Lecture 4

January 25, 2012

Addressing Modes

- MC9S12 Addressing Modes
  - Inherent, Extended, Direct, Immediate, Indexed and Relative Modes
  - Summary of MCS12 Addressing Modes
  - Using X and Y registers as pointers
  - How to tell which branch instruction to use
- Instruction Coding and Execution
  - How to hand assemble a program
  - Number of cycles and time taken to execute a program

The MC9S12 has 6 addressing modes

Most of the MC9S12's instructions access data in memory
There are several ways for the MC9S12 to determine which address to access

Effective Address:

Memory address used by instruction (all modes except INH)

ADDRESSING MODE:

How the MC9S12 calculates the effective address

MC9S12 ADDRESSING MODES:

INH	**Inherent**
IMM	**Immediate**
DIR	**Direct**
EXT	**Extended**
REL	**Relative (used only with branch instructions)**
IDX	**Indexed (won't study indirect indexed mode)**

The *Inherent* (INH) addressing mode

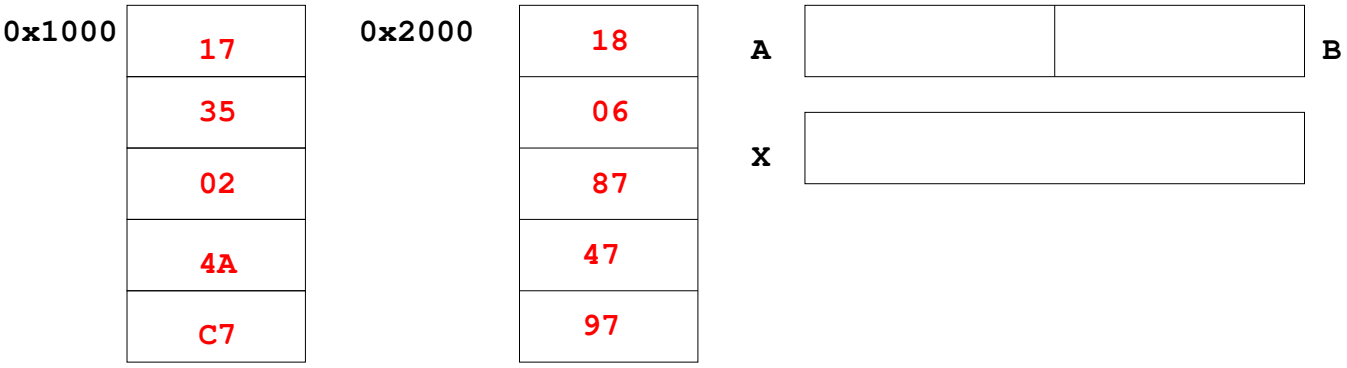
Inherent (INH) Addressing Mode

Instructions which work only with registers inside ALU

```
ABA       ; Add B to A    (A) + (B) -> A
  18 06

CLRA      ; Clear A       0 -> A
  87

ASRA      ; Arithmetic Shift Right A
  47

TSTA      ; Test A        (A) - 0x00    Set CCR
  97
```

