HD63B09EP Technical Reference Guide

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INDEX

Introduction.................................................1

Summary of Features..........................................1

Description of Additional Registers..........................2

Modes of Operation...........................................3

Native Mode and Timing Loops.................................3

Modes of the Fast Interrupt Request (FIRQ)...................4

Inter-Register Instructions..................................4

Bit Manipulation of Memory Locations.........................4

Bit Transfers Between Memory Locations and Registers.........5

Block Transfers..............................................6

New math instructions (MULD, DIVD, DIVQ).....................7

Error Trapping...............................................7

Additional instructions......................................7

OP-Code Table...............................................10

Mnemonic Table..............................................19

Branch Instructions........................................24

Bit Manipulation and Transfers.............................24

Logical Memory Instructions................................25

Inter-Register Instructions................................25

Index Addressing Modes and Post- Byte Information..........26

Register Description.......................................27

Push/Pull Order............................................27

Push/Pull Post-Byte........................................27

Condition Code Register....................................27

HD63B09EP Technical Reference Guide Page 1

Introduction

The HD63B09EP microprocessor by Hitachi, is a MC68B09E compatible

chip containing additional registers and an additional instruction set.

The 6309 was thought to be a flakey chip though, because it would

sometimes crash or change the values of registers when it encountered an

addressing mode or opcode invalid to the 6809. This was later found to be

an extended instruction set and a feature that would trap some programming

errors and jump to a specified location in memory.

Hitachi licensed the rights of the 6809 instruction set from

Motorola to make a 6809 compatible chip. When they finished the design,

they found there was a lot of unused space in the chip. With this in mind

they added extra registers and expanded on the instruction set, but due to

the licensing agreement with Motorola, they were unable to release the

information about the extra features.

Not only does the chip have an expanded instruction set, but it also

has a native mode that will run many of the instructions in fewer clock

cycles and a mode select for the FIRQ (Fast Interrupt ReQuest) that will

enable it to operate the same as the IRQ.

In fact, all new instructions will execute in emulation mode, which

was originally seen when 'illegal' 6809 instructions produced odd effects

when run on a computer with a 6309 installed.

The additional instruction set was first written about in the April

1988 issue of "Oh!FM", a Japanese magazine, and was later translated by

Hirotsugu Kakagawa. This opened a whole new door to those who wished to

use the 6309 in place of the 6809.

In the beginning of 1992, Tandy Color Computer users in the US found

out about these features. Although there has been limited and sometimes

incorrect information about the new functions of the chip, I hope to

bridge that gap with the information provided here.

Remember that this information is of technical nature and makes no

attempt to teach assembly language programming. It is ONLY a technical

reference guide for those who already know assembly and wish to use these

features in their programs. Although all of the opcodes for the 6309/6809

chip are listed in the appendix, only the additional features supplied by

the 6309 will be discussed.

Summary of Features

More registers:

one 8/16 bit 'zero' register

Two 8bit accumulators.

One 16bit concatenated register

One 16bit value register.

One 8bit mode/error register.

One 32bit concatenated register

Two modes: MC68B09E emulation mode and HD63B09EP native mode.

Reduced execution cycles when running in native mode.

Many additional instructions.

Error trapping of illegal instructions and zero divisions.

HD63B09EP Technical Reference Guide Page 2

Description of Additional Registers

The 6309 has 7 additional registers. Only 4 of these are actual

registers. 2 are combinations of registers, and the last is a

constant-value register. These registers are:

ACCE - 8 bit accumulator.

ACCF - 8 bit accumulator.

W - 16 bit concatenated register (ACCE and ACCF combined).

V - 16 bit register (which can only be accessed with the

inter-register instructions).

0 - zero register

MD - 8 bit mode/error register.

Q - 32 bit concatenated register (ACCA, ACCB ,ACCE and ACCF

combined).

ACCE and ACCF both work the same as the ACCA and ACCB

accumulators. This makes for easier programming in math and data oriented

routines.

The W register is like the D register in the 6809. It is a

concatenated register containing the values of ACCE and ACCF as one 16 bit

value. ACCE is contained in the high 8 bits and ACCF is contained in the

low 8 bits.

