre-dec 2E 2,-X	post-dec 3D 3,X- post-dec 3E 2,X-	5b const 4D 13,Y 5b const 4E 14,Y	5b const 5D -3,Y 5b const 5E -2,Y	pre-dec 8D 3,-Y pre-dec 8E 2,-Y	post-dec 7D 3,Y- post-dec 7E 2,Y-	5b const 8D 13,SP 5b const 8E 14,SP	5b const 9D -3,SP 5b const 9E -2,SP	pre-dec AD 3SP pre-dec AE 2SP	post-dec BD 3,SP- post-dec BE 2,SP-	5b const CD 13.PC 5b const CE 14.PC	5b const DD -3,PC 5b const DE -2,PC	A offset ED B,Y B offset EE D,Y	A offset FD B.PC B offset FE D,PC
5b const 0D 13,X 5b const 0E 14,X 5b const	5b const 1D -3,X 5b const 1E -2,X 5b const	pre-dec 2D 3,-X pre-dec 2E	post-dec 3D 3,X- post-dec 3E 2,X- post-dec	5b const 4D 13,Y 5b const 4E 14,Y 5b const	5b const 5D -3,Y 5b const 5E -2,Y 5b const	pre-dec 8D 3,-Y pre-dec 8E 2,-Y pre-dec	post-dec 7D 3,Y- post-dec 7E 2,Y- post-dec	5b const 8D 13,SP 5b const 8E 14,SP 5b const	5b const 9D -3,SP 5b const 9E -2,SP 5b const	pre-dec AD 3,-SP pre-dec AE 2,-SP pre-dec	post-dec BD 3,SP- post-dec BE 2,SP- post-dec	5b const CD 13,PC 5b const CE 14,PC 5b const	5b const DD -3,PC 5b const DE -2,PC 5b const	A offset ED B,Y B offset EE D,Y D offset	A offset FD B.PC B offset FE D.PC D offset
5b const 0D 13,X 5b const 0E 14,X	5b const 1D -3,X 5b const 1E -2,X	pre-dec 2D 3,-X pre-dec 2E 2,-X pre-dec	post-dec 3D 3,X- post-dec 3E 2,X-	5b const 4D 13,Y 5b const 4E 14,Y	5b const 5D -3,Y 5b const 5E -2,Y	pre-dec 8D 3,-Y pre-dec 8E 2,-Y	post-dec 7D 3,Y- post-dec 7E 2,Y-	5b const 8D 13,SP 5b const 8E 14,SP	5b const 9D -3,SP 5b const 9E -2,SP	pre-dec AD 3SP pre-dec AE 2SP	post-dec BD 3,SP- post-dec BE 2,SP-	5b const CD 13.PC 5b const CE 14.PC	5b const DD -3,PC 5b const DE -2,PC	A offset ED B,Y B offset EE D,Y	A offset FD B.PC B offset FE D,PC

### Table A-3. Indexed Addressing Mode Postbyte Encoding (xb)

Key to Table A-3 postbyte (hex)

