

APPENDIX A INSTRUCTION SET DETAILS

A.1 Introduction

This appendix contains complete detailed information for all M68HC11 instructions. The instructions are arranged in alphabetical order with the instruction mnemonic set in larger type for easy reference.

A.2 Nomenclature

The following nomenclature is used in the subsequent definitions.

A. Operators:

()	= Contents of register shown inside parentheses
←	= Is transferred to
↑	= Is pulled from stack
↓	= Is pushed onto stack
•	= Boolean AND
+	= Arithmetic addition symbol except where used as inclusive-OR symbol in boolean formula
⊕	= Exclusive OR
×	= Multiply
:	= Concatenation
−	= Arithmetic subtraction symbol or negation symbol (two's complement)

B. Registers in the MPU

ACCA	= Accumulator A
ACCB	= Accumulator B
ACCX	= Accumulator ACCA or ACCB
ACCD	= Double accumulator — Accumulator A concatenated with accumulator B where A is the most significant byte
CCR	= Condition code register
IX	= Index register X, 16 bits
IXH	= Index register X, high order 8 bits
IXL	= Index register X, low order 8 bits
PC	= Program counter, 16 bits
PCH	= Program counter, high order (most significant) 8 bits
PL	= Program counter, low order (least significant) 8 bits
SP	= Stack pointer, 16 bits
SPH	= Stack pointer, high order 8 bits
SPL	= Stack pointer, low order 8 bits

C. Memory and Addressing

M	= A memory location (one byte)
M+1	= The byte of memory at \$0001 plus the address of the memory location indicated by "M"

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- Rel = Relative offset (i.e., the two's complement number stored in the last byte of machine code corresponding to a branch instruction)
- (opr) = Operand
- (msk) = Mask used in bit manipulation instructions
- (rel) = Relative offset used in branch instructions
- D. Bits [7:0] of the Condition Code Register
- S = Stop disable, bit 7
- X = X interrupt mask, bit 6
- H = Half carry, bit 5
- I = I interrupt mask, bit 4
- N = Negative indicator, bit 3
- Z = Zero indicator, bit 2
- V = Two's complement overflow indicator, bit 1
- C = Carry/borrow, bit 0
- E. Status of individual bit before execution of an instruction
- An = Bit n of ACCA (n = 7, 6, 5... 0)
- Bn = Bit n of ACCB (n = 7, 6, 5... 0)
- Dn = Bit n of ACCD (n = 15, 14, 13... 0) where bits [15:8] refer to ACCA and bits [7:0] refer to ACCB
- IXn = Bit n of IX (n = 15, 14, 13... 0)
- IXHn = Bit n of IXH (n = 7, 6, 5... 0)
- IXLn = Bit n of IXL (n = 7, 6, 5... 0)
- IYn = Bit n of IY (n = 15, 14, 13... 0)
- IYHn = Bit n of IYH (n = 7, 6, 5... 0)
- IYLn = Bit n of IYL (n = 7, 6, 5... 0)
- Mn = Bit n of M (n = 7, 6, 5... 0)
- SPHn = Bit n of SPH (n = 7, 6, 5... 0)
- SPLn = Bit n of SPL (n = 7, 6, 5... 0)
- Xn = Bit n of X (n = 7, 6, 5... 0)
- F. Status of individual bit of result of execution of an instruction
- (i) For 8-bit results:
- Rn = Bit n of the result (n = 7, 6, 5... 0). This applies to instructions which provide a result contained in a single byte of memory or in an 8-bit register.
- (ii) For 16-bit results:
- RHn = Bit n of the most significant byte of the result (n = 7, 6, 5... 0)
- RLn = Bit n of the least significant byte of the result (n = 7, 6, 5... 0). This applies to instructions which provide a result contained in two consecutive bytes of memory or in a 16-bit register.
- Rn = Bit n of the result (n = 15, 14, 13... 0)
- G. Notation used in CCR activity summary figures
- = Bit not affected
- 0 = Bit forced to zero
- 1 = Bit forced to one
- Δ = Bit set or cleared according to results of operation

↓

= Bit may change from one to zero, remain zero, or remain one as a result of this operation, but cannot change from zero to one.

H. Notation used in cycle-by-cycle execution tables

—	= Irrelevant data
ii	= One byte of immediate data
jj	= High-order byte of 16-bit immediate data
kk	= Low-order byte of 16-bit immediate data
hh	= High-order byte of 16-bit extended address
ll	= Low-order byte of 16-bit extended address
dd	= Low-order eight bits of direct address \$0000–\$00FF (high byte assumed to be \$00)
mm	= 8-bit mask (set bits correspond to operand bits which will be affected)
ff	= 8-bit forward offset \$00 (0) to \$FF (255) (is added to index)
rr	= Signed relative offset \$80 (–128) to \$7F (+127) (offset relative to address following machine code offset byte)
OP	= Address of opcode byte
OP+n	= Address of n th location after opcode byte
SP	= Address pointed to by stack pointer value (at the start of an instruction)
SP+n	= Address of n th higher address past that pointed to by stack pointer
SP–n	= Address of n th lower address before that pointed to by stack pointer
Sub	=Address of called subroutine
Nxt op	= Opcode of next instruction
Rtn hi	= High-order byte of return address
Rtn lo	= Low-order byte of return address
Svc hi	= High-order byte of address for service routine
Svc lo	= Low-order byte of address for service routine
Vec hi	= High-order byte of interrupt vector
Vec lo	= Low-order byte of interrupt vector

A

ABA Add Accumulator B to Accumulator A ABA

Operation: $ACCA \leftarrow (ACCA) + (ACCB)$

Description: Adds the contents of accumulator B to the contents of accumulator A and places the result in accumulator A. Accumulator B is not changed. This instruction affects the H condition code bit so it is suitable for use in BCD arithmetic operations (see DAA instruction for additional information).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	Δ	—	Δ	Δ	Δ	Δ

H $A3 \cdot B3 + B3 \cdot R3 + R3 \cdot A3$

Set if there was a carry from bit 3; cleared otherwise.

N $R7$

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $A7 \cdot B7 \cdot \overline{R7} + \overline{A7} \cdot \overline{B7} \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $A7 \cdot B7 + B7 \cdot \overline{R7} + \overline{R7} \cdot A7$

Set if there was a carry from the MSB of the result; cleared otherwise.

Source Forms: ABA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ABA (INH)		
	Addr	Data	R/W
1	OP	1B	1
2	OP+1	—	1

ABX Add Accumulator B to Index Register X ABX

Operation: $IX \leftarrow (IX) + (ACCB)$

Description: Adds the 8-bit unsigned contents of accumulator B to the contents of index register X (IX) considering the possible carry out of the low-order byte of the index register X; places the result in index register X (IX). Accumulator B is not changed. There is no equivalent instruction to add accumulator A to an index register.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: ABX

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ABX (INH)		
	Addr	Data	R/W
1	OP	3A	1
2	OP+1	—	1
3	FFFF	—	1

A

ABY Add Accumulator B to Index Register Y ABY

Operation: $IY \leftarrow (IY) + (ACCB)$

Description: Adds the 8-bit unsigned contents of accumulator B to the contents of index register Y (IY) considering the possible carry out of the low-order byte of the index register Y; places the result in index register Y (IY). Accumulator B is not changed. There is no equivalent instruction to add accumulator A to an index register.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: ABY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ABY (INH)		
	Addr	Data	R/W
1	OP	1B	1
2	OP+1	3A	1
3	OP+2	—	1
4	FFFF	—	1

A

Operation: $ACCX \leftarrow (ACCX) + (M) + (C)$

Description: Adds the contents of the C bit to the sum of the contents of ACCX and M and places the result in ACCX. This instruction affects the H condition code bit so it is suitable for use in BCD arithmetic operations (see DAA instruction for additional information).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	Δ	—	Δ	Δ	Δ	Δ

H $X3 \cdot M3 + M3 \cdot R3 + R3 \cdot X3$

Set if there was a carry from bit 3; cleared otherwise.

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot M7 \cdot \overline{R7} + \overline{X7} \cdot \overline{M7} \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $X7 \cdot M7 + M7 \cdot \overline{R7} + \overline{R7} \cdot X7$

Set if there was a carry from the MSB of the result; cleared otherwise.

Source Forms: ADCA (opr); ADCB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ADCA(IMM)			ADCA(DIR)			ADCA(EXT)			ADCA(IND,X)			ADCA(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	89	1	OP	99	1	OP	B9	1	OP	A9	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A9	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	ADCB(IMM)			ADCB(DIR)			ADCB(EXT)			ADCB(IND,X)			ADCB(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C9	1	OP	D9	1	OP	F9	1	OP	E9	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E9	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

ADD

Add without Carry

ADD

Operation: ACCX \leftarrow (ACCX) + (M)

Description: Adds the contents of M to the contents of ACCX and places the result in ACCX. This instruction affects the H condition code bit so it is suitable for use in BCD arithmetic operations (see DAA instruction for additional information).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	Δ	—	Δ	Δ	Δ	Δ

H $X3 \cdot M3 + M3 \cdot R3 + R3 \cdot X3$

Set if there was a carry from bit 3; cleared otherwise.

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot M7 \cdot \overline{R7} + \overline{X7} \cdot \overline{M7} \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $X7 \cdot M7 + M7 \cdot \overline{R7} + \overline{R7} \cdot X7$

Set if there was a carry from the MSB of the result; cleared otherwise.

Source Forms: ADDA (opr); ADDB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ADDA(IMM)			ADDA(DIR)			ADDA(EXT)			ADDA(IND,X)			ADDA(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	BB	1	OP	9B	1	OP	BB	1	OP	AB	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	ADDB(IMM)			ADDB(DIR)			ADDB(EXT)			ADDB(IND,X)			ADDB(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	CB	1	OP	DB	1	OP	FB	1	OP	EB	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

ADDD

Add Double Accumulator

ADDD

Operation: $ACCD \leftarrow (ACCD) + (M : M + 1)$

Description: Adds the contents of M concatenated with M + 1 to the contents of ACCD and places the result in ACCD. Accumulator A corresponds to the high-order half of the 16-bit double accumulator D.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V $D15 \cdot M15 \cdot \overline{R15} + \overline{D15} \cdot \overline{M15} \cdot R15$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $D15 \cdot M15 + M15 \cdot \overline{R15} + \overline{R15} \cdot D15$

Set if there was a carry from the MSB of the result; cleared otherwise.

Source Forms: ADDD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ADDD (IMM)			ADDD (DIR)			ADDD (EXT)			ADDD (IND,X)			ADDD (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C3	1	OP	D3	1	OP	F3	1	OP	E3	1	OP	18	1
2	OP+1	jj	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E3	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	FFFF	—	1	00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5				FFFF	—	1	hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6							FFFF	—	1	FFFF	—	1	Y+ff+1	(Y+ff+1)	1
7													FFFF	—	1

A

AND

Logical AND

AND

Operation: $ACCX \leftarrow (ACCX) + (M)$

Description: Performs the logical AND between the contents of ACCX and the contents of M and places the result in ACCX. (Each bit of ACCX after the operation will be the logical AND of the corresponding bits of M and of ACCX before the operation.)

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

Source Forms: ANDA (opr); ANDB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ANDA(IMM)			ANDA(DIR)			ANDA(EXT)			ANDA(IND,X)			ANDA(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	84	1	OP	94	1	OP	B4	1	OP	A4	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	ANDB(IMM)			ANDB(DIR)			ANDB(EXT)			ANDB(IND,X)			ANDB(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C4	1	OP	D4	1	OP	F4	1	OP	E4	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

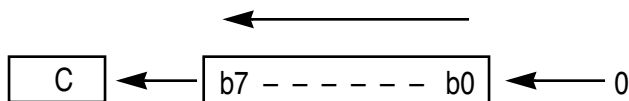
ASL

Arithmetic Shift Left

ASL

(Same as LSL)

Operation:



Description: Shifts all bits of the ACCX or M one place to the left. Bit 0 is loaded with a zero. The C bit in the CCR is loaded from the most significant bit of ACCX or M.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)

Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the shift).