The HC12 does not access memory

There is no effective address



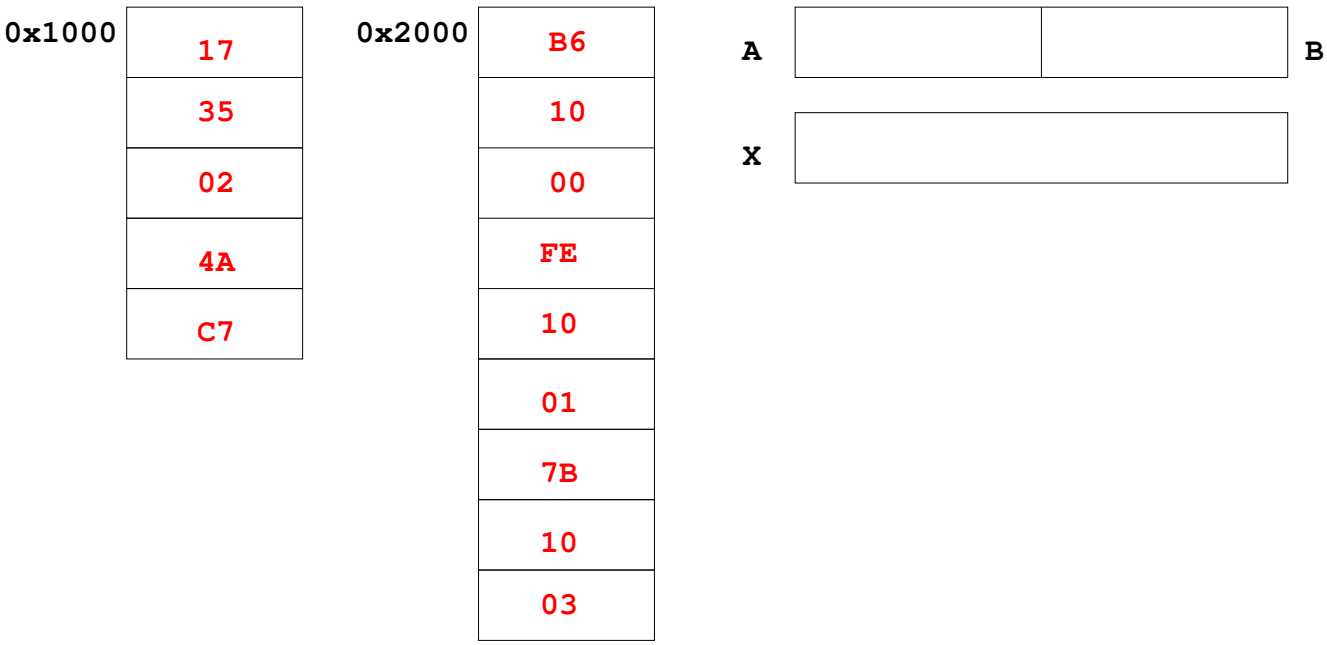
The *Extended* (EXT) addressing mode

Extended (EXT) Addressing Mode

Instructions which give the 16–bit address to be accessed

```
LDAA  $1000      ; ($1000) -> A
  B6 10 00       Effective Address:  $1000

LDX   $2001      ; ($2001:$1002) -> X
  FE 10 01       Effective Address:  $1001

STAB  $2003      ; (B) -> $1003
  7B 10 03       Effective Address:  $1003
```

Effective address is specified by the two bytes following op code



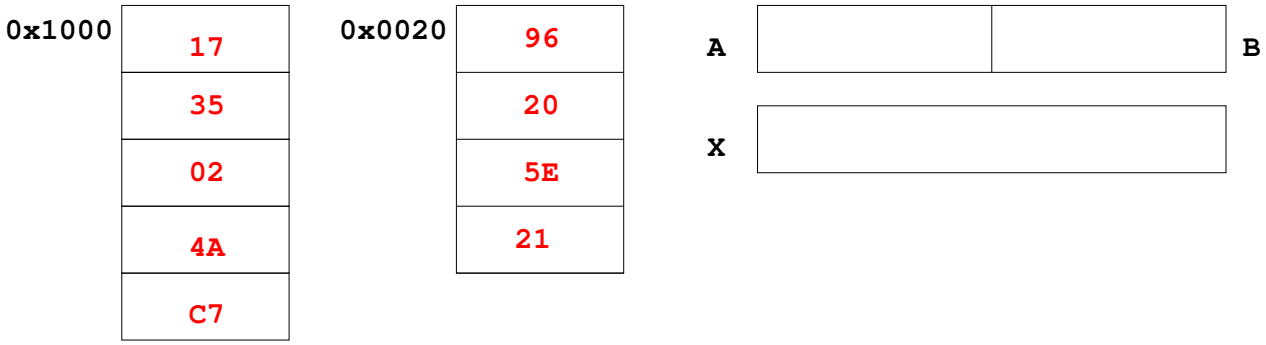
The *Direct* (DIR) addressing mode

Direct (DIR) Addressing Mode

Instructions which give 8 LSB of address (8 MSB all 0)

```
LDAA $20        ; ($0020) -> A
  96 20          Effective Address:  $0020

STX  $21        ; (X) -> $0021:$0022
  5E 21          Effective Address:  $0021
```

8 LSB of effective address is specified by byte following op code



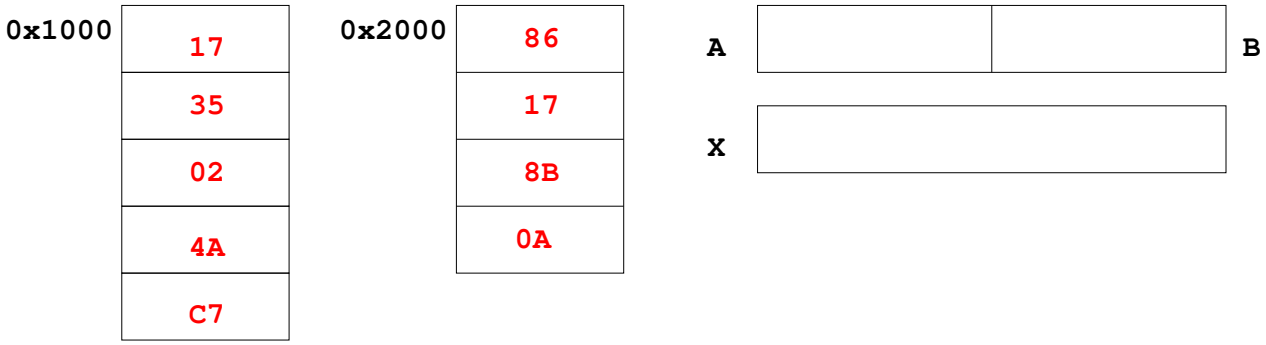
The *Immediate* (IMM) addressing mode

Immediate (IMM) Addressing Mode

Value to be used is part of instruction

```
LDAA  #$17      ; $17 -> A
  86 17           Effective Address:  PC + 1

ADDA  #10       ; (A) + $0A -> A
  8B 0A           Effective Address:  PC + 1
```

Effective address is the address following the op code



The *Indexed* (IDX, IDX1, IDX2) addressing mode

Indexed (IDX) Addressing Mode

Effective address is obtained from X or Y register (or SP or PC)

Simple Forms

```
LDAA  0,X      ; Use (X) as address to get value to load into A
  A6 00         Effective address:  contents of X

ADDA  5,Y      ; Use (Y) + 5 as address to get value to add to r
  AB 45         Effective address:  contents of Y + 5


STAA  B,Y      ; Use (Y) + (B) as address to store contents of A into
  AB 45         Effective address:  contents of Y + contents of B
```