B0 #,REG source code syntax , type

type offset used



TRANSFERS									
ULS MS⇒	0	1	2	3	4	5	6	7	
0	$A \rightrightarrows A$	$B \Rightarrow A$	$CCR \Rightarrow A$	TMP3 <sub>L</sub> ⇒ A	B⇒A	$X_L \Rightarrow A$	$Y_L \Rightarrow A$	$SP_L \Rightarrow A$	
1	$A \Rightarrow B$	B⇒B	$CCR \Rightarrow B$	$TMP3_L ⇒ B$	B⇒B	$X_L \Rightarrow B$	Y <sub>L</sub> ⇒B	$SP_L \Rightarrow B$	
2	$A \Rightarrow CCR$	$B \Rightarrow CCR$	$CCR \Rightarrow CCR$	TMP3 <sub>L</sub> ⇒ CCR	$B \Rightarrow CCR$	$X_L \Rightarrow CCR$	$Y_L \Rightarrow CCR$	$SP_L \Rightarrow CCR$	
3	sex:A ⇒ TMP2	sex:B ⇒ TMP2	sex:CCR $\Rightarrow$ TMP2	TMP3 ⇒ TMP2	$D \Rightarrow TMP2$	X⇒TMP2	Y ⇒ TMP2	$SP \Rightarrow TMP2$	
4	sex:A ⇒ D SEX A,D	sex:B ⇒ D SEX B,D	sex:CCR ⇒ D SEX CCR,D	TMP3 ⇒ D	D⇒D	X⇒D	Y⇒D	SP ⇒ D	
5	sex:A ⇒ X SEX A,X	sex:B⇒X SEX B,X	sex:CCR ⇒ X SEX CCR,X	TMP3 ⇒ X	D⇒X	×⇒×	$Y \mathrel{\Rightarrow} X$	SP⇒X	
6	sex:A ⇒ Y SEX A,Y	sex:B⇒Y SEX B,Y	sex:CCR ⇒ Y SEX CCR,Y	TMP3 ⇒ Y	D⇒Y	X⇒Y	$Y \rightrightarrows Y$	SP⇒Y	
7	sex:A ⇒ SP SEX A,SP	sex:B ⇒ SP SEX B,SP	sex:CCR ⇒ SP SEX CCR,SP	TMP3 ⇒ SP	$D \Rightarrow SP$	$X \Rightarrow SP$	$Y \Rightarrow SP$	$SP \Rightarrow SP$	
			EXCH	ANGES					
↓LS MS⇒	8	9	А	В	С	D	E	F	
0	$A \Leftrightarrow A$	$B \Leftrightarrow A$	$CCR \Leftrightarrow A$	TMP3 <sub>L</sub> ⇒ A \$00:A ⇒ TMP3	B⇒A A⇒B	$X_L \Rightarrow A$ \$00:A $\Rightarrow X$	$Y_L \Rightarrow A$ \$00:A $\Rightarrow Y$	SP <sub>L</sub> ⇒ A \$00:A ⇒ SP	
1	$A \Leftrightarrow B$	B⇔B	$CCR \Leftrightarrow B$	TMP3 <sub>L</sub> ⇒ B \$FF:B ⇒ TMP3	B⇒B \$FF⇒A	$X_L \Rightarrow B$ \$FF:B $\Rightarrow X$	$Y_L \Rightarrow B$ \$FF:B $\Rightarrow Y$	SP <sub>L</sub> ⇒ B \$FF:B ⇒ SP	
2	$A \Leftrightarrow CCR$	$B \Leftrightarrow CCR$	$CCR \Leftrightarrow CCR$	TMP3 <sub>L</sub> ⇒ CCR \$FF:CCR ⇒ TMP3	$B \Rightarrow CCR$ \$FF:CCR $\Rightarrow D$	$X_L \Rightarrow CCR$ \$FF:CCR $\Rightarrow X$	$Y_L \Rightarrow CCR$ \$FF:CCR $\Rightarrow Y$	$SP_L \Rightarrow CCR$ $FF:CCR \Rightarrow SP$	
3	$00:A \Rightarrow TMP2$ TMP2 <sub>L</sub> $\Rightarrow A$	$00:B \Rightarrow TMP2$ $TMP2_L \Rightarrow B$	\$00:CCR ⇒ TMP2 TMP2 <sub>L</sub> ⇒ CCR	TMP3 ⇔ TMP2	$D \Leftrightarrow TMP2$	$X \Leftrightarrow TMP2$	$Y \Leftrightarrow TMP2$	$SP \Leftrightarrow TMP2$	
4	\$00:A ⇒ D	\$00:B ⇒ D	$00:CCR \Rightarrow D$ B $\Rightarrow CCR$	TMP3 ⇔ D	D⇔D	$X \Leftrightarrow D$	$Y \Leftrightarrow D$	$SP \Leftrightarrow D$	
5	$00:A \Rightarrow X$ $X_L \Rightarrow A$	$00:B \Rightarrow X$ $X_L \Rightarrow B$	\$00:CCR ⇒ X X <sub>L</sub> ⇒ CCR	TMP3 ⇔ X	$D \Leftrightarrow X$	$X \Leftrightarrow X$	$Y \Leftrightarrow X$	$SP \Leftrightarrow X$	
6	$00:A \Rightarrow Y$ $Y_L \Rightarrow A$	$00:B \Rightarrow Y$ $Y_L \Rightarrow B$	$00:CCR \Rightarrow Y$ $Y_L \Rightarrow CCR$	TMP3 ⇔ Y	$D \Leftrightarrow Y$	$X \Leftrightarrow Y$	$Y \Leftrightarrow Y$	$SP \Leftrightarrow Y$	
7	\$00:A ⇒ SP SP <sub>L</sub> ⇒ A	$O:B \Rightarrow SP$ $SP_L \Rightarrow B$	$OD:CCR \Rightarrow SP$ $SP_L \Rightarrow CCR$	$TMP3 \Leftrightarrow SP$	$D \Leftrightarrow SP$	$X \Leftrightarrow SP$	$Y \Leftrightarrow SP$	$SP \Leftrightarrow SP$	