C M7

Set if, before the shift, the MSB of ACCX or M was set; cleared otherwise.

Source Forms: ASLA; ASLB; ASL (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

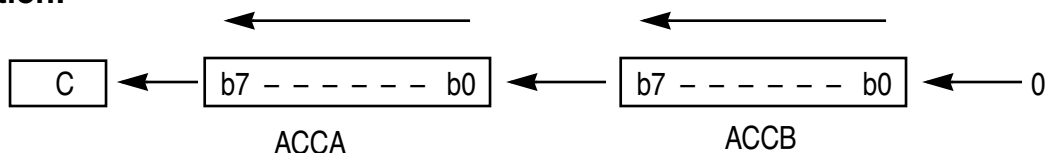
Cycle	ASLA (IMM)			ASLB (DIR)			ASL (EXT)			ASL (IND,X)			ASL (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	48	1	OP	58	1	OP	78	1	OP	68	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	68	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

A

ASLD Arithmetic Shift Left Double Accumulator ASLD

(Same as LSLD)

Operation:



Description: Shifts all bits of ACCD one place to the left. Bit 0 is loaded with a zero. The C bit in the CCR is loaded from the most significant bit of ACCD.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

A

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)
Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the shift).

C D15

Set if, before the shift, the MSB of ACCD was set; cleared otherwise.

Source Forms: ASLD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

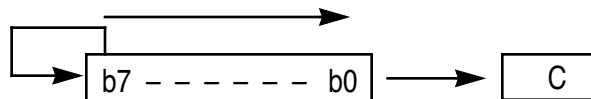
Cycle	ASLD (INH)		
	Addr	Data	R/W
1	OP	05	1
2	OP+1	—	1
3	FFFF	—	1

ASR

Arithmetic Shift Right

ASR

Operation:



Description: Shifts all bits of the ACCX or M one place to the right. Bit 7 is held constant. Bit 0 is loaded into the C bit of the CCR. This operation effectively divides a two's complement value by two without changing its sign. The carry bit can be used to round the result.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)

Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the shift).

C M0

Set if, before the shift, the LSB of ACCX or M was set; cleared otherwise.

Source Forms: ASRA; ASRB; ASR (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ASRA (IMM)			ASRB (DIR)			ASR (EXT)			ASR (IND,X)			ASR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	47	1	OP	57	1	OP	77	1	OP	67	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	68	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

A

BCC

Branch if Carry Clear

BCC

(Same as BHS)

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(C) = 0$

Description: Tests the state of the C bit in the CCR and causes a branch if C is clear. See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BCC (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BCC (INH)		
	Addr	Data	R/W
1	OP	24	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

Operation: $M \leftarrow (M) \cdot (\overline{PC + 2})$

$M \leftarrow (M) \cdot (\overline{PC + 3})$ (for IND,Y address mode only)

Description: Clear multiple bits in location M. The bit(s) to be cleared are specified by ones in the mask byte. All other bits in M are rewritten to their current state.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V 0

Cleared

Source Forms: BCLR (opr) (msk)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BCLR (DIR)			BCLR (IND,X)			BCLR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	15	1	OP	1D	1	OP	18	1
2	OP+1	dd	1	OP+1	ff	1	OP+1	1D	1
3	00dd	(00dd)	1	FFFF	—	1	OP+2	ff	1
4	OP+2	MM	1	X+ff	(X+ff)	1	FFFF	—	1
5	FFFF	—	1	OP+2	MM	1	(IY)+ff	(Y+ff)	1
6	00dd	result	0	FFFF	—	1	OP+3	mm	1
7				X+ff	result	0	FFFF	—	1
8							Y+ff	result	0

A

(Same as BLO)

Operation: $PC \leftarrow (PC) + \$0002 + \text{Rel}$ if (C) = 1**Description:** Tests the state of the C bit in the CCR and causes a branch if C is set. See BRA instruction for further details of the execution of the branch.**Condition Codes and Boolean Formulae:**

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BCS (rel)**Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:**

Cycle	BCS (REL)		
	Addr	Data	R/W
1	OP	25	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BEQ

Branch if Equal

BEQ

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(Z) = 1$

Description: Tests the state of the Z bit in the CCR and causes a branch if Z is set. See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BEQ (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BEQ (REL)		
	Addr	Data	R/W
1	OP	27	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

A

BGE Branch if Greater than or Equal to Zero BGE

Operation: $PC \leftarrow (PC) + \$0002 + \text{Rel}$ if $(N) \oplus (V) = 0$

i.e., if $(\text{ACCX}) \leq (M)$ (two's-complement signed numbers)

Description: If the BGE instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the two's complement number represented by ACCX was greater than or equal to the two's complement number represented by M.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BGE (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BGE (REL)		
	Addr	Data	R/W
1	OP	2C	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BGT

Branch if Greater than Zero

BGT

Operation: $PC \leftarrow (PC) + \$0002 + Rel$

if $(Z) + [(N) \oplus (V)] = 0$

i.e., if $(ACCX) > (M)$

(two's-complement signed numbers)

Description: If the BGT instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the two's complement number represented by ACCX was greater than the two's complement number represented by M.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BGT (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BGT (REL)		
	Addr	Data	R/W
1	OP	2E	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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



BHI

Branch if Higher

BHI

Operation: $PC \leftarrow (PC) + \$0002 + Rel$

if $(C) + (Z) = 0$

i.e., if $(ACCX) > (M)$

(unsigned binary numbers)

Description: If the BHI instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the unsigned binary number represented by ACCX was greater than unsigned binary number represented by M. Generally not useful after INC/DEC, LD/ST, TST/CLR/COM because these instructions do not affect the C bit in the CCR.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BHI (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BHI (REL)		
	Addr	Data	R/W
1	OP	22	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

(Same as BCC)

Operation: $PC \leftarrow (PC) + \$0002 + \text{Rel}$ if (C) = 0
 i.e., if $(\text{ACCX}) \geq (M)$ (unsigned binary numbers)

Description: If the BHS instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the unsigned binary number represented by ACCX was greater than or equal to the unsigned binary number represented by M. Generally not useful after INC/DEC, LD/ST, TST/CLR/COM because these instructions do not affect the C bit in the CCR.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BHS (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BHS (REL)		
	Addr	Data	R/W
1	OP	24	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

Operation: (ACCX)•(M)

Description: Performs the logical AND between the contents of ACCX and the contents of M and modifies the condition codes accordingly. Neither the contents of ACCX or M operands are affected. (Each bit of the result of the AND would be the logical AND of the corresponding bits of ACCX and M.)

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

Source Forms: BITA (opr); BITB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BITA(IMM)			BITA(DIR)			BITA(EXT)			BITA(IND,X)			BITA(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	85	1	OP	95	1	OP	B5	1	OP	A5	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	BITB(IMM)			BITB(DIR)			BITB(EXT)			BITB(IND,X)			BITB(IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C5	1	OP	D5	1	OP	F5	1	OP	E5	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EB	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

BLE Branch if Less than or Equal to Zero BLE

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(Z) + [(N) \oplus (V)] = 1$
 i.e., if $(ACCX) \leq (M)$ (two's complement signed numbers)

Description: If the BLE instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the two's complement signed number represented by ACCX was less than or equal to the two's complement signed number represented by M.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BLE (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BLE (REL)		
	Addr	Data	R/W
1	OP	2F	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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



(Same as BCS)

Operation: $PC \leftarrow (PC) + \$0002 + \text{Rel}$ if (C) = 1
 i.e., if (ACCX) < (M) (unsigned binary numbers)

Description: If the BLO instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the unsigned binary number represented by ACCX was less than the unsigned binary number represented by M. Generally not useful after INC/DEC, LD/ST, TST/CLR/COM because these instructions do not affect the C bit in the CCR.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BLO (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BLO (REL)		
	Addr	Data	R/W
1	OP	25	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BLS

Branch if Lower or Same

BLS

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(C) + (Z) = 1$
 i.e., if $(ACCX) \leq (M)$ (unsigned binary numbers)

Description: If the BLS instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the unsigned binary number represented by ACCX was less than or equal to the unsigned binary number represented by M. Generally not useful after INC/DEC, LD/ST, TST/CLR/COM because these instructions do not affect the C bit in the CCR.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BLS (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BLS (REL)		
	Addr	Data	R/W
1	OP	23	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

A

BLT

Branch if Less than Zero

BLT

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(N) \oplus (V) = 1$
 i.e., if $(ACCX) < (M)$ (two's complement signed numbers)

Description: If the BLT instruction is executed immediately after execution of any of the instructions, CBA, CMP(A, B, or D), CP(X or Y), SBA, SUB(A, B, or D), the branch will occur if and only if the two's-complement number represented by ACCX was less than the two's-complement number represented by M.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BLT (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BLT (REL)		
	Addr	Data	R/W
1	OP	2D	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BMI

Branch if Minus

BMI

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if (N) = 1

Description: Tests the state of the N bit in the CCR and causes a branch if N is set. See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BMI (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BMI (REL)		
	Addr	Data	R/W
1	OP	2B	1
2	OP+1	rr	1
3	FFFF	—	1

A

The following table is a summary of all branch instructions.

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

BNE

Branch if Not Equal to Zero

BNE

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(Z) = 0$

Description: Tests the state of the Z bit in the CCR and causes a branch if Z is clear. See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BLT (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	BNE (REL)		
	Addr	Data	R/W
1	OP	26	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BPL

Branch if Plus

BPL

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if (N) = 0

Description: Tests the state of the N bit in the CCR and causes a branch if N is clear.
See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BPL (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BPL (REL)		
	Addr	Data	R/W
1	OP	2A	1
2	OP+1	rr	1
3	FFFF	—	1

A

The following table is a summary of all branch instructions.

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

BRA

Branch Always

BRA

Operation: $PC \leftarrow (PC) + \$0002 + Rel$

Description: Unconditional branch to the address given by the foregoing formula, in which Rel is the relative offset stored as a two's-complement number in the second byte of machine code corresponding to the branch instruction.