The V register is a 16 bit register that can only be accessed with

inter-register instructions such a TFR and EXG. The contents of this

register will not change if the CPU is reset, allowing this register to be

used as a constant value for the program.

The 0 register is always zero, independent of reads/writes to it.

It enables a zero value to be used in inter-register operations without

accessing memory, or changing the value of another register. If a 0 byte

is stored at address $0000, it may also be used to clear large amounts of

memory quickly via 'TFM 0,r+'

The MD register is a mode and error register and works much in the

same way as the CC register. The bit definitions are as follows:

Write bits

Bit 0 - Execution mode of the 6309.

If clear ( 0 ), the cpu is in 6809 emulation mode.

If set ( 1 ), the cpu is in 6309 native mode.

Bit 1 - FIRQ mode

If clear ( 0 ), the FIRQ will occur normally.

If set ( 1 ) , the FIRQ will operate the same as the

IRQ

Bits 2 to 5 are unused

Read bits - One of these bits is set when the 6309 traps an error

Bit 6 - This bit is set ( 1 ) if an illegal instruction is

encountered

Bit 7 - This bit is set ( 1 ) if a zero division occurs.

The Q register is a 32 bit concatenated register. This register is

the same as the D and W register except for one respect. It contains the

values of ACCA, ACCB, ACCE and ACCF respectively. This register is used

mostly with the additional math instructions supplied with the 6309 which

will be discussed later.

HD63B09EP Technical Reference Guide Page 3

Modes of Operation

The 6309 has two modes of operation; 6809 Emulation mode in which

the chip acts and executes instructions the same as the 6809, and 6309

Native mode which stores an extra two bytes on the stack when an interrupt

(IRQ) occurs, and executes instructions in fewer clock cycles.

When in native mode, the W register (2 additional bytes) is stored

(PSHS) on the system stack when an interrupt occurs, it is stored on the

stack right after the D (general data) register. Since ALL register

values are stored on the system stack when an IRQ (NOT FIRQ - See FIRQ

modes for more information) occurs, great care should be taken when

writing or patching those routines to run in native mode.

Pull <- CC,A,B,E\*,F\*,DP,Xhi,Xlo,Yhi,Ylo,Uhi,Ulo,PChi,PClo <- Push

\* indicates the additional registers stored on the system stack

When in native mode those interrupt routines which modify the return

address by modifying the 10th and 11th byte offsets from the stack (STX

10,S or STY 10,S etc.) will have to be changed to modify the 12th and 13th

byte offsets from the stack (STX 12,S or STY 12,S etc.). If those routines

are not patched to run in native mode they will either get stuck in a

continuous loop or will crash the system due to the fact that they are not

returning to the correct address. This poses a MAJOR problem for OS-9

Level II since its main interrupt handling routine relies highly on the

changing of the return (PC) address on the stack. Disk read/write and

formatting routines also rely heavily on changing the return address

during an NMI (Non-Maskable Interrupt).

To patch those routines which do modify the return address, the

program or routine must be disassembled or modified with a disk sector

editing program. Look for instructions such as STX 10,S or STY 10,S that

has an RTI (Return from Interrupt) instruction within the next few lines

of the routine. The line containing STX 10,S or STY 10,S should be changed

to STX 12,S or STY 12,S respectively.

Remember, after those routines are patched, those programs using them

will NOT work in emulation mode and will require native mode to be enabled

upon startup.

Native Mode and Timing Loops

There is at least one more problem that needs to be addressed. Those

are routines which are dependent on timing loops for accurate operation.

Since the 6309 executes instructions faster when in native mode, those

routines that use timing loops would be effected. Since this can pose a

problem and can create erratic operation, the delay value or routine will

need to be changed for the routine to operate correctly.

Those routines are usually serial-printer routines, cassette

read/write timing routines, software clocks and some disk read/write

routines.

HD63B09EP Technical Reference Guide Page 4

Modes of the Fast Interrupt Request (FIRQ)

The designers of the 6309 decided that with the additional

instructions and native mode of operation, the FIRQ may be used more than

it usually is. With this in mind they decided to allow you to make the

FIRQ run the same as the IRQ and store (PSHS) all the current values of

the registers on the system stack. Normally, the FIRQ only stores the CC

(condition code) and the PC (Program Counter/return address) on the stack,

so to keep compatibility with the 6809, they included it as a selectable

feature in the MD (Mode/status) register.