More Complicated Forms

```
INC  2,X-      ; Post-decrement Indexed
               ; Increment the number at address (X),
               ; then subtract 2 from X
  62 3E         Effective address:  contents of X


INC  4,+X      ; Pre-increment Indexed
               ; Add 4 to X
               ; then increment the number at address (X)
  62 23         Effective address:  contents of X + 4
```

X		EFF ADDR	
Y		EFF ADDR	

Table 3-1. M68HC12 Addressing Mode Summary

Addressing Mode	Source Format	Abbreviation	Description
Inherent	**INST** (no externally supplied operands)	INH	Operands (if any) are in CPU registers
Immediate	**INST #***opr8i* or **INST #***opr16i*	IMM	Operand is included in instruction stream 8- or 16-bit size implied by context
Direct	**INST** *opr8a*	DIR	Operand is the lower 8 bits of an address in the range $0000–$00FF
Extended	**INST** *opr16a*	EXT	Operand is a 16-bit address
Relative	**INST** *rel8* or **INST** *rel16*	REL	An 8-bit or 16-bit relative offset from the current pc is supplied in the instruction
Indexed (5-bit offset)	**INST** *oprx5*,*xysp*	IDX	5-bit signed constant offset from X, Y, SP, or PC
Indexed (pre-decrement)	**INST** *oprx3*,–*xys*	IDX	Auto pre-decrement x, y, or sp by 1 ~ 8
Indexed (pre-increment)	**INST** *oprx3*,+*xys*	IDX	Auto pre-increment x, y, or sp by 1 ~ 8
Indexed (post-decrement)	**INST** *oprx3*,*xys*–	IDX	Auto post-decrement x, y, or sp by 1 ~ 8
Indexed (post-increment)	**INST** *oprx3*,*xys*+	IDX	Auto post-increment x, y, or sp by 1 ~ 8
Indexed (accumulator offset)	**INST** *abd*,*xysp*	IDX	Indexed with 8-bit (A or B) or 16-bit (D) accumulator offset from X, Y, SP, or PC
Indexed (9-bit offset)	**INST** *oprx9*,*xysp*	IDX1	9-bit signed constant offset from X, Y, SP, or PC (lower 8 bits of offset in one extension byte)
Indexed (16-bit offset)	**INST** *oprx16*,*xysp*	IDX2	16-bit constant offset from X, Y, SP, or PC (16-bit offset in two extension bytes)
Indexed-Indirect (16-bit offset)	**INST [***oprx16*,*xysp***]**	[IDX2]	Pointer to operand is found at... 16-bit constant offset from X, Y, SP, or PC (16-bit offset in two extension bytes)
Indexed-Indirect (D accumulator offset)	**INST [D,***xysp***]**	[D,IDX]	Pointer to operand is found at... X, Y, SP, or PC plus the value in D

Different types of indexed addressing modes
(Note: We will not discuss indirect indexed mode)

INDEXED ADDRESSING MODES

(Does not include indirect modes)

	Example	Effective Address	Offset	Value in X After Done	Registers To Use
Constant Offset	LDAA n,X	(X)+n	0 to FFFF	(X)	X, Y, SP, PC
Constant Offset	LDAA −n,X	(X)−n	0 to FFFF	(X)	X, Y, SP, PC
Postincrement	LDAA n,X+	(X)	1 to 8	(X)+n	X, Y, SP
Preincrement	LDAA n,+X	(X)+n	1 to 8	(X)+n	X, Y, SP
Postdecrement	LDAA n,X−	(X)	1 to 8	(X)−n	X, Y, SP
Predecrement	LDAA n,−X	(X)−n	1 to 8	(X)−n	X, Y, SP

ACC Offset	LDAA A,X
	LDAA B,X
	LDAA D,X
		(X)+(A)
		(X)+(B)
		(X)+(D)
			0 to FF
			0 to FF
			0 to FFFF
				(X)	X, Y, SP, PC

The data books list three different types of indexed modes:

- Table 3.2 of the **S12CPUV2 Reference Manual** shows details
- **IDX**: One byte used to specify address
  - Called the postbyte
  - Tells which register to use
  - Tells whether to use autoincrement or autodecrement
  - Tells offset to use
- **IDX1**: Two bytes used to specify address
  - First byte called the postbyte
  - Second byte called the extension
  - Postbyte tells which register to use, and sign of offset
  - Extension tells size of offset
- **IDX2**: Three bytes used to specify address
  - First byte called the postbyte
  - Next two bytes called the extension
  - Postbyte tells which register to use
  - Extension tells size of offset

Table 3-2. Summary of Indexed Operations

Postbyte Code (xb)	Source Code Syntax	Comments rr; 00 = X, 01 = Y, 10 = SP, 11 = PC
rr0nnnnn	,r n,r –n,r	**5-bit constant offset** n = –16 to +15 r can specify X, Y, SP, or PC
111rr0zs	n,r –n,r	**Constant offset** (9- or 16-bit signed) z- 0 = 9-bit with sign in LSB of postbyte(s) –256 ≤ n ≤ 255 1 = 16-bit –32,768 ≤ n ≤ 65,535 if z = s = 1, 16-bit offset indexed-indirect (see below) r can specify X, Y, SP, or PC
111rr011	[n,r]	**16-bit offset indexed-indirect** rr can specify X, Y, SP, or PC –32,768 ≤ n ≤ 65,535
rr1pnnnn	n,–r n,+r n,r– n,r+	**Auto predecrement**, **preincrement**, **postdecrement**, or **postincrement**; p = pre-(0) or post-(1), n = –8 to –1, +1 to +8 r can specify X, Y, or SP (PC not a valid choice) +8 = 0111 … +1 = 0000 –1 = 1111 … –8 = 1000
111rr1aa	A,r B,r D,r	**Accumulator offset** (unsigned 8-bit or 16-bit) aa-00 = A 01 = B 10 = D (16-bit) 11 = see accumulator D offset indexed-indirect r can specify X, Y, SP, or PC
111rr111	[D,r]	**Accumulator D offset indexed-indirect** r can specify X, Y, SP, or PC