The source program specifies the destination of any branch instruction by its absolute address, either as a numerical value or as a symbol or expression, that can be numerically evaluated by the assembler. The assembler obtains the relative address, Rel, from the absolute address and the current value of the location counter.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BRA (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BRA (REL)		
	Addr	Data	R/W
1	OP	20	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BRCLR

Branch if Bit(s) Clear

BRCLR

Operation: $PC \leftarrow (PC) + \$0004 + Rel$

if $(M) \cdot (PC + 2) = 0$

$PC \leftarrow (PC) + \$0005 + Rel$
mode only)

if $(M) \cdot (PC + 3) = 0$ (for IND,Y address

Description: Performs the logical AND of location M and the mask supplied with the instruction, then branches if the result is zero (only if all bits corresponding to ones in the mask byte are zeros in the tested byte).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BRCLR (opr) (msk) (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	BRCLR (DIR)			BRCLR (IND,X)			BRCLR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	13	1	OP	1F	1	OP	18	1
2	OP+1	dd	1	OP+1	ff	1	OP+1	1F	1
3	00dd	(00dd)	1	FFFF	—	1	OP+2	ff	1
4	OP+2	mm	1	X+ff	(X+ff)	1	FFFF	—	1
5	OP+3	rr	1	OP+2	mm	1	(IY)+ff	(Y+ff)	1
6	FFFF	—	1	OP+3	rr	1	OP+3	mm	1
7				FFFF	—	1	OP+4	rr	1
8							FFFF	—	1

BRN

Branch Never

BRN

Operation: $PC \leftarrow (PC) + \$0002$

Description: Never branches. In effect, this instruction can be considered as a two-byte NOP (no operation) requiring three cycles for execution. Its inclusion in the instruction set is to provide a complement for the BRA instruction. This instruction is useful during program debug to negate the effect of another branch instruction without disturbing the offset byte. Having a complement for BRA is also useful in compiler implementations.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BRN (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BRN (REL)		
	Addr	Data	R/W
1	OP	21	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BRSET

Branch if Bit(s) Set

BRSET

Operation: $PC \leftarrow (PC) + \$0004 + Rel$

if $(\overline{M}) \cdot (PC + 2) = 0$

$PC \leftarrow (PC) + \$0005 + Rel$
mode only)

if $(\overline{M}) \cdot (PC + 3) = 0$ (for IND,Y address

Description: Performs the logical AND of location M and the mask supplied with the instruction, then branches if the result is zero (only if all bits corresponding to ones in the mask byte are ones in the tested byte).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BRSET (opr) (msk) (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	BRSET (DIR)			BRSET (IND,X)			BRSET (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	12	1	OP	1E	1	OP	18	1
2	OP+1	dd	1	OP+1	ff	1	OP+1	1E	1
3	00dd	(00dd)	1	FFFF	—	1	OP+2	ff	1
4	OP+2	mm	1	X+ff	(X+ff)	1	FFFF	—	1
5	OP+3	rr	1	OP+2	mm	1	(IY)+ff	(Y+ff)	1
6	FFFF	—	1	OP+3	rr	1	OP+3	mm	1
7				FFFF	—	1	OP+4	rr	1
8							FFFF	—	1

BSET

Set Bit(s) in Memory

BSET

Operation: $M \leftarrow (M) + (PC + 2)$

$M \leftarrow (M) + (PC + 3)$ (for IND,Y address mode only)

Description: Set multiple bits in location M. The bit(s) to be set are specified by ones in the mask byte (last machine code byte of the instruction). All other bits in M are unaffected.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

Source Forms: BSET (opr) (msk)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BSET (DIR)			BSET (IND,X)			BSET (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	14	1	OP	1C	1	OP	18	1
2	OP+1	dd	1	OP+1	ff	1	OP+1	1C	1
3	00dd	(00dd)	1	FFFF	—	1	OP+2	ff	1
4	OP+2	mm	1	X+ff	(X+ff)	1	FFFF	—	1
5	FFFF	—	1	OP+2	mm	1	(IY)+ff	(Y+ff)	1
6	00dd	result	0	FFFF	—	1	OP+3	mm	1
7				X+ff	result	0	FFFF	—	1
8							Y+ff	result	0

A

BSR

Branch to Subroutine

BSR

Operation: $PC \leftarrow (PC) + \$0002$

$\Downarrow(PCL)$

$SP \leftarrow (SP) - \$0001$

$\Downarrow(PCH)$

$SP \leftarrow (SP) - \$0001$

$PC \leftarrow (PC) + Rel$

Advance PC to return address

Push low-order return onto stack

Push high-order return onto stack

Load start address of requested address

Description: The program counter is incremented by two (this will be the return address). The least significant byte of the contents of the program counter (low-order return address) is pushed onto the stack. The stack pointer is then decremented by one. The most significant byte of the contents of the program counter (high-order return address) is pushed onto the stack. The stack pointer is then decremented by one. A branch then occurs to the location specified by the branch offset.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BSR (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BSR (REL)		
	Addr	Data	R/ \bar{W}
1	OP	8D	1
2	OP+1	rr	1
3	FFFF	—	1
4	Sub	Nxt op	1
5	SP	Rtn lo	0
6	SP-1	Rtn hi	0

BVC

Branch if Overflow Clear

BVC

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(V) = 0$

Description: Tests the state of the V bit in the CCR and causes a branch if V is clear. Used after an operation on two's-complement binary values, this instruction will cause a branch if there was NO overflow. That is, branch if the two's-complement result was valid.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BVC (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	BVC (REL)		
	Addr	Data	R/W
1	OP	28	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

BVS

Branch if Overflow Set

BVS

Operation: $PC \leftarrow (PC) + \$0002 + Rel$ if $(V) = 1$

Description: Tests the state of the V bit in the CCR and causes a branch if V is set. Used after an operation on two's-complement binary values, this instruction will cause a branch if there was an overflow. That is, branch if the two's-complement result was invalid.

See BRA instruction for further details of the execution of the branch.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: BVS (rel)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	BVS (REL)		
	Addr	Data	R/W
1	OP	29	1
2	OP+1	rr	1
3	FFFF	—	1

The following table is a summary of all branch instructions.

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

Operation: (ACCA) – (ACCB)

Description: Compares the contents of ACCA to the contents of ACCB and sets the condition codes, which may be used for arithmetic and logical conditional branches. Both operands are unaffected.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $A7 \cdot \overline{B7} \cdot \overline{R7} + \overline{A7} \cdot B7 \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{A7} \cdot B7 + B7 \cdot R7 + R7 \cdot \overline{A7}$

Set if there was a borrow from the MSB of the result; cleared otherwise.

Source Forms: CBA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CBA (INH)		
	Addr	Data	R/W
1	OP	11	1
2	OP+1	—	1

CLC

Clear Carry

CLC

Operation: C bit \leftarrow 0

Description: Clears the C bit in the CCR.

CLC may be used to set up the C bit prior to a shift or rotate instruction involving the C bit.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	0

C 0
Cleared

Source Forms: CLC

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	CLC (INH)		
	Addr	Data	R/W
1	OP	0C	1
2	OP+1	—	1

Operation: I bit \leftarrow 0

Description: Clears the interrupt mask bit in the CCR. When the I bit is clear, interrupts are enabled. There is one E-clock cycle delay in the clearing mechanism for the I bit so that, if interrupts were previously disabled, the next instruction after a CLI will always be executed, even if there was an interrupt pending prior to execution of the CLI instruction.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	0	—	—	—	—

I 0
Cleared

Source Forms: CLI

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CLI (INH)		
	Addr	Data	R/W
1	OP	0E	1
2	OP+1	—	1

CLR

Clear

CLR

Operation: ACCX \leftarrow 0 or:

M \leftarrow 0

Description: The contents of ACCX or M are replaced with zeros.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	0	1	0	0

N 0
Cleared

Z 1
Set

V 0
Cleared

C 0
Cleared

Source Forms: CLRA; CLRB; CLR (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CLRA (IMM)			CLRB (DIR)			CLR (EXT)			CLR (IND,X)			CLR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	4F	1	OP	5F	1	OP	7F	1	OP	6F	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	6F	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	00	0	X+ff	00	0	FFFF	—	1
7													Y+ff	00	0

A

CLV Clear Two's Complement Overflow Bit CLV

Operation: V bit \leftarrow 0

Description: Clears the two's complement overflow bit in the CCR.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	0	—

V 0
Cleared

Source Forms: CLV

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	CLV (INH)		
	Addr	Data	R/W
1	OP	0A	1
2	OP+1	—	1

CMP

Compare

CMP

Operation: (ACCA) – (M)

Description: Compares the contents of ACCX to the contents of M and sets the condition codes, which may be used for arithmetic and logical conditional branching. Both operands are unaffected.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot \overline{M7} \cdot \overline{R7} + \overline{X7} \cdot M7 \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{X7} \cdot M7 + M7 \cdot R7 + R7 \cdot \overline{X7}$

Set if there was a borrow from the MSB of the result; cleared otherwise.

Source Forms: CMPA (opr); CMPB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CMPA(IMM)			CMPA (DIR)			CMPA (EXT)			CMPA (IND,X)			CMPA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	81	1	OP	91	1	OP	B1	1	OP	A1	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A1	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	CMPB (IMM)			CMPB (DIR)			CMPB (EXT)			CMPB (IND,X)			CMPB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C1	1	OP	D1	1	OP	F1	1	OP	E1	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E1	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

A

COM

Complement

COM

Operation: $ACCX \leftarrow (\overline{ACCX}) + \$FF - (ACCX)$ or: $M \leftarrow (\overline{M}) + \$FF - (M)$

Description: Replaces the contents of ACCX or M with its one's complement. (Each bit of the contents of ACCX or M is replaced with the complement of that bit.) To complement a value without affecting the C-bit, EXclusive-OR the value with \$FF.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	1

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

C 1
Set (For compatibility with M6800)

Source Forms: COMA; COMB; COM (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	COMA (INH)			COMB (INH)			COM (EXT)			COM (IND,X)			COM (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	43	1	OP	53	1	OP	73	1	OP	63	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	63	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

Operation: (ACCD) – (M : M + 1)

Description: Compares the contents of accumulator D with a 16-bit value at the address specified and sets the condition codes accordingly. The compare is accomplished internally by doing a 16-bit subtract of (M : M + 1) from accumulator D without modifying either accumulator D or (M : M + 1).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V $D15 \cdot \overline{M15} \cdot \overline{R15} + \overline{D15} \cdot M15 \cdot R15$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{D15} \cdot M15 + M15 \cdot R15 + R15 \cdot \overline{D15}$

Set if the absolute value of the contents of memory is larger than the absolute value of the accumulator; cleared otherwise.

Source Forms: CPD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CPD (IMM)			CPD (DIR)			CPD (EXT)			CPD (IND,X)			CPD (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	1A	1	OP	1A	1	OP	1A	1	OP	1A	1	OP	CD	1
2	OP+1	83	1	OP+1	93	1	OP+1	B3	1	OP+1	A3	1	OP+1	A3	1
3	OP+2	jj	1	OP+2	dd	1	OP+2	hh	1	OP+2	ff	1	OP+2	ff	1
4	OP+3	kk	1	00dd	(00dd)	1	OP+3	ll	1	FFFF	—	1	FFFF	—	1
5	FFFF	—	1	00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	Y+ff	(Y+ff)	1
6				FFFF	—	1	hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff+1	(Y+ff+1)	1
7							FFFF	—	1	FFFF	—	1	FFFF	—	1



Operation: $(IX) - (M : M + 1)$

Description: Compares the contents of index register X with a 16-bit value at the address specified and sets the condition codes accordingly. The compare is accomplished internally by doing a 16-bit subtract of $(M : M + 1)$ from index register X without modifying either index register X or $(M : M + 1)$.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V $IX15 \cdot \overline{M15} \cdot \overline{R15} + \overline{IX15} \cdot M15 \cdot R15$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{IX15} \cdot M15 + M15 \cdot R15 + R15 \cdot \overline{IX15}$

Set if the absolute value of the contents of memory is larger than the absolute value of the index register; cleared otherwise.

Source Forms: CPX (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CPX (IMM)			CPX (DIR)			CPX (EXT)			CPX (IND,X)			CPX (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	8C	1	OP	9C	1	OP	BC	1	OP	AC	1	OP	CD	1
2	OP+1	jj	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AC	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	hh	1	FFFF	—	1	OP+2	ff	1
4	FFFF	—	1	00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5				FFFF	—	1	hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6							FFFF	—	1	FFFF	—	1	Y+ff+1	(Y+ff+1)	1
7													FFFF	—	1

Operation: $(IY) - (M : M + 1)$

Description: Compares the contents of index register Y with a 16-bit value at the address specified and sets the condition codes accordingly. The compare is accomplished internally by doing a 16-bit subtract of $(M : M + 1)$ from index register Y without modifying either index register Y or $(M : M + 1)$.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V $IY15 \cdot \overline{M15} \cdot \overline{R15} + \overline{IY15} \cdot M15 \cdot R15$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{IY15} \cdot M15 + M15 \cdot R15 + R15 \cdot \overline{IY15}$

Set if the absolute value of the contents of memory is larger than the absolute value of the index register; cleared otherwise.