Inter-Register Instructions

The new Inter-Register instructions (ADCR, ADDR, CMPR, EORR, ORR,

SBCR, and SUBR) all work the same as their register/memory (ADCA, ADDA,

etc.) counterparts except that they operate between registers. All of the

new instructions use the same post-byte information as the normal TFR

instruction and use the format of R0,R1 (register 0 and Register 1

respectively) with the result going into R1. See Block Transfers for

information on the TFR block move instructions.

Mixed-size inter-register operations default to using

identical sized register. So TFR A,X actually executes as TFR D,X.

You could also do 'lea(d) d,pc' type things by doing 'addr pc,d'. As

the new inter-register instructions can now perform math using the PC

register, REALLY odd possibilities exist. Try looking at code like

'eorr d,pc', and figuring out where it ends up.

Inter-register instructions with 16-bit r1 and CC or DP (8-bit r2)

are legal, but the results are unknown.

Bit Manipulation of Memory Locations

The AIM, EIM, OIM and TIM instructions all do logical bit

manipulations to locations in memory, with the result stored into the

location, and the respective bits for each instruction set in the CC

register. They can be used in the DIRECT, INDEXED or EXTENDED adressing

modes.

Instruction descriptions:

AIM - AND IN MEMORY

EIM - EOR IN MEMORY

OIM - OR IN MEMORY

TIM - TEST bits IN MEMORY

Instruction format: X, post byte, operand

Where X is the instruction op-code, post-byte contains the bits to

AND, OR, EOR or TEST against the memory location, and the operand is the

memory location or indexing post-byte depending on the mode of operation.

Mnemonic format:

Instruction logical operation value, memory location or index operation

Mnemonic example:

AIM #$0F,$E00

The example takes the contents of memory location $E00, does a LOGICAL

and with the Value #$0F and then stores the result back into $E00.

HD63B09EP Technical Reference Guide Page 5

Bit Transfers Between Memory Locations and Registers

The BAND, BIAND, BOR, BIOR, BEOR, BIEOR, LDBT, and STBT all do

logical operations to bits for the n-th bit in a memory location and the

m-th bit of a register. The LDBT and STBT instructions allow you to

transfer certain bits between registers and memory locations. All

instructions allow you to specify which register to use, which bit

location to use in the register, which bit location to use in the memory

location, and the memory location to use. This allows you to transfer/or

do a logical operation with the 7th bit of a register and the 3rd bit of a

memory location. All bits are accessible on either the register or memory

locations. The only limitations are that the instructions can only be used

with the A and B accumulators and the CC (condition Code) registers. It

should also be noted that these instructions can only be used in the

DIRECT addressing mode.

Instruction description:

BAND - AND a bit in a register with bit from memory location

BIAND - AND a bit in a register with the complement of the bit in memory

BOR - OR a bit in a register with a bit from a memory location

BIOR - OR a bit in a register with the complement of the bit in memory

BEOR - EOR a bit in a register with a bit from a memory location

BIEOR - EOR a bit in a register with the complement of the bit in memory

LDBT - Load a bit from a memory location into a bit in a register

STBT - Store a bit from a register into a memory location.

Instruction format:

x, post-byte, memory location

Where X is the instruction op-code, the post-byte contains the

register, source and destination bit information and the memory location

is the 8 bit value of the memory location to be used (Remember only DIRECT

mode is allowed with these instructions).

Mnemonic format:

instruction, register, source bit, destination bit, memory location

Mnemonic example:

BOR A,1,7,$00

The example would take the first (1) bit of register A (A) and OR it

into the 7th (7) bit of memory location $00 ($00) of the direct page (DP

register value)

The post-byte of these instructions are not the same as the post-byte

used in any other operation (indexed or inter-register) as all of the

information (register, source and destination bit) is contained in one

post-byte value.

HD63B09EP Technical Reference Guide Page 6

Block Transfers

Block transfers are used to move a certain number of bytes from one

place in memory to another with the use of one instruction. Two 16 bit

registers (X, Y, U or S) are used to specify the source and destination

addresses, and the size of the block to be transferred is specified with

the W register. It should be noted that even though the IRQ and FIRQ only

occur after the current instruction is finished, block moves can be

interrupted. After the interrupt returns, the last byte read is read once

more. i.e. It is read \_twice\_ by the CPU This can cause problems with

memory mapped I/O devices, so caution is advised when using the block

transfers. There isn't much control over these 4 instructions so the only

thing applicable for them would be large block moves such as scrolling the

screen or clearing an area in memory with a certain value.