### Table A-5. Transfer and Exchange Postbyte Encoding

TMP2 and TMP3 registers are for factory use only.



00 A	10 A	20 A	30 A	40 A	50 A	60 A	70 A	80 A	90 A	Ao A	Bo A
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
01 B	11 B	21 B	31 B	41 B	51 B	61 B	71 B	81 B	91 B	A1 B	B1 B
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
02	12	22	32	42	52	62	72	82	92	A2	82
_	_	_	_	_	_	_	_	_	_	_	_
03	13	23	33	43	53	63	73	83	93	A3	Ba
_	_	_	_	_	_	_	_	_	_	_	
04 D	14 D	24 D	34 D	44 D	54 D	64 D	74 D	84 D	94 D	A4 D	B4 D
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
05 X	15 X	25 X	35 X	45 X	55 X	65 X	75 X	85 X	95 X	A5 X	B5 X
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
06 Y	16 Y	26 Y	36 Y	46 Y	56 Y	66 Y	76 Y	86 Y	96 Y	A6 Y	B6 Y
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
07 SP	17 SP		37 SP	47 SP	57 SP	67 SP	77 SP	87 SP	97 SP	A7 SP	B7 SP
DBEQ	DBEQ	DBNE	DBNE	TBEQ	TBEQ	TBNE	TBNE	IBEQ	IBEQ	IBNE	IBNE
(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)

### Table A-6. Loop Primitive Postbyte Encoding (lb)



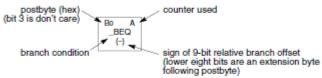


Table A-7. Branch/Complementary	Branch
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	Br	anch		Complementary Branch					
Test	Mnemonic	Opcode	Boolean	Test	Mnemonic	Opcode	Comment		
r>m	BGT	2E	$Z + (N \oplus V) = 0$	r≤m	BLE	2F	Signed		
r≥m	BGE	2C	N ⊕ V = 0	r <m< td=""><td>BLT</td><td>2D</td><td>Signed</td></m<>	BLT	2D	Signed		
r=m	BEQ	27	Z = 1	r≠m	BNE	26	Signed		
r≤m	BLE	2F	Z + (N ⊕ V) = 1	r>m	BGT	2E	Signed		
r <m< td=""><td>BLT</td><td>2D</td><td>N ⊕ V = 1</td><td>r≥m</td><td>BGE</td><td>2C</td><td>Signed</td></m<>	BLT	2D	N ⊕ V = 1	r≥m	BGE	2C	Signed		
r>m	BHI	22	C + Z = 0	r≤m	BLS	23	Unsigned		
r≥m	BHS/BCC	24	C = 0	r <m< td=""><td>BLO/BCS</td><td>25</td><td>Unsigned</td></m<>	BLO/BCS	25	Unsigned		
r=m	BEQ	27	Z = 1	r≠m	BNE	26	Unsigned		
r≤m	BLS	23	C + Z = 1	r>m	BHI	22	Unsigned		
r <m< td=""><td>BLO/BCS</td><td>25</td><td>C = 1</td><td>r≥m</td><td>BHS/BCC</td><td>24</td><td>Unsigned</td></m<>	BLO/BCS	25	C = 1	r≥m	BHS/BCC	24	Unsigned		
Carry	BCS	25	C = 1	No Carry	BCC	24	Simple		
Negative	BMI	2B	N = 1	Plus	BPL	2A	Simple		
Overflow	BVS	29	V = 1	No Overflow	BVC	28	Simple		
r=0	BEQ	27	Z = 1	r≠0	BNE	26	Simple		
Always	BRA	20	_	Never	BRN	21	Unconditional		

For 16-bit offset long branches precede opcode with a \$18 page prebyte.