Source Forms: CPY (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	CPY (IMM)			CPY (DIR)			CPY (EXT)			CPY (IND,X)			CPY (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	18	1	OP	18	1	OP	18	1	OP	1A	1	OP	18	1
2	OP+1	8C	1	OP+1	9C	1	OP+1	BC	1	OP+1	AC	1	OP+1	AC	1
3	OP+2	jj	1	OP+2	dd	1	OP+2	hh	1	OP+2	ff	1	OP+2	ff	1
4	OP+3	kk	1	00dd	(00dd)	1	OP+3	ll	1	FFFF	—	1	FFFF	—	1
5	FFFF	—	1	00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	Y+ff	(Y+ff)	1
6				FFFF	—	1	hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff+1	(Y+ff+1)	1
7							FFFF	—	1	FFFF	—	1	FFFF	—	1

Operation: The following table summarizes the operation of the DAA instruction for all legal combinations of input operands. A correction factor (column 5 in the following table) is added to ACCA to restore the result of an addition of two BCD operands to a valid BCD value and set or clear the carry bit.

State of C Bit Before DAA (Column 1)	Upper Half-Byte of ACCA (Bits [7:4]) (Column 2)	Initial Half-Carry H Bit from CCR (Column 3)	Lower Half-Byte of ACCA (Bits [3:0]) (Column 4)	Number Added to ACCA by DAA (Column 5)	State of C Bit After DAA (Column 6)
0	0-9	0	0-9	00	0
0	0-8	0	A-F	06	0
0	0-9	1	0-3	06	0
0	A-F	0	0-9	60	1
0	9-F	0	A-F	66	1
0	A-F	1	0-3	66	1
1	0-2	0	0-9	60	1
1	0-2	0	A-F	66	1
1	0-3	1	0-3	66	1

NOTE

Columns (1) through (4) of the above table represent all possible cases which can result from any of the operations ABA, ADD, or ADC, with initial carry either set or clear, applied to two binary-coded-decimal operands. The table shows hexadecimal values.

Description: If the contents of ACCA and the state of the carry/borrow bit C and the state of the half-carry bit H are all the result of applying any of the operations ABA, ADD, or ADC to binary-coded-decimal operands, with or without an initial carry, the DAA operation will adjust the contents of ACCA and the carry bit C in the CCR to represent the correct binary-coded-decimal sum and the correct state of the C bit.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	?	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V ?

Not defined

C See table above

(Continued)

Source Forms: DAA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	DAA (INH)		
	Addr	Data	R/W
1	OP	19	1
2	OP+1	—	1

For the purpose of illustration, consider the case where the BCD value \$99 was just added to the BCD value \$22. The add instruction is a binary operation, which yields the result \$BB with no carry (C) or half carry (H). This corresponds to the fifth row of the table on the previous page. The DAA instruction will therefore add the correction factor \$66 to the result of the addition, giving a result of \$21 with the carry bit set. This result corresponds to the BCD value \$121, which is the expected BCD result.

A

DEC

Decrement

DEC

Operation: $ACCX \leftarrow (ACCX) - \01 or: $M \leftarrow (M) - \$01$

Description: Subtract one from the contents of ACCX or M.

The N, Z, and V bits in the CCR are set or cleared according to the results of the operation. The C bit in the CCR is not affected by the operation, thus allowing the DEC instruction to be used as a loop counter in multiple-precision computations.

When operating on unsigned values, only BEQ and BNE branches can be expected to perform consistently. When operating on two's complement values, all signed branches are available.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	—

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot \overline{X6} \cdot \overline{X5} \cdot \overline{X4} \cdot X3 \cdot \overline{X2} \cdot \overline{X1} \cdot \overline{X0} = \overline{R7} \cdot R6 \cdot R5 \cdot R4 \cdot R3 \cdot R2 \cdot R1 \cdot R0$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

Source Forms: DECA; DECB; DEC (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	DECA (INH)			DECB (INH)			DEC (EXT)			DEC (IND,X)			DEC (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	4A	1	OP	5A	1	OP	7A	1	OP	6A	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	6A	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	1

DES**Decrement Stack Pointer****DES****Operation:** $SP \leftarrow (SP) - \$0001$ **Description:** Subtract one from the stack pointer**Condition Codes and Boolean Formulae:**

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: DES**Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:**

Cycle	DES (INH)		
	Addr	Data	R/W
1	OP	34	1
2	OP+1	—	1
3	SP	—	1

A

DEX

Decrement Index Register X

DEX

Operation: $IX \leftarrow (IX) - \$0001$

Description: Subtract one from index register X

Only the Z bit is set or cleared according to the result of this operation.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	—	—

$Z = \overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
 Set if result is \$0000; cleared otherwise.

Source Forms: DEX

A

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	DEX (INH)		
	Addr	Data	R/W
1	OP	09	1
2	OP+1	—	1
3	FFFF	—	1

DEY

Decrement Index Register Y

DEY

Operation: $IY \leftarrow (IY) - \$0001$

Description: Subtract one from index register Y

Only the Z bit is set or cleared according to the result of this operation.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	—	—

$Z = \overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
 Set if result is \$0000; cleared otherwise.

Source Forms: DEY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	DEY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	09	1
3	OP+2	—	1
4	FFFF	—	1

EOR

Exclusive OR

EOR

Operation: $(ACCX) \leftarrow (ACCX) \oplus (M)$

Description: Performs the logical exclusive-OR between the contents of ACCX and the contents of M and places the result in ACCX. (Each bit of ACCX after the operation will be the logical exclusive-OR of the corresponding bits of M and ACCX before the operation.)

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V 0

Cleared

Source Forms: EORA (opr); EORB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	EORA(IMM)			EORA (DIR)			EORA (EXT)			EORA (IND,X)			EORA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	88	1	OP	98	1	OP	B8	1	OP	A8	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A8	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	EORB (IMM)			EORB (DIR)			EORB (EXT)			EORB (IND,X)			EORB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C8	1	OP	D8	1	OP	F8	1	OP	E8	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E8	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Operation: (ACCD)/(IX); IX \leftarrow Quotient, ACCD \leftarrow Remainder

Description: Performs an unsigned fractional divide of the 16-bit numerator in the D accumulator by the 16-bit denominator in the index register X and sets the condition codes accordingly. The quotient is placed in the index register X, and the remainder is placed in the D accumulator. The radix point is assumed to be in the same place for both the numerator and the denominator. The radix point is to the left of bit 15 for the quotient. The numerator is assumed to be less than the denominator. In the case of overflow (the denominator is less than or equal to the numerator) or divide by zero, the quotient is set to \$FFFF, and the remainder is indeterminate.

FDIV is equivalent to multiplying the numerator by 2¹⁶ and then performing a 32 by 16-bit integer divide. The result is interpreted as a binary-weighted fraction, which resulted from the division of a 16-bit integer by a larger 16-bit integer. A result of \$0001 corresponds to 0.000015, and \$FFFF corresponds to 0.99998. The remainder of an IDIV instruction can be resolved into a binary-weighted fraction by an FDIV instruction. The remainder of an FDIV instruction can be resolved into the next 16-bits of binary-weighted fraction by another FDIV instruction.

A

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	Δ	Δ

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if quotient is \$0000; cleared otherwise.

V 1 if IX \leq D
Set if denominator was less than or equal to the numerator; cleared otherwise.

Z $\overline{IX15} \cdot \overline{IX14} \cdot \overline{IX13} \cdot \overline{IX12} \cdot \overline{IX11} \cdot \overline{IX10} \cdot \overline{IX9} \cdot \overline{IX8} \cdot \overline{IX7} \cdot \overline{IX6} \cdot \overline{IX5} \cdot \overline{IX4} \cdot \overline{IX3} \cdot \overline{IX2} \cdot \overline{IX1} \cdot \overline{IX0}$
Set if denominator was \$0000; cleared otherwise.

Source Forms: FDIV

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	FDIV (INH)		
	Addr	Data	R/W
1	OP	03	1
2	OP+1	—	1
3-41	FFFF	—	1

Operation: (ACCD)/(IX); IX \leftarrow Quotient, ACCD \leftarrow Remainder

Description: Performs an unsigned integer divide of the 16-bit numerator in D accumulator by the 16-bit denominator in index register X and sets the condition codes accordingly. The quotient is placed in index register X, and the remainder is placed in the D accumulator. The radix point is assumed to be in the same place for both the numerator and the denominator. The radix point is to the right of bit zero for the quotient. In the case of divide by zero, the quotient is set to \$FFFF, and the remainder is indeterminate.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	0	Δ

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V 0
Cleared

C $\overline{IX15} \cdot \overline{IX14} \cdot \overline{IX13} \cdot \overline{IX12} \cdot \overline{IX11} \cdot \overline{IX10} \cdot \overline{IX9} \cdot \overline{IX8} \cdot \overline{IX7} \cdot \overline{IX6} \cdot \overline{IX5} \cdot \overline{IX4} \cdot \overline{IX3} \cdot \overline{IX2} \cdot \overline{IX1} \cdot \overline{IX0}$
Set if denominator was \$0000; cleared otherwise.

Source Forms: IDIV

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	IDIV (INH)		
	Addr	Data	R/W
1	OP	02	1
2	OP+1	—	1
3-41	FFFF	—	1

INC

Increment

INC

Operation: $ACCX \leftarrow (ACCX) + \01 or: $M \leftarrow (M) + \$01$

Description: Add one to the contents of ACCX or M.

The N, Z, and V bits in the CCR are set or cleared according to the results of the operation. The C bit in the CCR is not affected by the operation, thus allowing the INC instruction to be used as a loop counter in multiple-precision computations.

When operating on unsigned values, only BEQ and BNE branches can be expected to perform consistently. When operating on two's-complement values, all signed branches are available.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	∇

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $\overline{X7} \cdot X6 \cdot X5 \cdot X4 \cdot X3 \cdot X2 \cdot X1 \cdot X0$

Set if there is a two's complement overflow as a result of the operation; cleared otherwise. Two's complement overflow occurs if and only if (ACCX) or (M) was \$7F before the operation.

Source Forms: INCA; INCB; INC (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	INCA (INH)			INCB (INH)			INC (EXT)			INC (IND,X)			INC (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	4C	1	OP	5C	1	OP	7C	1	OP	6C	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	6C	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	1

A

INS**Increment Stack Pointer****INS****Operation:** $SP \leftarrow (SP) + \$0001$ **Description:** Adds one to the stack pointer.**Condition Codes and Boolean Formulae:**

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: INS**Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:****A**

Cycle	INS (INH)		
	Addr	Data	R/W
1	OP	31	1
2	OP+1	—	1
3	SP	—	1

INX

Increment Index Register X

INX

Operation: $IX \leftarrow (IX) + \$0001$

Description: Adds one to index register X.

Only the Z bit is set or cleared according to the result of this operation.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	—	—

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
 Set if result is \$0000; cleared otherwise.

Source Forms: INX

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	INX (INH)		
	Addr	Data	R/W
1	OP	08	1
2	OP+1	—	1
3	FFFF	—	1

INY

Increment Index Register Y

INY

Operation: $IY \leftarrow (IY) + \$0001$

Description: Adds one to index register Y.

Only the Z bit is set or cleared according to the result of this operation.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	Δ	—	—

$Z = \overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
 Set if result is \$0000; cleared otherwise.