TFM r0+,r1 and TFM r0,r1+ can be considered a poor mans DMA channel.

Since all the data is either copied into or read from one memory location.

Four types of block transfers have been provided.

Mnemonic examples:

(R0 - source address register, R1 - destination address register.)

TFM r0+,r1+

- Transfer from R0 to R1 in incrementing order.

TFM r0-,r1-

- Transfer from R0 to R1 in decrementing order.

TFM r0+,r1

- Pour from R0 into R1, only incrementing R0 (R1 stays the same).

TFM r0,r1+

- Read from R0 into R1, only incrementing R0 (R1 stays the same).

Mnemonic example:

LDW #$100

LDX #$600

LDY #$700

TFM X+,Y+

The example would move 256 (LDW $100) bytes from #$600 (LDX #$&00) in

memory to #$700 (LDY #$700) in memory, incrementing the value of each

register (X and Y), and decrementing the value of the W register each time

a byte if moved.

When moves like this are done, the pointer registers (X and Y in the

example) will not be the same value they were before the transfer was

initiated, but will but will be their original values PLUS the value of

the W register (#$100 in the example). So in the example once the move is

complete, the value of X will be returned as #$700 and the value of Y will

be returned as #$800. The value of W register will be 0.

The 0 register may be used as a source or destination address register,

and the data will be read from, or written to, address $0000.

It is illegal to use any of the CC, DP, W, V, or PC registers as either

a source or destination register.

HD63B09EP Technical Reference Guide Page 7

New math commands

The 6309 has 3 additional math instructions. A 16 bit by 16 bit

signed multiply (MULD), a 16 bit by 8 bit signed divide (DIVD) and a 32

bit by 16 bit signed divide (DIVQ). These instructions can all be used in

Immediate, direct, indexed and extended addressing modes.

The MULD (16 bit by 16 bit) instruction does a signed multiply of the

contents of the D register and a value from memory (or in direct mode).

The signed result is stored in the Q register.

The DIVD (16 bit by 8 bit) instruction does a signed divide of the

contents of the D register with a value from memory (or in direct mode).

The signed result is stored with the quotient in W and the modulo

(remainder) in D.

The DIVQ (32 bit by 16 bit) instruction does a signed divide of the

contents of the Q register with a value from memory (or in direct mode).

The signed result is stored with the quotient in W and the modulo

(remainder) in D.

Error Trapping

The 6309 has an internal error trapping handler that will jump to a

specific location in memory when either an error is encountered in the

DIVision instructions (only divide by zero) or an illegal instruction is

encountered. When an error is encountered, the 6309 will jump to the

memory location contained in $FFF0 (and $FFF1) which was originally

reserved by the 6809.

The trap may cause problems with machines that have $FF00 hardcoded

with the values $0000. A new EPROM should be burned to correct for the

new behaviour of the 6309.

As many people know, an illegal instruction trap is extremely useful

for debugging programs, as it prevents the entire machine from crashing

when a bug is encountered.

Note that many pseudo-legal instructions on the 6809 are now illegal

on the 6309, e.g. $1020xxxx executes as an LBRA on a 6809, but results in

a trap on a 6309.

Additional Instructions

The 6309 has MANY new instructions. Most are variations of old

instructions of the 6809 for use with the new registers. The new

instruction set can be used in both native and emulation mode. Here is a

list of the new instructions of the 6309:

ADCD

- Adds immediate or memory operand to the D register plus the current

status of the carry with the result going to D.

ADCR

- Adds two registers together plus the current status of the carry.

HD63B09EP Technical Reference Guide Page 8

ADDE , ADDF, ADDW

- Add of immediate or memory operand to E, F or W with results going

to E, F or W

ADDR

- Adds two registers together

ANDD

- Logical AND of immediate or memory operand to D register with

result going to D.

ANDR

- Logical AND of a register with the contents of another register

ASLD (Same as LSLD)

- Arithmetic shift left. Shifts D one bit left, clearing LSB.