Indexed addressing mode instructions use a postbyte to specify index registers (X and Y), stack pointer (SP), or program counter (PC) as the base index register and to further classify the way the effective address is formed. A special group of instructions cause this calculated effective address to be loaded into an index register for further calculations:

- Load stack pointer with effective address (LEAS)
- Load X with effective address (LEAX)
- Load Y with effective address (LEAY)

The *Relative* (REL) addressing mode

Relative (REL) Addressing Mode

The relative addressing mode is used only in branch and long branch instructions.

Branch instruction: One byte following op code specifies how far to branch

Treat the offset as a signed number; add the offset to the address following the current instruction to get the address of the instruction to branch to

```
BRA    20 35          PC + 2 + 0035 -> PC

BRA    20 C7          PC + 2 + FFC7 -> PC
                      PC + 2 -  0039   -> PC
```

Long branch instruction: Two bytes following op code specifies how far to branch

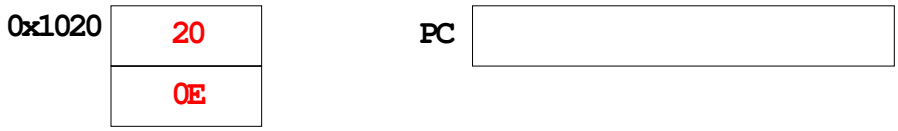
Treat the offset as an usigned number; add the offset to the address following the current instruction to get the address of the instruction to branch to

```
LBEQ   18 27 02 1A    If Z == 1 then PC + 4 + 021A -> PC
                      If Z == 0 then PC + 4 -> PC
```

When writing assembly language program, you don't have to calculate offset

You indicate what address you want to go to, and the assembler calculates the offset

```
$1020          BRA     $1030    ; Branch to instruction at address $1030
```



Summary of MC9S12 addressing modes

ADDRESSING MODES

Name	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 Indexed
IDX1
IDX2
	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 0E CF	PC + 2 + Offset PC + 4 + Offset

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 => X
```

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

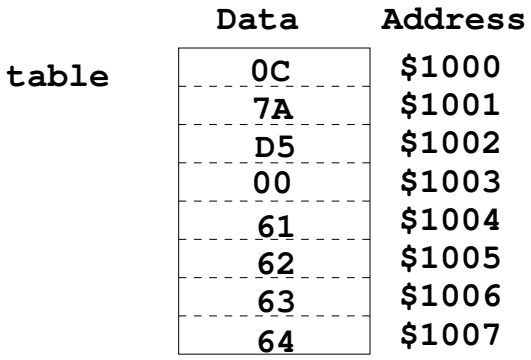
```
ldx     table     ;  First two bytes of table => X
```

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