Source Forms: INY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	INY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	08	1
3	OP+2	—	1
4	FFFF	—	1

A

JMP

Jump

JMP

Operation: PC \leftarrow Effective Address

Description: A jump occurs to the instruction stored at the effective address. The effective address is obtained according to the rules for EXTended or INDexed addressing.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: JMP (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	JMP (EXT)			JMP (IND,X)			JMP (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	7E	1	OP	6E	1	OP	18	1
2	OP+1	hh	1	OP+1	ff	1	OP+1	6E	1
3	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							FFFF	—	1

A

JSR

Jump to Subroutine

JSR

Operation: $PC \leftarrow (PC) + \$0003$ (for EXTended or INDexed, Y addressing) or:
 $PC \leftarrow (PC) + \$0002$ (for DIRect or INDexed, X addressing)
 $\downarrow (PCL)$ Push low-order return address onto stack
 $SP \leftarrow (SP) - \$0001$
 $\downarrow (PCH)$ Push high-order return address onto stack
 $SP \leftarrow (SP) - \$0001$
 $PC \leftarrow \text{Effective Addr}$ Load Start address or requested subroutine

Description: The program counter is incremented by three or by two, depending on the addressing mode, and is then pushed onto the stack, eight bits at a time, least significant byte first. The stack pointer points to the next empty location in the stack. A jump occurs to the instruction stored at the effective address. The effective address is obtained according to the rules for EXTended, DIRect, or INDexed addressing.

A

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: JSR (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	JSR (DIR)			JSR (EXT)			JSR (IND,X)			JSR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	9D	1	OP	BD	1	OP	AD	1	OP	18	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AD	1
3	00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	SP	Rtn lo	0	hhl	(hhl)	1	X+ff	(X+ff)	1	FFFF	—	1
5	Sp-1	Rtn hi	0	SP	Rtn lo	0	SP	Rtn lo	0	Y+ff	(Y+ff)	1
6				SP-1	Rtn hi	0	SP-1	Rtn hi	0	SP	Rtn lo	0
7										SP-1	Rtn hi	0

LDA

Load Accumulator

LDA

Operation: ACCX \leftarrow (M)

Description: Loads the contents of memory into the 8-bit accumulator. The condition codes are set according to the data.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

Source Forms: LDAA (opr); LDAB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LDAA (IMM)			LDAA (DIR)			LDAA (EXT)			LDAA (IND,X)			LDAA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	86	1	OP	96	1	OP	B6	1	OP	A6	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A6	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	LDAB (IMM)			LDAB (DIR)			LDAB (EXT)			LDAB (IND,X)			LDAB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C6	1	OP	D6	1	OP	F6	1	OP	E6	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E6	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

A

LDD

Load Double Accumulator

LDD

Operation: $ACCX \leftarrow (M : M + 1)$; $ACCA \leftarrow (M)$, $ACCB \leftarrow (M + 1)$

Description: Loads the contents of memory locations M and M + 1 into the double accumulator D. The condition codes are set according to the data. The information from location M is loaded into accumulator A, and the information from location M + 1 is loaded into accumulator B.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: LDD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LDD (IMM)			LDD (DIR)			LDD (EXT)			LDD (IND,X)			LDD (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	CC	1	OP	DC	1	OP	FC	1	OP	EC	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EC	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4				00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6													Y+ff+1	(Y+ff+1)	1

Operation: $SPH \leftarrow (M)$, $SPL \leftarrow (M + 1)$

Description: Loads the most significant byte of the stack pointer from the byte of memory at the address specified by the program, and loads the least significant byte of the stack pointer from the next byte of memory at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: LDS (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LDS (IMM)			LDS (DIR)			LDS (EXT)			LDS (IND,X)			LDS (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	BE	1	OP	9E	1	OP	EE	1	OP	AE	1	OP	18	1
2	OP+1	jj	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AE	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4				00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6													Y+ff+1	(Y+ff+1)	1

LDX

Load Index Register X

LDX

Operation: $IXH \leftarrow (M)$, $IXL \leftarrow (M + 1)$

Description: Loads the most significant byte of index register X from the byte of memory at the address specified by the program, and loads the least significant byte of index register X from the next byte of memory at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: LDX (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LDX (IMM)			LDX (DIR)			LDX (EXT)			LDX (IND,X)			LDX (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	CE	1	OP	DE	1	OP	FE	1	OP	EE	1	OP	CD	1
2	OP+1	jj	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EE	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4				00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6													Y+ff+1	(Y+ff+1)	1

Operation: $IYH \leftarrow (M)$, $IYL \leftarrow (M + 1)$

Description: Loads the most significant byte of index register Y from the byte of memory at the address specified by the program, and loads the least significant byte of index register Y from the next byte of memory at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: LDY (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LDY (IMM)			LDY (DIR)			LDY (EXT)			LDY (IND,X)			LDY (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	18	1	OP	18	1	OP	18	1	OP	1A	1	OP	18	1
2	OP+1	CE	1	OP+1	DE	1	OP+1	FE	1	OP+1	EE	1	OP+1	EE	1
3	OP+2	jj	1	OP+2	dd	1	OP+2	hh	1	OP+2	ff	1	OP+2	ff	1
4	OP+3	kk	1	00dd	(00dd)	1	OP+3	ll	1	FFFF	—	1	FFFF	—	1
5				00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	Y+ff	(Y+ff)	1
6							hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff+1	(Y+ff+1)	1

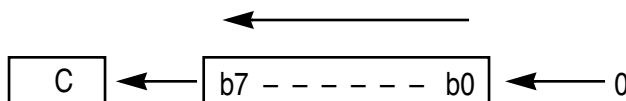
LSL

Logical Shift Left

LSL

(Same as ASL)

Operation:



Description: Shifts all bits of the ACCX or M one place to the left. Bit 0 is loaded with a zero. The C bit in the CCR is loaded from the most significant bit of ACCX or M.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

A

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)

Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the shift).

C M7

Set if, before the shift, the MSB of ACCX or M was set; cleared otherwise.

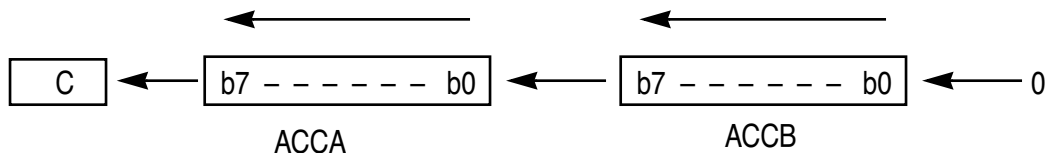
Source Forms: LSLA; LSLB; LSL (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LSLA (INH)			LSLB (INH)			LSL (EXT)			LSL (IND,X)			LSL (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	48	1	OP	58	1	OP	78	1	OP	68	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	68	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

(Same as ASLD)

Operation:



Description: Shifts all bits of ACCD one place to the left. Bit 0 is loaded with a zero. The C bit in the CCR is loaded from the most significant bit of ACCD.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)
Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the shift).

C D15

Set if, before the shift, the MSB of ACCD was set; cleared otherwise.

Source Forms: LSLD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LSLD (INH)		
	Addr	Data	R/W
1	OP	05	1
2	OP+1	—	1
3	FFFF	—	1

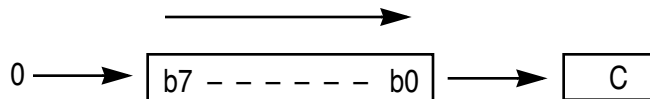
A

LSR

Logical Shift Right

LSR

Operation:



Description: Shifts all bits of the ACCX or M one place to the right. Bit 7 is loaded with zero. The C bit is loaded from the least significant bit of ACCX or M.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	0	Δ	Δ	Δ

N 0
Cleared.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the shift)
Since N = 0, this simplifies to C (after the shift).

C M0
Set if, before the shift, the LSB of ACCX or M was set; cleared otherwise.

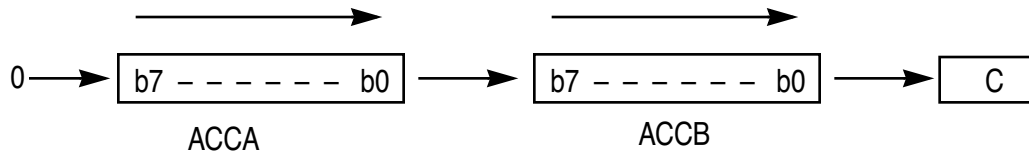
Source Forms: LSRA; LSRB; LSR (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LSRA (INH)			LSRB (INH)			LSR (EXT)			LSR (IND,X)			LSR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	44	1	OP	54	1	OP	74	1	OP	64	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	64	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

LSRD Logical Shift Right Double Accumulator LSRD

Operation:



Description: Shifts all bits of ACCD one place to the right. Bit 15 (MSB of ACCA) is loaded with zero. The C bit is loaded from the least significant bit of ACCD (LSB of ACCB).

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	0	Δ	Δ	Δ

N 0
Cleared.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V D0
Set if, after the shift operation, C is set; cleared otherwise.

C D0
Set if, before the shift, the least significant bit of ACCD was set; cleared otherwise.

Source Forms: LSRD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	LSRD (INH)		
	Addr	Data	R/W
1	OP	04	1
2	OP+1	—	1
3	FFFF	—	1

MUL

Multiply Unsigned

MUL

Operation: $ACCD \leftarrow (ACCA) \times (ACCB)$

Description: Multiplies the 8-bit unsigned binary value in accumulator A by the 8-bit unsigned binary value in accumulator B to obtain a 16-bit unsigned result in the double accumulator D. Unsigned multiply allows multiple-precision operations. The carry flag allows rounding the most significant byte of the result through the sequence: MUL, ADCA #0.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	Δ

C R7

Set if bit 7 of the result (ACCB bit 7) is set; cleared otherwise.

Source Forms: MUL

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	MUL (INH)		
	Addr	Data	R/W
1	OP	3D	1
2	OP+1	—	1
3–10	FFFF	—	1

A

NEG

Negate

NEG

Operation: $ACCX \leftarrow -(ACCX) = \$00 - (ACCX)$ or: $M \leftarrow -(M) = \$00 - (M)$

Description: Replaces the contents of ACCX or M with its two's complement; the value \$80 is left unchanged

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $R7 \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if there is a two's complement overflow from the implied subtraction from zero; cleared otherwise. A two's complement overflow will occur if and only if the contents of ACCX or M is \$80.

C $R7 + R6 + R5 + R4 + R3 + R2 + R1 + R0$

Set if there is a borrow in the implied subtraction from zero; cleared otherwise. The C bit will be set in all cases except when the contents of ACCX or M is \$00.

Source Forms: NEGA; NEGB; NEG (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	NEGA (INH)			NEGB (INH)			NEG (EXT)			NEG (IND,X)			NEG (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	40	1	OP	50	1	OP	70	1	OP	60	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	60	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

A

NOP

No Operation

NOP

Description: This is a single-byte instruction that causes only the program counter to be incremented. No other registers are affected. This instruction is typically used to produce a time delay although some software disciplines discourage CPU frequency-based time delays. During debug, NOP instructions are sometimes used to temporarily replace other machine code instructions, thus disabling the replaced instructions.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: NOP

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	NOP (INH)		
	Addr	Data	R/W
1	OP	01	1
2	OP+1	—	1

A

ORA

Inclusive OR

ORA

Operation: (ACCX) \leftarrow (ACCX) + (M)

Description: Performs the logical inclusive-OR between the contents of ACCX and the contents of M and places the result in ACCX. (Each bit of ACCX after the operation will be the logical inclusive-OR of the corresponding bits of M and ACCX before the operation.)