ASRD

- Arithmetic shift right of the D register with sign extending.

BITD

- Test any bit or bits of the D register.

BITMD

- Test any bit or bits of the MD (mode) register.

CLRD, CLRE, CLRF, CLRW

- Clear register D, E, F or W to zero.

CMPE, CMPF, CMPW

- Compares the contents of E, F or W with the immediate or memory

operand. Sets all CC except H on result.

CMPR

- Compares one register to another and sets all CC bits except H on

result.

COMD, COME, COMF, COMW

- One's complement D ,E, F, or W. Changes all zero's to one's and

all one's to zero's.

DECD, DECE, DECF, DECW

- Decrement D, E, F, or W by 1.

DIVD, DIVQ

- Does a 16 bit by 8 bit (DIVD) or a 32 bit by 16 bit (DIVQ) signed

divide with immediate or memory operand with quotient in W and modulo

(remainder) in D.

EORD

- Logical exclusive OR of D and immediate or memory operand.

EORR

- Logical exclusive OR of one register with the value of another

register.

INCD, INCE, INCF, INCW

- Increment D, E, F or W by 1.

LDE, LDF, LDQ, LDW, LDMD

- Standard loading of E, F, Q, W or MD with immediate data value or

operand from memory. (LDMD only valid with IMMEDIATE mode)

HD63B09EP Technical Reference Guide Page 9

LSLD (Same as ASLD)

- Logical shift left. Shifts D one bit left, clearing LSB.

LSRD, LSRW

- Logical shift right. Shifts D or W one bit right, clearing MSB.

MULD

- Performs as 16bit by 16bit signed multiply with immediate or operand

from memory. Result stored in Q.

NEGD

- Two's complement D register.

ORD

- Logical OR of register D and immediate or memory operand.

ORR

- Logical OR of one register with another.

PSHSW, PSHUW

- Stores contents of the W register on the (system or user) stack.

PULSW, PULUW

- Pull value from (system or user) stack into register W.

ROLD, ROLW

- Rotate D or W one bit left through the Carry Condition code.

RORD, RORW

- Rotate D or W one bit right through the Carry Condition code.

SBCD

- Subtract an immediate or memory operand plus any borrow in Carry from

contents of D. Result stored in D.

SBCR

- Subtract the value of one register from another plus any borrow in

the CC carry.

SEXW

- sign exdend the W register into the D register.

STE, STF, STQ, STW

- Store register E, F, Q or W to memory location (E,F), two memory

locations(W), or four memory locations (Q).

SUBE, SUBF, SUBW

- Subtract immediate or memory operand from E, F or W. Result stored

back in same register.

SUBR

- Subtract the value of one register from another.

TFM (Block transfer)

- Transfer W number of bytes from one location to another. Returns

pointer registers offset of the starting value in the W register and

returns the W register as 0. Indexed operation only

TSTD, TSTE, TSTF, TSTW

- Test contents of D, E, F or W by setting N and X condition codes

based on data in register.

Opcode and Mnemonics Reference Table Page 10

The Opcode and Mnemonics opcode reference tables are both complete

listings that contain both the Opcode instruction and the HEX equivalant

in all available addressing modes. The first table is arranged

sequentially by the binary opcodes, while the second table is arranged

alphabetically by the Mnemonic instructions.

At the end of the second table there are data tables containing

information on Bit transfer/manipulation, branch instructions,

inter-register instructions, and general register and stack information.

These are all helpful to the serious assembly language programmer, who

should always have one.