```
ldaa    0,x
inx
```

or

```
ldaa    1,x+
```




```
        org   $1000
table:  dc.b  12,122,-43,0
        dc.b  'a'
        dc.b  'b'
        dc.b  'c'
        dc.b  'd'
```

Which branch instruction should you use?

Branch if A > B

Is 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., `ldab 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., `ldab #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 addrss of the next instruction.)

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

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

Source Form	Operation	Addr. Mode	Machine Coding (hex)	Access Detail HCS12	Access Detail M68HC12	S X H I	N Z V C
LBGT *rel16*	Long Branch if Greater Than (if Z + (N ⊕ V) = 0) (signed)	REL	18 2E qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBHI *rel16*	Long Branch if Higher (if C + Z = 0) (unsigned)	REL	18 22 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBHS *rel16*	Long Branch if Higher or Same (if C = 0) (unsigned) same function as LBCC	REL	18 24 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBLE *rel16*	Long Branch if Less Than or Equal (if Z + (N ⊕ V) = 1) (signed)	REL	18 2F qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBLO *rel16*	Long Branch if Lower (if C = 1) (unsigned) *same function as LBCS*	REL	18 25 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBLS *rel16*	Long Branch if Lower or Same (if C + Z = 1) (unsigned)	REL	18 23 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBLT *rel16*	Long Branch if Less Than (if N ⊕ V = 1) (signed)	REL	18 2D qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBMI *rel16*	Long Branch if Minus (if N = 1)	REL	18 2B qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBNE *rel16*	Long Branch if Not Equal (if Z = 0)	REL	18 26 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBPL *rel16*	Long Branch if Plus (if N = 0)	REL	18 2A qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBRA *rel16*	Long Branch Always (if 1=1)	REL	18 20 qq rr	OPPP	OPPP	----	----
LBRN *rel16*	Long Branch Never (if 1 = 0)	REL	18 21 qq rr	OPO	OPO	----	----
LBVC *rel16*	Long Branch if Overflow Bit Clear (if V=0)	REL	18 28 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----
LBVS *rel16*	Long Branch if Overflow Bit Set (if V = 1)	REL	18 29 qq rr	OPPP/OPO[1]	OPPP/OPO[1]	----	----

LDAA #*opr8i*
LDAA *opr8a*
LDAA *opr16a*
LDAA *oprx0_xysp*
LDAA *oprx9,xysp*
LDAA *oprx16,xysp*
LDAA [D,*xysp*]
LDAA [*oprx16,xysp*]
	(M) ⇒ A
	Load Accumulator A
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			86 ii
			96 dd
			B6 hh ll
			A6 xb
			A6 xb ff
			A6 xb ee ff
			A6 xb
			A6 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					P
					rfP
					rOP
					rfP
					rPO
					frPP
					fIfrfP
					fIPrfP
						----	Δ Δ 0 –

LDAB #*opr8i*
LDAB *opr8a*
LDAB *opr16a*
LDAB *oprx0_xysp*
LDAB *oprx9,xysp*
LDAB *oprx16,xysp*
LDAB [D,*xysp*]
LDAB [*oprx16,xysp*]
	(M) ⇒ B
	Load Accumulator B
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			C6 ii
			D6 dd
			F6 hh ll
			E6 xb
			E6 xb ff
			E6 xb ee ff
			E6 xb
			E6 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					P
					rfP
					rOP
					rfP
					rPO
					frPP
					fIfrfP
					fIPrfP
						----	Δ Δ 0 –

LDD #*opr16i*
LDD *opr8a*
LDD *opr16a*
LDD *oprx0_xysp*
LDD *oprx9,xysp*
LDD *oprx16,xysp*
LDD [D,*xysp*]
LDD [*oprx16,xysp*]
	(M:M+1) ⇒ A:B
	Load Double Accumulator D (A:B)
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			CC jj kk
			DC dd
			FC hh ll
			EC xb
			EC xb ff
			EC xb ee ff
			EC xb
			EC xb ee ff
				PO
				RPf
				RPO
				RPf
				RPO
				fRPP
				fIfRPf
				fIPRPf
					OP
					RfP
					ROP
					RfP
					RPO
					fRPP
					fIfRfP
					fIPRfP
						----	Δ Δ 0 –

Note 1. OPPP/OPO indicates this instruction takes four cycles to refill the instruction queue if the branch is taken and three cycles if the branch is not taken.

LDS #*opr16i*
LDS *opr8a*
LDS *opr16a*
LDS *oprx0_xysp*
LDS *oprx9,xysp*
LDS *oprx16,xysp*
LDS [D,*xysp*]
LDS [*oprx16,xysp*]
	(M:M+1) ⇒ SP
	Load Stack Pointer