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V 0

Cleared

Source Forms: ORAA (opr); ORAB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ORAA (IMM)			ORAA (DIR)			ORAA (EXT)			ORAA (IND,X)			ORAA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	8A	1	OP	9A	1	OP	BA	1	OP	AA	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AA	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	ORAB (IMM)			ORAB (DIR)			ORAB (EXT)			ORAB (IND,X)			ORAB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	CA	1	OP	DA	1	OP	FA	1	OP	EA	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EA	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1



Operation: \downarrow ACCX, $SP \leftarrow (SP) - \$0001$

Description: The contents of ACCX are stored on the stack at the address contained in the stack pointer. The stack pointer is then decremented.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PSHA; PS HB;

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PSHA (INH)			PSHB (INH)		
	Addr	Data	R/W	Addr	Data	R/W
1	OP	36	1	OP	37	1
2	OP+1	—	1	OP+1	—	1
3	SP	(A)	0	SP	(B)	0

PSHX Push Index Register X onto Stack PSHX

Operation: $\Downarrow(\text{IXL}), \text{SP} \leftarrow (\text{SP}) - \0001

$\Downarrow(\text{IXH}), \text{SP} \leftarrow (\text{SP}) - \0001

Description: The contents of index register X are pushed onto the stack (low-order byte first) at the address contained in the stack pointer. The stack pointer is then decremented by two.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PSHX

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PSHX (INH)		
	Addr	Data	R/W
1	OP	3C	1
2	OP+1	—	1
3	SP	(IXL)	0
4	SP-1	(IXH)	0

A

PSHY Push Index Register Y onto Stack PSHY

Operation: $\Downarrow(\text{IYL}), \text{SP} \leftarrow (\text{SP}) - \0001

$\Downarrow(\text{IYH}), \text{SP} \leftarrow (\text{SP}) - \0001

Description: The contents of index register Y are pushed onto the stack (low-order byte first) at the address contained in the stack pointer. The stack pointer is then decremented by two.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PSHY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PSHY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	3C	1
3	OP+2	—	1
4	SP	(IYL)	0
5	SP-1	(IYH)	0

PUL

Pull Data from Stack

PUL

Operation: $SP \leftarrow (SP) + \$0001, \uparrow ACCX$

Description: The stack pointer is incremented. The ACCX is then loaded from the stack at the address contained in the stack pointer.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PULA; PULB;

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PULA (INH)			PULB (INH)		
	Addr	Data	R/W	Addr	Data	R/W
1	OP	32	1	OP	33	1
2	OP+1	—	1	OP+1	—	1
3	SP	—	1	SP	—	1
4	SP+1	get A	1	SP+1	get B	1

A

PULX Pull Index Register X from Stack PULX

Operation: $SP \leftarrow (SP) + \$0001; \uparrow(IXH)$

$SP \leftarrow (SP) + \$0001; \uparrow(IXL)$

Description: Index register X is pulled from the stack (high-order byte first) beginning at the address contained in the stack pointer plus one. The stack pointer is incremented by two in total.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PULX

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PULX (INH)		
	Addr	Data	R/W
1	OP	38	1
2	OP+1	—	1
3	SP	—	1
4	SP+1	get IXH	1
5	SP+2	get IXL	1

PULY Pull Index Register Y from Stack PULY

Operation: $SP \leftarrow (SP) + \$0001; \uparrow(IYH)$

$SP \leftarrow (SP) + \$0001; \uparrow(IYL)$

Description: Index register Y is pulled from the stack (high-order byte first) beginning at the address contained in the stack pointer plus one. The stack pointer is incremented by two in total.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Just before returning from the subroutine, corresponding pull instructions are used to restore the saved CPU registers so the subroutine will appear not to have affected these registers.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: PULY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	PULY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	38	1
3	OP+2	—	1
4	SP	—	1
5	SP+1	get IYH	1
6	SP+2	get IYL	1

A

ROL

Rotate Left

ROL

Operation:

Description: Shifts all bits of the ACCX or M one place to the left. Bit 0 is loaded from the C bit. The C bit in the CCR is loaded from the most significant bit of ACCX or M. The rotate operations include the carry bit to allow extension of the shift and rotate operations to multiple bytes. For example, to shift a 24-bit value left one bit, the sequence ASL LOW, ROL MID, ROL HIGH could be used where LOW, MID, and HIGH refer to the low-order, middle, and high-order bytes of the 24-bit value, respectively.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the rotate)

Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the rotate).

C M7

Set if, before the rotate, the MSB of ACCX or M was set; cleared otherwise.

Source Forms: ROLA; ROLB; ROL (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	ROLA (INH)			ROLB (INH)			ROL (EXT)			ROL (IND,X)			ROL (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	49	1	OP	59	1	OP	79	1	OP	69	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	69	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

ROR

Rotate Right

ROR

Operation:

Description: Shifts all bits of the ACCX or M one place to the right. Bit 7 is loaded from the C bit. The C bit in the CCR is loaded from the least significant bit of ACCX or M. The rotate operations include the carry bit to allow extension of the shift and rotate operations to multiple bytes. For example, to shift a 24-bit value right one bit, the sequence LSR HIGH, ROR MID, ROR LOW could be used where LOW, MID, and HIGH refer to the low-order, middle, and high-order bytes of the 24-bit value, respectively. The first LSR could be replaced by ASR to maintain the original value of the sign bit (MSB of high-order byte) of the 24-bit value.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $N \oplus C = [N \cdot \overline{C}] + [\overline{N} \cdot C]$ (for N and C after the rotate)

Set if (N is set and C is clear) or (N is clear and C is set); cleared otherwise (for values of N and C after the rotate).

C M0

Set if, before the rotate, the LSB of ACCX or M was set; cleared otherwise.

Source Forms: RORA; RORB; ROR (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	RORA (INH)			RORB (INH)			ROR (EXT)			ROR (IND,X)			ROR (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	46	1	OP	56	1	OP	76	1	OP	66	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	66	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							hhll	result	0	X+ff	result	0	FFFF	—	1
7													Y+ff	result	0

A

Operation: $SP \leftarrow (SP) + \$0001, \uparrow (CCR)$
 $SP \leftarrow (SP) + \$0001, \uparrow (ACCB)$
 $SP \leftarrow (SP) + \$0001, \uparrow (ACCA)$
 $SP \leftarrow (SP) + \$0001, \uparrow (IXH)$
 $SP \leftarrow (SP) + \$0001, \uparrow (IXL)$
 $SP \leftarrow (SP) + \$0001, \uparrow (IYH)$
 $SP \leftarrow (SP) + \$0001, \uparrow (IYL)$
 $SP \leftarrow (SP) + \$0001, \uparrow (PCH)$
 $SP \leftarrow (SP) + \$0001, \uparrow (PCL)$

Description: The condition code, accumulators B and A, index registers X and Y, and the program counter will be restored to a state pulled from the stack. The X bit in the CCR may be cleared as a result of an RTI instruction but may not be set if it was cleared prior to execution of the RTI instruction.

Condition Codes and Boolean Formulae:

A

S	X	H	I	N	Z	V	C
Δ	\downarrow	Δ	Δ	Δ	Δ	Δ	Δ

Condition code bits take on the value of the corresponding bit of the unstacked CCR except that the X bit may not change from a zero to a one. Software can leave X set, leave X clear, or change X from one to zero. The \overline{XIRQ} interrupt mask can only become set as a result of a \overline{RESET} or recognition of an \overline{XIRQ} interrupt.

Source Forms: RTI

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	RTI (INH)		
	Addr	Data	R/W
1	OP	3B	1
2	OP+1	—	1
3	SP	—	1
4	SP+1	get CC	1
5	SP+2	get B	1
6	SP+3	get A	1
7	SP+4	get IXH	1
8	SP+5	get IXL	1
9	SP+6	get IYH	1
10	SP+7	get IYL	1
11	SP+8	Rtn hi	1
12	SP+9	Rtn lo	1

RTS

Return from Subroutine

RTS

Operation: $SP \leftarrow (SP) + \$0001, \uparrow (PCH)$
 $SP \leftarrow (SP) + \$0001, \uparrow (PCL)$

Description: The stack pointer is incremented by one. The contents of the byte of memory, at the address now contained in the stack pointer, are loaded into the high-order eight bits of the program counter. The stack pointer is again incremented by one. The contents of the byte of memory, at the address now contained in the stack pointer, are loaded into the low-order eight bits of the program counter.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: RTS

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	RTS (INH)		
	Addr	Data	R/W
1	OP	39	1
2	OP+1	—	1
3	SP	—	1
4	SP+1	Rtn hi	1
5	SP+2	Rtn lo	1

A

Operation: $ACCA \leftarrow (ACCA) - (ACCB)$

Description: Subtracts the contents of ACCB from the contents of ACCA and places the result in ACCA. The contents of ACCB are not affected. For subtract instructions, the C bit in the CCR represents a borrow.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $A7 \cdot \overline{B7} \cdot \overline{R7} + \overline{A7} \cdot B7 \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{A7} \cdot B7 + B7 \cdot R7 + R7 \cdot \overline{A7}$

Set if the absolute value of ACCB is larger than the absolute value of ACCA; cleared otherwise.

Source Forms: SBA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SBA (INH)		
	Addr	Data	R/W
1	OP	10	1
2	OP+1	—	1

SBC

Subtract with Carry

SBC

Operation: $ACCX \leftarrow (ACCA) - (M) - (C)$

Description: Subtracts the contents of M and the contents of C from the contents of ACCX and places the result in ACCX. For subtract instructions the C bit in the CCR represents a borrow.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot \overline{M7} \cdot \overline{R7} + \overline{X7} \cdot M7 \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{X7} \cdot M7 + M7 \cdot R7 + R7 \cdot \overline{X7}$

Set if the absolute value of the contents of memory plus previous carry is larger than the absolute value of the accumulator; cleared otherwise.

Source Forms: SBCA (opr); SBCB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SBCA (IMM)			SBCA (DIR)			SBCA (EXT)			SBCA (IND,X)			SBCA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	82	1	OP	92	1	OP	B2	1	OP	A2	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A2	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	SBCB (IMM)			SBCB (DIR)			SBCB (EXT)			SBCB (IND,X)			SBCB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C2	1	OP	D2	1	OP	F2	1	OP	E2	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E2	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1



SEC**Set Carry****SEC****Operation:** C bit \leftarrow 1**Description:** Sets the C bit in the CCR.**Condition Codes and Boolean Formulae:**

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	1

C 1
Set

Source Forms: SEC**Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:****A**

Cycle	SEC (INH)		
	Addr	Data	R/W
1	OP	0D	1
2	OP+1	—	1

SEI

Set Interrupt Mask

SEI

Operation: I bit \leftarrow 1

Description: Sets the interrupt mask bit in the CCR. When the I bet is set, all maskable interrupts are inhibited, and the MPU will recognize only non-maskable interrupt sources or an SWI.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	1	—	—	—	—

I 1
Set

Source Forms: SEI

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	SEI (INH)		
	Addr	Data	R/W
1	OP	0F	1
2	OP+1	—	1

SEV Set Two's Complement Overflow Bit SEV

Operation: V bit \leftarrow 1

Description: Sets the interrupt mask bit in the CCR. When the I bet is set, all maskable interrupts are inhibited, and the MPU will recognize only non-maskable interrupt sources or an SWI.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	1	—

V 1
Set

Source Forms: SEV

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SEV (INH)		
	Addr	Data	R/W
1	OP	0B	1
2	OP+1	—	1

A

STA

Store Accumulator

STA

Operation: (M) \leftarrow (ACCX)

Description: Stores the contents of ACCX in memory. The contents of ACCX remains the same.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N X7
Set if MSB of result is set; cleared otherwise.