Opcode table

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) 6809 (6309) |

|----------------------------------------------------------------|

| 00 NEG Direct 6 (5) 2 |

| \* 01 OIM Direct 6 3 |

| \* 02 AIM Direct 6 3 |

| 03 COM Direct 6 (5) 2 |

| 04 LSR Direct 6 (5) 2 |

| \* 05 EIM Direct 6 3 |

| 06 ROR Direct 6 (5) 2 |

| 07 ASR Direct 6 (5) 2 |

| 08 ASL/LSL Direct 6 (5) 2 |

| 09 ROL Direct 6 (5) 2 |

| 0A DEC Direct 6 (5) 2 |

| \* 0B TIM Direct 6 |

| 0C INC Direct 6 (5) 2 |

| 0D TST Direct 6 (4) 2 |

| 0E JMP Direct 3 (2) 2 |

| 0F CLR Direct 6 (5) 2 |

| 10 (PREBYTE) |

| 11 (PREBYTE) |

| 12 NOP Inherent 2 (1) 1 |

| 13 SYNC Inherent 2 (1) 1 |

| \* 14 SEXW Inherent 4 1 |

| 16 LBRA Relative 5 (4) 3 |

| 17 LBSR Relative 9 (7) 3 |

| 19 DAA Inherent 2 (1) 1 |

| 1A ORCC Immediate 3 (2) 2 |

| 1C ANDCC Immediate 3 2 |

| 1D SEX Inherent 2 (1) 1 |

| 1E EXG Immediate 8 (5) 2 |

| 1F TFR Immediate 6 (4) 2 |

| 20 BRA Relative 3 2 |

| 21 BRN Relative 3 2 |

| 22 BHI Relative 3 2 |

| 23 BLS Relative 3 2 |

| 24 BHS/BCC Relative 3 2 |

| 25 BLO/BCS Relative 3 2 |

| 26 BNE Relative 3 2 |

| 27 BEQ Relative 3 2 |

----------------------------------------------------------------

Opcode and Mnemonics opcode reference table Page 11

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| 28 BVC Relative 3 2 |

| 29 BVS Relative 3 2 |

| 2A BPL Relative 3 2 |

| 2B BMI Relative 3 2 |

| 2C BGE Relative 3 2 |

| 2D BLT Relative 3 2 |

| 2E BGT Relative 3 2 |

| 2F BLE Relative 3 2 |

| 30 LEAX Indexed 4+ 2 |

| 31 LEAY Indexed 4+ 2 |

| 32 LEAS Indexed 4+ 2 |

| 33 LEAU Indexed 4+ 2 |

| 34 PSHS Immediate 5+ (4+) 2 |

| 35 PULS Immediate 5+ (4+) 2 |

| 36 PSHU Immediate 5+ (4+) 2 |

| 37 PULU Immediate 5+ (4+) 2 |

| 39 RTS Inherent 5 (1) 1 |

| 3A ABX Inherent 3 (1) 1 |

| 3B RTI Inherent 6/15 (17) 1 |

| 3C CWAI Immediate 22 (20) 2 |

| 3D MUL Inherent 11 (10) 1 |

| 3F SWI Inherent 19 (21) 1 |

| 40 NEGA Inherent 2 (1) 1 |

| 43 COMA Inherent 2 (1) 1 |

| 44 LSRA Inherent 2 (1) 1 |

| 46 RORA Inherent 2 (1) 1 |

| 47 ASRA Inherent 2 (1) 1 |

| 48 ASLA/LSLA Inherent 2 (1) 1 |

| 49 ROLA Inherent 2 (1) 1 |

| 4A DECA Inherent 2 (1) 1 |

| 4C INCA Inherent 2 (1) 1 |

| 4D TSTA Inherent 2 (1) 1 |

| 4F CLRA Inherent 2 (1) 1 |

| 50 NEGB Inherent 2 (1) 1 |

| 53 COMB Inherent 2 (1) 1 |

| 54 LSRB Inherent 2 (1) 1 |

| 56 RORB Inherent 2 (1) 1 |

| 57 ASRB Inherent 2 (1) 1 |

| 58 ASLB/LSLB Inherent 2 (1) 1 |

| 59 ROLB Inherent 2 (1) 1 |

| 5A DECB Inherent 2 (1) 1 |

| 5C INCB Inherent 2 (1) 1 |

| 5D TSTB Inherent 2 (1) 1 |

| 5F CLRB Inherent 2 (1) 1 |

| 60 NEG Indexed 6+ 2+ |

| \* 61 OIM Indexed 6+ 3+ |

| \* 62 AIM Indexed 7 3+ |

| 63 COM Indexed 6+ 2+ |

| 64 LSR Indexed 6+ 2+ |

| \* 65 EIM Indexed 7+ 3+ |

| 66 ROR Indexed 6+ 2+ |

| 67 ASR Indexed 6+ 2+ |

| 68 ASL/LSL Indexed 6+ 2+ |

| 69 ROL Indexed 6+ 2+ |

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Opcode and Mnemonics opcode reference table Page 12