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			CF jj kk
			DF dd
			FF hh ll
			EF xb
			EF xb ff
			EF xb ee ff
			EF xb
			EF xb ee ff
				PO
				RPf
				RPO
				RPf
				RPO
				fRPP
				fIfRPf
				fIPRPf
					OP
					RfP
					ROP
					RfP
					RPO
					fRPP
					fIfRfP
					fIPRfP
						----	Δ Δ 0 –

LDX #*opr16i*
LDX *opr8a*
LDX *opr16a*
LDX *oprx0_xysp*
LDX *oprx9,xysp*
LDX *oprx16,xysp*
LDX [D,*xysp*]
LDX [*oprx16,xysp*]
	(M:M+1) ⇒ X
	Load Index Register X
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			CE jj kk
			DE dd
			FE hh ll
			EE xb
			EE xb ff
			EE xb ee ff
			EE xb
			EE xb ee ff
				PO
				RPf
				RPO
				RPf
				RPO
				fRPP
				fIfRPf
				fIPRPf
					OP
					RfP
					ROP
					RfP
					RPO
					fRPP
					fIfRfP
					fIPRfP
						----	Δ Δ 0 –

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

Source Form	Operation	Addr. Mode	Machine Coding (hex)	Access Detail HCS12	Access Detail M68HC12	S X H I	N Z V C
BLS *rel8*	Branch if Lower or Same (if C + Z = 1) (unsigned)	REL	23 rr	PPP/P[1]	PPP/P[1]	----	----
BLT *rel8*	Branch if Less Than (if N ⊕ V = 1) (signed)	REL	2D rr	PPP/P[1]	PPP/P[1]	----	----
BMI *rel8*	Branch if Minus (if N = 1)	REL	2B rr	PPP/P[1]	PPP/P[1]	----	----
BNE *rel8*	Branch if Not Equal (if Z = 0)	REL	26 rr	PPP/P[1]	PPP/P[1]	----	----
BPL *rel8*	Branch if Plus (if N = 0)	REL	2A rr	PPP/P[1]	PPP/P[1]	----	----
BRA *rel8*	Branch Always (if 1 = 1)	REL	20 rr	PPP	PPP	----	----
BRCLR *opr8a, msk8, rel8* BRCLR *opr16a, msk8, rel8* BRCLR *oprx0_xysp, msk8, rel8* BRCLR *oprx9,xysp, msk8, rel8* BRCLR *oprx16,xysp, msk8, rel8*	Branch if (M) • (mm) = 0 (if All Selected Bit(s) Clear)	DIR EXT IDX IDX1 IDX2	4F dd mm rr 1F hh ll mm rr 0F xb mm rr 0F xb ff mm rr 0F xb ee ff mm rr	rPPP rfPPP rPPP rfPPP PrfPPP	rPPP rfPPP rPPP rffPPP frPffPPP	----	----
BRN *rel8*	Branch Never (if 1 = 0)	REL	21 rr	P	P	----	----
BRSET *opr8, msk8, rel8* BRSET *opr16a, msk8, rel8* BRSET *oprx0_xysp, msk8, rel8* BRSET *oprx9,xysp, msk8, rel8* BRSET *oprx16,xysp, msk8, rel8*	Branch if ($\overline{M}$) • (mm) = 0 (if All Selected Bit(s) Set)	DIR EXT IDX IDX1 IDX2	4E dd mm rr 1E hh ll mm rr 0E xb mm rr 0E xb ff mm rr 0E xb ee ff mm rr	rPPP rfPPP rPPP rfPPP PrfPPP	rPPP rfPPP rPPP rffPPP frPffPPP	----	----
BSET *opr8, msk8* BSET *opr16a, msk8* BSET *oprx0_xysp, msk8* BSET *oprx9,xysp, msk8* BSET *oprx16,xysp, msk8*	(M) + (mm) ⇒ M Set Bit(s) in Memory	DIR EXT IDX IDX1 IDX2	4C dd mm 1C hh ll mm 0C xb mm 0C xb ff mm 0C xb ee ff mm	rPwO rPwP rPwO rPwP frPwPO	rPOw rPPw rPOw rPwP frPwOP	----	Δ Δ 0 –
BSR *rel8*	(SP) – 2 ⇒ SP; RTN_H:RTN_L ⇒ $M_{(SP)}$:$M_{(SP+1)}$ Subroutine address ⇒ PC Branch to Subroutine	REL	07 rr	SPPP	PPPS	----	----
BVC *rel8*	Branch if Overflow Bit Clear (if V = 0)	REL	28 rr	PPP/P[1]	PPP/P[1]	----	----
BVS *rel8*	Branch if Overflow Bit Set (if V = 1)	REL	29 rr	PPP/P[1]	PPP/P[1]	----	----
CALL *opr16a, page* CALL *oprx0_xysp, page* CALL *oprx9,xysp, page* CALL *oprx16,xysp, page* CALL [D,*xysp*] CALL [*oprx16, xysp*]	(SP) – 2 ⇒ SP; RTN_H:RTN_L ⇒ $M_{(SP)}$:$M_{(SP+1)}$ (SP) – 1 ⇒ SP; (PPG) ⇒ $M_{(SP)}$; 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,IDX] [IDX2]	4A hh ll pg 4B xb pg 4B xb ff pg 4B xb ee ff pg 4B xb 4B xb ee ff	gnSsPPP gnSsPPP gnSsPPP fgnSsPPP fIignSsPPP fIignSsPPP	gnfSsPPP gnfSsPPP gnfSsPPP fgnfSsPPP fIignSsPPP fIignSsPPP	----	----
CBA	(A) – (B) Compare 8-Bit Accumulators	INH	18 17	OO	OO	----	Δ Δ Δ Δ
CLC	0 ⇒ C *Translates to* ANDCC #$FE	IMM	10 FE	P	P	----	---0
CLI	0 ⇒ I *Translates to* ANDCC #$EF (enables I-bit interrupts)	IMM	10 EF	P	P	---0	----
CLR *opr16a* CLR *oprx0_xysp* CLR *oprx9,xysp* CLR *oprx16,xysp* CLR [D,*xysp*] CLR [*oprx16,xysp*] CLRA CLRB	0 ⇒ M Clear Memory Location 0 ⇒ A Clear Accumulator A 0 ⇒ B Clear Accumulator B	EXT IDX IDX1 IDX2 [D,IDX] [IDX2] INH INH	79 hh ll 69 xb 69 xb ff 69 xb ee ff 69 xb 69 xb ee ff 87 C7	PwO Pw PwO PwP PIfw PIPw O O	wOP Pw PwO PwP PIfPw PIPPw O O	----	0 1 0 0
CLV	0 ⇒ V *Translates to* ANDCC #$FD	IMM	10 FD	P	P	----	--0–

Note 1. PPP/P indicates this instruction takes three cycles to refill the instruction queue if the branch is taken and one program fetch cycle if the branch is not taken.