Z $\overline{X7} \cdot \overline{X6} \cdot \overline{X5} \cdot \overline{X4} \cdot \overline{X3} \cdot \overline{X2} \cdot \overline{X1} \cdot \overline{X0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

Source Forms: STAA (opr); STAB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STAA (DIR)			STAA (EXT)			STAA (IND,X)			STAA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	97	1	OP	B7	1	OP	A7	1	OP	18	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A7	1
3	00dd	(A)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4				hhll	(A)	1	X+ff	(A)	1	FFFF	—	1
5										Y+ff	(A)	0

Cycle	STAB (DIR)			STAB (EXT)			STAB (IND,X)			STAB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	D7	1	OP	F7	1	OP	E7	1	OP	18	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E7	1
3	00dd	(B)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4				hhll	(B)	1	X+ff	(B)	1	FFFF	—	1
5										Y+ff	(B)	0



STD**Store Double Accumulator****STD**

Operation: $M : M + 1 \leftarrow (ACCD)$; $M \leftarrow (ACCA)$, $M + 1 \leftarrow (ACCB)$

Description: Stores the contents of double accumulator ACCD in memory. The contents of ACCD remain unchanged.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N D15

Set if MSB of result is set; cleared otherwise.

Z $\overline{D15} \cdot \overline{D14} \cdot \overline{D13} \cdot \overline{D12} \cdot \overline{D11} \cdot \overline{D10} \cdot \overline{D9} \cdot \overline{D8} \cdot \overline{D7} \cdot \overline{D6} \cdot \overline{D5} \cdot \overline{D4} \cdot \overline{D3} \cdot \overline{D2} \cdot \overline{D1} \cdot \overline{D0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: STD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STD (DIR)			STD (EXT)			STD (IND,X)			STD (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	DD	1	OP	FD	1	OP	ED	1	OP	18	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	ED	1
3	00dd	(A)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	00dd+1	(B)	1	hhll	(A)	1	X+ff	(A)	1	FFFF	—	1
5				hhll+1	(B)	1	X+ff+1	(B)	1	Y+ff	(A)	1
6										Y+ff+1	(B)	1

STOP

Stop Processing

STOP

Description: If the S bit in the CCR is set, then the STOP instruction is disabled and operates like the NOP instruction. If the S bit in the CCR is clear, the STOP instruction causes all system clocks to halt, and the system is placed in a minimum-power standby mode. All CPU registers remain unchanged. I/O pins also remain unaffected.

Recovery from STOP may be accomplished by $\overline{\text{RESET}}$, $\overline{\text{XIRQ}}$, or an unmasked $\overline{\text{IRQ}}$. When recovering from STOP with $\overline{\text{XIRQ}}$, if the X bit in the CCR is clear, execution will resume with the stacking operations for the $\overline{\text{XIRQ}}$ interrupt. If the X bit in the CCR is set, masking $\overline{\text{XIRQ}}$ interrupts, execution will resume with the opcode fetch for the instruction which follows the STOP instruction (continue).

An error in some mask sets of the M68HC11 caused incorrect recover from STOP under very specific unusual conditions. If the opcode of the instruction before the STOP instruction came from column 4 or 5 of the opcode map, the STOP instruction was incorrectly interpreted as a two-byte instruction. A simple way to avoid this potential problem is to put a NOP instruction (which is a column 0 opcode) immediately before any STOP instruction.

A

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: STOP

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STOP (INH)		
	Addr	Data	R/W
1	OP	CF	1
2	OP+1	—	1

Operation: $M \leftarrow (SPH), M + 1 \leftarrow (SPL)$

Description: Stores the most significant byte of the stack pointer in memory at the address specified by the program and stores the least significant byte of the stack pointer at the next location in memory, at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N SP15

Set if MSB of result is set; cleared otherwise.

Z $\overline{SP15} \cdot \overline{SP14} \cdot \overline{SP13} \cdot \overline{SP12} \cdot \overline{SP11} \cdot \overline{SP10} \cdot \overline{SP9} \cdot \overline{SP8} \cdot \overline{SP7} \cdot \overline{SP6} \cdot \overline{SP5} \cdot \overline{SP4} \cdot \overline{SP3} \cdot \overline{SP2} \cdot \overline{SP1} \cdot \overline{SP0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: STS (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STS (DIR)			STS (EXT)			STS (IND,X)			STS (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	9F	1	OP	BF	1	OP	AF	1	OP	18	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	AF	1
3	00dd	(SPH)	0	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	00dd+1	(SPL)	0	hhll	(SPH)	0	X+ff	(SPH)	0	FFFF	—	1
5				hhll+1	(SPL)	0	X+ff+1	(SPL)	0	Y+ff	(SPH)	0
6										Y+ff+1	(SPL)	0

STX

Store Index Register X

STX

Operation: $M \leftarrow (IXH), M + 1 \leftarrow (IXL)$

Description: Stores the most significant byte of index register X in memory at the address specified by the program, and stores the least significant byte of index register X at the next location in memory, at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N IX15

Set if MSB of result is set; cleared otherwise.

Z $\overline{IX15} \cdot \overline{IX14} \cdot \overline{IX13} \cdot \overline{IX12} \cdot \overline{IX11} \cdot \overline{IX10} \cdot \overline{IX9} \cdot \overline{IX8} \cdot \overline{IX7} \cdot \overline{IX6} \cdot \overline{IX5} \cdot \overline{IX4} \cdot \overline{IX3} \cdot \overline{IX2} \cdot \overline{IX1} \cdot \overline{IX0}$

Set if result is \$0000; cleared otherwise.

V 0

Cleared

Source Forms: STX (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STX (DIR)			STX (EXT)			STX (IND,X)			STX (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	DF	1	OP	FF	1	OP	EF	1	OP	CD	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EF	1
3	00dd	(IXH)	0	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	00dd+1	(IXL)	0	hll	(IXH)	0	X+ff	(IXH)	0	FFFF	—	1
5				hll+1	(IXL)	0	X+ff+1	(IXL)	0	Y+ff	(IXH)	0
6										Y+ff+1	(IXL)	0

A

Operation: $M \leftarrow (IYH), M + 1 \leftarrow (IYL)$

Description: Stores the most significant byte of index register Y in memory at the address specified by the program, and stores the least significant byte of index register Y at the next location in memory, at one plus the address specified by the program.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N IY15
Set if MSB of result is set; cleared otherwise.

Z $\overline{IY15} \cdot \overline{IY14} \cdot \overline{IY13} \cdot \overline{IY12} \cdot \overline{IY11} \cdot \overline{IY10} \cdot \overline{IY9} \cdot \overline{IY8} \cdot \overline{IY7} \cdot \overline{IY6} \cdot \overline{IY5} \cdot \overline{IY4} \cdot \overline{IY3} \cdot \overline{IY2} \cdot \overline{IY1} \cdot \overline{IY0}$
Set if result is \$0000; cleared otherwise.

V 0
Cleared

Source Forms: STY (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	STY (DIR)			STY (EXT)			STY (IND,X)			STY (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	DF	1	OP	FF	1	OP	EF	1	OP	CD	1
2	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	EF	1
3	00dd	(IYH)	0	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4	00dd+1	(IYL)	0	hll	(IYH)	0	X+ff	(IYH)	0	FFFF	—	1
5				hll+1	(IYL)	0	X+ff+1	(IYL)	0	Y+ff	(IYH)	0
6										Y+ff+1	(IYL)	0

A

SUB

Subtract

SUB

Operation: ACCX \leftarrow (ACCX) – (M)

Description: Subtracts the contents of M from the contents of ACCX and places the result in ACCX. For subtract instructions, the C bit in the CCR represents a borrow.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R7

Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$

Set if result is \$00; cleared otherwise.

V $X7 \cdot \overline{M7} \cdot \overline{R7} + \overline{X7} \cdot M7 \cdot R7$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{X7} \cdot M7 + M7 \cdot R7 + R7 \cdot \overline{X7}$

Set if the absolute value of the contents of memory plus previous carry is larger than the absolute value of the accumulator; cleared otherwise.

Source Forms: SUBA (opr); SUBB (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SUBA (IMM)			SUBA (DIR)			SUBA (EXT)			SUBA (IND,X)			SUBA (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	80	1	OP	90	1	OP	B0	1	OP	A0	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A0	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1

Cycle	SUBB (IMM)			SUBB (DIR)			SUBB (EXT)			SUBB (IND,X)			SUBB (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	C0	1	OP	D0	1	OP	F0	1	OP	E0	1	OP	18	1
2	OP+1	ii	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	E0	1
3				00dd	(00dd)	1	OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5													Y+ff	(Y+ff)	1



SUBD

Subtract Double Accumulator

SUBD

Operation: $ACCD \leftarrow (ACCD) - (M : M + 1)$

Description: Subtracts the contents of M : M + 1 from the contents of double accumulator D and places the result in ACCD. For subtract instructions, the C bit in the CCR represents a borrow.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	Δ	Δ

N R15

Set if MSB of result is set; cleared otherwise.

Z $\overline{R15} \cdot \overline{R14} \cdot \overline{R13} \cdot \overline{R12} \cdot \overline{R11} \cdot \overline{R10} \cdot \overline{R9} \cdot \overline{R8} \cdot \overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$0000; cleared otherwise.

V $D15 \cdot \overline{M15} \cdot \overline{R15} + \overline{D15} \cdot M15 \cdot R15$

Set if a two's complement overflow resulted from the operation; cleared otherwise.

C $\overline{D15} \cdot M15 + M15 \cdot R15 + R15 \cdot \overline{D15}$

Set if the absolute value of the contents of memory is larger than the absolute value of the accumulator; cleared otherwise.

Source Forms: SUBD (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SUBD (IMM)			SUBD (DIR)			SUBD (EXT)			SUBD (IND,X)			SUBD (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	83	1	OP	93	1	OP	B3	1	OP	A3	1	OP	18	1
2	OP+1	jj	1	OP+1	dd	1	OP+1	hh	1	OP+1	ff	1	OP+1	A3	1
3	OP+2	kk	1	00dd	(00dd)	1	OP+2	hh	1	FFFF	—	1	OP+2	ff	1
4	FFFF	—	1	00dd+1	(00dd+1)	1	hhll	(hhll)	1	X+ff	(X+ff)	1	FFFF	—	1
5				FFFF	—	1	hhll+1	(hhll+1)	1	X+ff+1	(X+ff+1)	1	Y+ff	(Y+ff)	1
6							FFFF	—	1	FFFF	—	1	Y+ff+1	(Y+ff+1)	1
7													FFFF	—	1

Operation: $PC \leftarrow (PC) + \$0001$

\downarrow (PCL), $SP \leftarrow (SP) - \$0001$
 \downarrow (PCH), $SP \leftarrow (SP) - \$0001$
 \downarrow (IYL), $SP \leftarrow (SP) - \$0001$
 \downarrow (IYH), $SP \leftarrow (SP) - \$0001$
 \downarrow (IXL), $SP \leftarrow (SP) - \$0001$
 \downarrow (IXH), $SP \leftarrow (SP) - \$0001$
 \downarrow (ACCA), $SP \leftarrow (SP) - \$0001$
 \downarrow (ACCB), $SP \leftarrow (SP) - \$0001$
 \downarrow (CCR), $SP \leftarrow (SP) - \$0001$
 $I \leftarrow 1$, $PC \leftarrow$ (SWI vector)

Description: The program counter is incremented by one. The program counter, index registers Y and X, and accumulators A and B are pushed onto the stack. The CCR is then pushed onto the stack. The stack pointer is decremented by one after each byte of data is stored on the stack. The I bit in the CCR is then set. The program counter is loaded with the address stored at the SWI vector, and instruction execution resumes at this location. This instruction is not maskable by the I bit.

A

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	1	—	—	—	—

I 1
Set

Source Forms: SWI

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	SWI (INH)		
	Addr	Data	R/W
1	OP	3F	1
2	OP+1	—	1
3	SP	Rtn lo	0
4	SP-1	Rtn hi	0
5	SP-2	(IYL)	0
6	SP-3	(IYH)	0
7	SP-4	(IXL)	0
8	SP-5	(IXH)	0
9	SP-6	(A)	0
10	SP-7	(B)	0
11	SP-8	(CCR)	0
12	SP-8	(CCR)	1
13	Vec hi	Svc hi	1
14	Vec lo	Svc lo	1

TAB Transfer from Accumulator A to B TAB

Operation: ACCB \leftarrow (ACCA)

Description: Moves the contents of ACCA to ACCB. The former contents of ACCB are lost; the contents of ACCA are not affected.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared.