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| 6A DEC Indexed 6+ 2+ |

| \* 6B TIM Indexed 7+ 3+ |

| 6C INC Indexed 6+ 2+ |

| 6D TST Indexed 6+ (5+) 2+ |

| 6E JMP Indexed 3+ 2+ |

| 6F CLR Indexed 6+ 2+ |

| 70 NEG Extended 7 (6) 3 |

| \* 71 OIM Extended 7 4 |

| \* 72 AIM Extended 7 4 |

| 73 COM Extended 7 (6) 3 |

| 74 LSR Extended 7 (6) 3 |

| 76 ROR Extended 7 (6) 3 |

| \* 75 EIM Extended 7 4 |

| 77 ASR Extended 7 (6) 3 |

| 78 ASL/LSL Extended 7 (6) 3 |

| 79 ROL Extended 7 (6) 3 |

| 7A DEC Extended 7 (6) 3 |

| \* 7B TIM Extended 7 4 |

| 7C INC Extended 7 (6) 3 |

| 7D TST Extended 7 (5) 3 |

| 7E JMP Extended 4 (3) 3 |

| 7F CLR Extended 7 (6) 3 |

| 80 SUBA Immediate 2 2 |

| 81 CMPA Immediate 2 2 |

| 82 SBCA Immediate 2 2 |

| 83 SUBD Immediate 4 (3) 3 |

| 84 ANDA Immediate 2 2 |

| 85 BITA Immediate 2 2 |

| 86 LDA Immediate 2 2 |

| 88 EORA Immediate 2 2 |

| 89 ADCA Immediate 2 2 |

| 8A ORA Immediate 2 2 |

| 8B ADDA Immediate 2 2 |

| 8C CMPX Immediate 4 (3) 3 |

| 8D BSR Relative 7 (6) 2 |

| 8E LDX Immediate 3 3 |

| 90 SUBA Direct 4 (3) 2 |

| 91 CMPA Direct 4 (3) 2 |

| 92 SBCA Direct 4 (3) 2 |

| 93 SUBD Direct 6 (4) 2 |

| 94 ANDA Direct 4 (3) 2 |

| 95 BITA Direct 4 (3) 2 |

| 96 LDA Direct 4 (3) 2 |

| 97 STA Direct 4 (3) 2 |

| 98 EORA Direct 4 (3) 2 |

| 99 ADCA Direct 4 (3) 2 |

| 9A ORA Direct 4 (3) 2 |

| 9B ADDA Direct 4 (3) 2 |

| 9C CMPX Direct 6 (4) 2 |

| 9D JSR Direct 7 (6) 2 |

| 9E LDX Direct 5 (4) 2 |

| 9F STX Direct 5 (4) 2 |

| A0 SUBA Indexed 4+ 2+ |

| A1 CMPA Indexed 4+ 2+ |

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Opcode and Mnemonics opcode reference table Page 13

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| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| A2 SBCA Indexed 4+ 2+ |