CMPA #*opr8i*
CMPA *opr8a*
CMPA *opr16a*
CMPA *oprx0_xysp*
CMPA *oprx9,xysp*
CMPA *oprx16,xysp*
CMPA [D,*xysp*]
CMPA [*oprx16,xysp*]
	(A) – (M)
	Compare Accumulator A with Memory
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			81 ii
			91 dd
			B1 hh ll
			A1 xb
			A1 xb ff
			A1 xb ee ff
			A1 xb
			A1 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					P
					rfP
					rOP
					rfP
					rPO
					frPP
					fIfrfP
					fIPrfP
						----	Δ Δ Δ Δ

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

Source Form	Operation	Addr. Mode	Machine Coding (hex)	Access Detail HCS12	Access Detail M68HC12	S X H I	N Z V C

CMPB #*oprl8i*
CMPB *opr8a*
CMPB *opr16a*
CMPB *oprx0_xysp*
CMPB *oprx9,xysp*
CMPB *oprx16,xysp*
CMPB [D,*xysp*]
CMPB [*oprx16,xysp*]
	(B) – (M)
	Compare Accumulator B with Memory
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			C1 ii
			D1 dd
			F1 hh ll
			E1 xb
			E1 xb ff
			E1 xb ee ff
			E1 xb
			E1 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					P
					rfP
					rOP
					rfP
					rPO
					frPP
					fIfrfP
					fIPrfP
						----	Δ Δ Δ Δ

COM *opr16a* COM *oprx0_xysp* COM *oprx9,xysp* COM *oprx16,xysp* COM [D,*xysp*] COM [*oprx16,xysp*] COMA COMB	($\overline{M}$) ⇒ M *equivalent to* $FF – (M) ⇒ M 1's Complement Memory Location ($\overline{A}$) ⇒ A Complement Accumulator A ($\overline{B}$) ⇒ B Complement Accumulator B	EXT IDX IDX1 IDX2 [D,IDX] [IDX2] INH INH	71 hh ll 61 xb 61 xb ff 61 xb ee ff 61 xb 61 xb ee ff 41 51	rPwO rPw rPwO frPwP fIfrPw fIPrPw O O	rOPw rPw rPOw frPPw fIfrPw fIPrPw O O	----	Δ Δ 0 1
CPD #*opr16i* CPD *opr8a* CPD *opr16a* CPD *oprx0_xysp* CPD *oprx9,xysp* CPD *oprx16,xysp* CPD [D,*xysp*] CPD [*oprx16,xysp*]	(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 ll AC xb AC xb ff AC xb ee ff AC xb AC xb ee ff	PO RPf RPO RPf RPO fRPP fIfRPf fIPRPf	OP RfP ROP RfP RPO fRPP fIfRfP fIPRfP	----	Δ Δ Δ Δ
CPS #*opr16i* CPS *opr8a* CPS *opr16a* CPS *oprx0_xysp* CPS *oprx9,xysp* CPS *oprx16,xysp* CPS [D,*xysp*] CPS [*oprx16,xysp*]	(SP) – (M:M+1) Compare SP to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	8F jj kk 9F dd BF hh ll AF xb AF xb ff AF xb ee ff AF xb AF xb ee ff	PO RPf RPO RPf RPO fRPP fIfRPf fIPRPf	OP RfP ROP RfP RPO fRPP fIfRfP fIPRfP	----	Δ Δ Δ Δ
CPX #*opr16i* CPX *opr8a* CPX *opr16a* CPX *oprx0_xysp* CPX *oprx9,xysp* CPX *oprx16,xysp* CPX [D,*xysp*] CPX [*oprx16,xysp*]	(X) – (M:M+1) Compare X to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	8E jj kk 9E dd BE hh ll AE xb AE xb ff AE xb ee ff AE xb AE xb ee ff	PO RPf RPO RPf RPO fRPP fIfRPf fIPRPf	OP RfP ROP RfP RPO fRPP fIfRfP fIPRfP	----	Δ Δ Δ Δ
CPY #*opr16i* CPY *opr8a* CPY *opr16a* CPY *oprx0_xysp* CPY *oprx9,xysp* CPY *oprx16,xysp* CPY [D,*xysp*] CPY [*oprx16,xysp*]	(Y) – (M:M+1) Compare Y to Memory (16-Bit)	IMM DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	8D jj kk 9D dd BD hh ll AD xb AD xb ff AD xb ee ff AD xb AD xb ee ff	PO RPf RPO RPf RPO fRPP fIfRPf fIPRPf	OP RfP ROP RfP RPO fRPP fIfRfP fIPRfP	----	Δ Δ Δ Δ
DAA	Adjust Sum to BCD Decimal Adjust Accumulator A	INH	18 07	OfO	OfO	----	Δ Δ ? Δ
DBEQ *abdxys, rel9*	(cntr) – 1⇒ cntr if (cntr) = 0, then Branch else Continue to next instruction Decrement Counter and Branch if = 0 (cntr = A, B, D, X, Y, or SP)	REL (9-bit)	04 lb rr	PPP (branch) PPO (no branch)	PPP	----	----
DBNE *abdxys, rel9*	(cntr) – 1 ⇒ cntr If (cntr) not = 0, then Branch; else Continue to next instruction Decrement Counter and Branch if ≠ 0 (cntr = A, B, D, X, Y, or SP)	REL (9-bit)	04 lb rr	PPP (branch) PPO (no branch)	PPP	----	----

DBNE Decrement and Branch if Not Equal to Zero DBNE

Operation

(counter) – 1 ⇒ counter
If (counter) not = 0, then (PC) + $0003 + rel ⇒ 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

S	X	H	I	N	Z	V	C
–	–	–	–	–	–	–	–

Code and CPU Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
DBNE *abdxysp*, *rel9*	REL (9-bit)	`04 lb rr`	PPP (branch) PPO (no branch)

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

NOTES:
1. 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.

Source Form	Operation	Address Mode	Machine Coding (Hex)	Access Detail	S X H I N Z V C
STY *opr8a* STY *opr16a* STY *oprx0_xysppc* STY *oprx9,xysppc* STY *oprx16,xysppc* STY [D,*xysppc*] STY [*oprx16,xysppc*]	Store Y $(Y_H:Y_L) \Rightarrow M:M+1$	DIR EXT IDX IDX1 IDX2 [D,IDX] [IDX2]	5D dd 7D hh ll 6D xb 6D xb ff 6D xb ee ff 6D xb 6D xb ee ff	PW PWO PW PWO PWP PIfW PIPW	– – – – Δ Δ 0 –

SUBA #*opr8i*
SUBA *opr8a*
SUBA *opr16a*
SUBA *oprx0_xysppc*
SUBA *oprx9,xysppc*
SUBA *oprx16,xysppc*
SUBA [D,*xysppc*]
SUBA [*oprx16,xysppc*]
	Subtract from A
	(A)–(M)⇒A
	or (A)–imm⇒A
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			80 ii
			90 dd
			B0 hh ll
			A0 xb
			A0 xb ff
			A0 xb ee ff
			A0 xb
			A0 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					– – – – Δ Δ Δ Δ

SUBB #*opr8i*
SUBB *opr8a*
SUBB *opr16a*
SUBB *oprx0_xysppc*
SUBB *oprx9,xysppc*
SUBB *oprx16,xysppc*
SUBB [D,*xysppc*]
SUBB [*oprx16,xysppc*]
	Subtract from B
	(B)–(M)⇒B
	or (B)–imm⇒B
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			C0 ii
			D0 dd
			F0 hh ll
			E0 xb
			E0 xb ff
			E0 xb ee ff
			E0 xb
			E0 xb ee ff
				P
				rPf
				rPO
				rPf
				rPO
				frPP
				fIfrPf
				fIPrPf
					– – – – Δ Δ Δ Δ

SUBD #*opr16i*
SUBD *opr8a*
SUBD *opr16a*
SUBD *oprx0_xysppc*
SUBD *oprx9,xysppc*
SUBD *oprx16,xysppc*
SUBD [D,*xysppc*]
SUBD [*oprx16,xysppc*]
	Subtract from D
	(A:B)–(M:M+1)⇒A:B
	or (A:B)–imm⇒A:B
		IMM
		DIR
		EXT
		IDX
		IDX1
		IDX2
		[D,IDX]
		[IDX2]
			83 jj kk
			93 dd
			B3 hh ll
			A3 xb
			A3 xb ff
			A3 xb ee ff
			A3 xb
			A3 xb ee ff
				PO
				RPf
				RPO
				RPf
				RPO
				fRPP
				fIfRPf
				fIPRPf
					– – – – Δ Δ Δ Δ

SWI	Software interrupt; (SP)–2⇒SP $RTN_H:RTN_L \Rightarrow M_{SP}:M_{SP+1}$ (SP)–2⇒SP; $(Y_H:Y_L) \Rightarrow M_{SP}:M_{SP+1}$ (SP)–2⇒SP; $(X_H:X_L) \Rightarrow M_{SP}:M_{SP+1}$ (SP)–2⇒SP; (B:A)⇒$M_{SP}:M_{SP+1}$ (SP)–1⇒SP; (CCR)⇒M_{SP};1⇒I (SWI vector)⇒PC	INH	3F	VSPSSPSsP*	– – – 1 – – – –
*The CPU also uses VSPSSPSsP for hardware interrupts and unimplemented opcode traps.					
TAB	Transfer A to B; (A)⇒B	INH	18 0E	OO	– – – – Δ Δ 0 –
TAP	Transfer A to CCR; (A)⇒CCR Assembled as TFR A, CCR	INH	B7 02	P	Δ ⇓ Δ Δ Δ Δ Δ Δ
TBA	Transfer B to A; (B)⇒A	INH	18 0F	OO	– – – – Δ Δ 0 –
TBEQ *abdxysp,rel9*	Test and branch if equal to 0 If (counter)=0, then (PC)+2+rel⇒PC	REL (9-bit)	04 lb rr	PPP (branch) PPO (no branch)	– – – – – – – –
TBL *oprx0_xysppc*	Table lookup and interpolate, 8-bit (M)+[(B)×((M+1)–(M))]⇒A	IDX	18 3D xb	ORfffP	– – – – Δ Δ – Δ
TBNE *abdxysp,rel9*	Test and branch if not equal to 0 If (counter)≠0, then (PC)+2+rel⇒PC	REL (9-bit)	04 lb rr	PPP (branch) PPO (no branch)	– – – – – – – –
TFR *abcdxysp,abcdxysp*	Transfer from register to register (r1)⇒r2r1 and r2 same size $00:(r1) \Rightarrow r2r1$=8-bit; r2=16-bit $(r1_L) \Rightarrow r2r1$=16-bit; r2=8-bit	INH	B7 eb	P	– – – – – – – – or Δ ⇓ Δ Δ Δ Δ Δ Δ
TPASame as TFR CCR ,A	Transfer CCR to A; (CCR)⇒A	INH	B7 20	P	– – – – – – – –

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 μs) 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 S12CPUV2 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 MC9S12 is doing during each of the different types of CPU cycles.

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

The program executes the `ldab #10` instruction once (which takes one cycle). It then goes through loop 10 times (which has two instructions, on 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 cycles = 50 $\times$ 41.7 ns/cycle = 2.08 μs

LDAB Load B LDAB

Operation

(M) ⇒ B
or
imm ⇒ B

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

CCR Effects

S	X	H	I	N	Z	V	C
–	–	–	–	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 Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
LDAB #*opr8i*	IMM	C6 ii	P
LDAB *opr8a*	DIR	D6 dd	rPf
LDAB *opr16a*	EXT	F6 hh ll	rPO
LDAB *oprx0_xysppc*	IDX	E6 xb	rPf
LDAB *oprx9,xysppc*	IDX1	E6 xb ff	rPO
LDAB *oprx16,xysppc*	IDX2	E6 xb ee ff	frPP
LDAB [D,*xysppc*]	[D,IDX]	E6 xb	fIfrPf
LDAB [*oprx16,xysppc*]	[IDX2]	E6 xb ee ff	fIPrPf