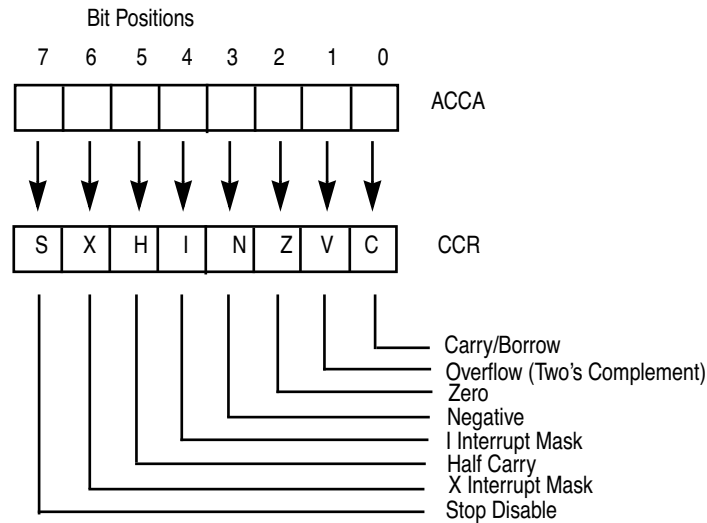
Source Forms: TAB

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TAB (INH)		
	Addr	Data	R/W
1	OP	16	1
2	OP+1	—	1

A

Operation: $CCR \leftarrow (ACCA)$



Description: Transfers the contents of bit positions 7–0 of accumulator A to the corresponding bit positions of the CCR. The contents of accumulator A remain unchanged. The X bit in the CCR may be cleared as a result of a TAP instruction but may not be set if it was clear prior to execution of the TAP instruction.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
Δ	↓	Δ	Δ	Δ	Δ	Δ	Δ

Condition code bits take on the value of the corresponding bit of accumulator A except that the X bit may not change from a zero to a one. Software can leave X set, leave X clear, or change X from one to zero. The \overline{XIRQ} interrupt mask can only become set as a result of a \overline{RESET} or recognition of an \overline{XIRQ} interrupt.

Source Forms: TAP

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TAP (INH)		
	Addr	Data	R/W
1	OP	06	1
2	OP+1	—	1

TBA Transfer from Accumulator B to A TBA

Operation: $ACCA \leftarrow (ACCB)$

Description: Moves the contents of ACCB to ACCA. The former contents of ACCA are lost; the contents of ACCB are not affected.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	—

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{R7} \cdot \overline{R6} \cdot \overline{R5} \cdot \overline{R4} \cdot \overline{R3} \cdot \overline{R2} \cdot \overline{R1} \cdot \overline{R0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared.

Source Forms: TBA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TBA (INH)		
	Addr	Data	R/W
1	OP	17	1
2	OP+1	—	1

A

TEST

Test Operation (Test Mode Only)

TEST

Description: This is a single-byte instruction that causes the program counter to be continuously incremented. It can only be executed while in the test mode. The MPU must be reset to exit this instruction. Code execution is suspended during this instruction. This is an illegal opcode when not in test mode.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TEST

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

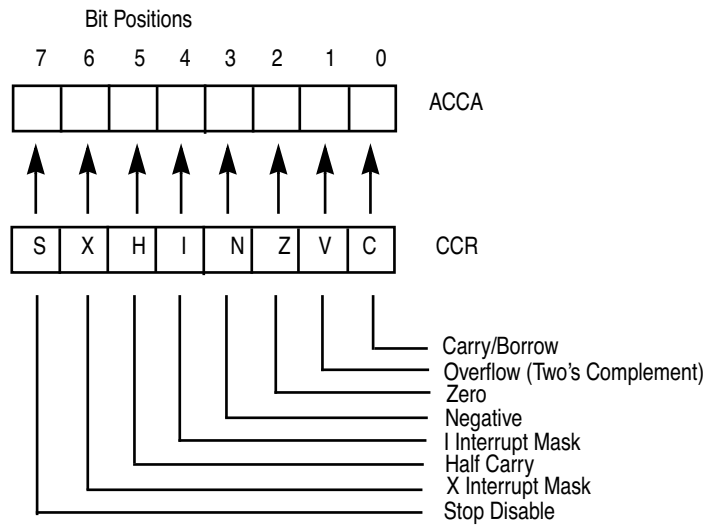
Cycle	TEST (INH)		
	Addr	Data	R/W
1	OP	00	1
2	OP+1	—	1
3	OP+2	—	1
4	OP+3	—	1
5-n	PREV-1	(PREV-1)	1

A

TPA Transfer from CCR to Accumulator A

TPA

Operation: (ACCA) \leftarrow (CCR)



A

Description: Transfers the contents of the CCR to corresponding bit positions of accumulator A. The CCR remains unchanged.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TPA

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TPA (INH)		
	Addr	Data	R/W
1	OP	07	1
2	OP+1	—	1

TST

Test

TST

Operation: (ACCX) – \$00 or: (M) – \$00

Description: Subtracts \$00 from the contents of ACCX or M and sets the condition codes accordingly.

The subtraction is accomplished internally without modifying either ACCX or M.

The TST instruction provides only minimum information when testing unsigned values. Since no unsigned value is less than zero, BLO and BLX have no utility. While BHI could be used after TST, it provides exactly the same control as BNE, which is preferred. After testing signed values, all signed branches are available.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	Δ	Δ	0	0

N R7
Set if MSB of result is set; cleared otherwise.

Z $\overline{M7} \cdot \overline{M6} \cdot \overline{M5} \cdot \overline{M4} \cdot \overline{M3} \cdot \overline{M2} \cdot \overline{M1} \cdot \overline{M0}$
Set if result is \$00; cleared otherwise.

V 0
Cleared

C 0
Cleared

Source Forms: TSTA; TSTB; TST (opr)

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TSTA (INH)			TSTB (INH)			TST (EXT)			TST (IND,X)			TST (IND,Y)		
	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W	Addr	Data	R/W
1	OP	4D	1	OP	5D	1	OP	7D	1	OP	6D	1	OP	18	1
2	OP+1	—	1	OP+1	—	1	OP+1	hh	1	OP+1	ff	1	OP+1	6D	1
3							OP+2	ll	1	FFFF	—	1	OP+2	ff	1
4							hll	(hll)	1	X+ff	(X+ff)	1	FFFF	—	1
5							FFFF	—	1	FFFF	—	1	Y+ff	(Y+ff)	1
6							FFFF	—	1	FFFF	—	1	FFFF	—	1
7													FFFF	—	1

A

TSX Transfer from SP to Index Register X TSX

Operation: $IX \leftarrow (SP) + \$0001$

Description: Loads the index register X with one plus the contents of the stack pointer. The contents of the stack pointer remain unchanged. After a TSX instruction the index register X points at the last value that was stored on the stack.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TSX

A

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TSX (INH)		
	Addr	Data	R/W
1	OP	30	1
2	OP+1	—	1
3	SP	—	1

TSY Transfer from SP to Index Register Y TSY

Operation: $IY \leftarrow (SP) + \$0001$

Description: Loads the index register Y with one plus the contents of the stack pointer. The contents of the stack pointer remain unchanged. After a TSY instruction the index register Y points at the last value that was stored on the stack.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TSY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TSY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	30	1
3	OP+2	—	1
4	SP	—	1

A

TXS Transfer from Index Register X to SP TXS

Operation: $SP \leftarrow (IX) - \$0001$

Description: Loads the stack pointer with the contents of index register X minus one. The contents of index register X remain unchanged.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TXS

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

A

Cycle	TXS (INH)		
	Addr	Data	R/W
1	OP	35	1
2	OP+1	—	1
3	FFFF	—	1

TYS Transfer from Index Register Y to SP TYS

Operation: $SP \leftarrow (IY) - \$0001$

Description: Loads the stack pointer with the contents of index register Y minus one. The contents of index register Y remain unchanged.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: TYS

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	TYS (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	35	1
3	OP+2	—	1
4	FFFF	—	1

A

WAI

Wait for Interrupt

WAI

Operation: $PC \leftarrow (PC) + \$0001$
 \downarrow (PCL), $SP \leftarrow (SP) - \$0001$
 \downarrow (PCH), $SP \leftarrow (SP) - \$0001$
 \downarrow (IYL), $SP \leftarrow (SP) - \$0001$
 \downarrow (IYH), $SP \leftarrow (SP) - \$0001$
 \downarrow (IXL), $SP \leftarrow (SP) - \$0001$
 \downarrow (IXH), $SP \leftarrow (SP) - \$0001$
 \downarrow (ACCA), $SP \leftarrow (SP) - \$0001$
 \downarrow (ACCB), $SP \leftarrow (SP) - \$0001$
 \downarrow (CCR), $SP \leftarrow (SP) - \$0001$

Description: The program counter is incremented by one. The program counter, index registers Y and X, and accumulators A and B are pushed onto the stack. The CCR is then pushed onto the stack. The stack pointer is decremented by one after each byte of data is stored on the stack.

A The MPU then enters a wait state for an integer number of MPU E-clock cycles. While in the wait state, the address/data bus repeatedly runs read bus cycles to the address where the CCR contents were stacked. The MPU leaves the wait state when it senses any interrupt that has not been masked.

Upon leaving the wait state, the MPU sets the I bit in the CCR, fetches the vector (address) corresponding to the interrupt sensed, and instruction execution is resumed at this location.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	1	—	—	—	—

Although the WAI instruction itself does not alter the condition code bits, the interrupt which causes the MCU to resume processing causes the I bit (and the X bit if the interrupt was \overline{XIRQ}) to be set as the interrupt vector is being fetched.

WAI Wait for Interrupt (Continued)

WAI

Source Forms: WAI

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	WAI (INH)		
	Addr	Data	R/ \bar{W}
1	OP	3E	1
2	OP+1	—	1
3	SP	Rtn lo	0
4	SP-1	Rtn hi	0
5	SP-2	(IYL)	0
6	SP-3	(IYH)	0
7	SP-4	(IXL)	0
8	SP-5	(IXH)	0
9	SP-6	(A)	0
10	SP-7	(B)	0
11	SP-8	(CCR)	0
12	SP-8	(CCR)	1
13	Vec hi	Svc hi	1
14	Vec lo	Svc lo	1

A

XGDX Exchange Double Accumulator and XGDX Index Register X

Operation: (IX) \Leftrightarrow (ACCD)

Description: Exchanges the contents of double accumulator ACCD and the contents of index register X. A common use for XGDX is to move an index value into the double accumulator to allow 16-bit arithmetic calculations on the index value before exchanged the updated index value back into the X index register.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: XGDX

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	XGDX (INH)		
	Addr	Data	R/W
1	OP	8F	1
2	OP+1	—	1
3	FFFF	—	1

A

XGDY Exchange Double Accumulator and XGDY Index Register Y

Operation: (IY) \Leftrightarrow (ACCD)

Description: Exchanges the contents of double accumulator ACCD and the contents of index register Y. A common use for XGDY is to move an index value into the double accumulator to allow 16-bit arithmetic calculations on the index value before exchanged the updated index value back into the Y index register.

Condition Codes and Boolean Formulae:

S	X	H	I	N	Z	V	C
—	—	—	—	—	—	—	—

None affected

Source Forms: XGDY

Addressing Modes, Machine Code, and Cycle-by-Cycle Execution:

Cycle	XGDY (INH)		
	Addr	Data	R/W
1	OP	18	1
2	OP+1	8F	1
3	OP+2	—	1
4	FFFF	—	1

A

A