| A3 SUBD Indexed 6+ (5+) 2+ |

| A4 ANDA Indexed 4+ 2+ |

| A5 BITA Indexed 4+ 2+ |

| A6 LDA Indexed 4+ 2+ |

| A7 STA Indexed 4+ 2+ |

| A8 EORA Indexed 4+ 2+ |

| A9 ADCA Indexed 4+ 2+ |

| AA ORA Indexed 4+ 2+ |

| AB ADDA Indexed 4+ 2+ |

| AC CMPX Indexed 6+ (5+) 2+ |

| AD JSR Indexed 7+ (6+) 2+ |

| AE LDX Indexed 5+ 2+ |

| AF STX Indexed 5+ 2+ |

| B0 SUBA Extended 5 (4) 3 |

| B1 CMPA Extended 5 (4) 3 |

| B2 SBCA Extended 5 (4) 3 |

| B3 SUBD Extended 7 (5) 3 |

| B4 ANDA Extended 5 (4) 3 |

| B5 BITA Extended 5 (4) 3 |

| B6 LDA Extended 5 (4) 3 |

| B7 STA Extended 5 (4) 3 |

| B8 EORA Extended 5 (4) 3 |

| B9 ADCA Extended 5 (4) 3 |

| BA ORA Extended 5 (4) 3 |

| BB ADDA Extended 5 (4) 3 |

| BC CMPX Extended 7 (5) 3 |

| BD JSR Extended 8 (7) 3 |

| BE LDX Extended 6 (5) 3 |

| BF STX Extended 6 (5) 3 |

| C0 SUBB Immediate 2 2 |

| C1 CMPB Immediate 2 2 |

| C2 SBCB Immediate 2 2 |

| C3 ADDD Immediate 4 (3) 3 |

| C4 ANDB Immediate 2 2 |

| C5 BITB Immediate 2 2 |

| C6 LDB Immediate 2 2 |

| C8 EORB Immediate 2 2 |

| C9 ADCB Immediate 2 2 |

| CA ORB Immediate 2 2 |

| CB ADDB Immediate 2 2 |

| CC LDD Immediate 3 3 |

| \* CD LDQ Immediate 5 5 |

| CE LDU Immediate 3 3 |

| D0 SUBB Direct 4 (3) 2 |

| D1 CMPB Direct 4 (3) 2 |

| D2 SBCB Direct 4 (3) 2 |

| D3 ADDD Direct 6 (4) 2 |

| D4 ANDB Direct 4 (3) 2 |

| D5 BITB Direct 4 (3) 2 |

| D6 LDB Direct 4 (3) 2 |

| D7 STB Direct 4 (3) 2 |

| D8 EORB Direct 4 (3) 2 |

| D9 ADCB Direct 4 (3) 2 |

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Opcode and Mnemonics opcode reference table Page 14

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| DA ORB Direct 4 (3) 2 |

| DB ADDB Direct 4 (3) 2 |

| DC LDD Direct 5 (4) 2 |

| DD STD Direct 5 (4) 2 |

| DE LDU Direct 5 (4) 2 |

| DF STU Direct 5 (4) 2 |

| E0 SUBB Indexed 4+ 2+ |

| E1 CMPB Indexed 4+ 2+ |

| E2 SBCB Indexed 4+ 2+ |

| E3 ADDD Indexed 6+ (5+) 2+ |

| E4 ANDB Indexed 4+ 2+ |

| E5 BITB Indexed 4+ 2+ |

| E6 LDB Indexed 4+ 2+ |

| E7 STB Indexed 4+ 2+ |

| E8 EORB Indexed 4+ 2+ |

| E9 ADCB Indexed 4+ 2+ |

| EA ORB Indexed 4+ 2+ |

| EB ADDB Indexed 4+ 2+ |

| EC LDD Indexed 5+ 2+ |

| ED STD Indexed 5+ 2+ |

| EE LDU Indexed 5+ 2+ |

| EF STU Indexed 5+ 2+ |

| F0 SUBB Extended 5 (4) 3 |

| F1 CMPB Extended 5 (4) 3 |

| F2 SBCB Extended 5 (4) 3 |

| F3 ADDD Extended 7 (5) 3 |

| F4 ANDB Extended 5 (4) 3 |

| F5 BITB Extended 5 (4) 3 |

| F6 LDB Extended 5 (4) 3 |

| F7 STB Extended 5 (4) 3 |

| F8 EORB Extended 5 (4) 3 |

| F9 ADCB Extended 5 (4) 3 |

| FA ORB Extended 5 (4) 3 |

| FB ADDB Extended 5 (4) 3 |

| FC LDD Extended 6 (5) 3 |

| FD STD Extended 6 (5) 3 |

| FE LDU Extended 6 (5) 3 |

| FF STU Extended 6 (5) 3 |

| 1021 LBRN Reletive 5/6 ( ) 4 |

| 1022 LBHI Reletive 5/6 ( ) 4 |

| 1023 LBLS Reletive 5/6 ( ) 4 |

| 1024 LBHS/LBCC Reletive 5/6 ( ) 4 |

| 1025 LBCS/LBLO Reletive 5/6 ( ) 4 |

| 1026 LBNE Reletive 5/6 ( ) 4 |

| 1027 LBEQ Reletive 5/6 ( ) 4 |

| 1028 LBVC Reletive 5/6 ( ) 4 |

| 1029 LBVS Reletive 5/6 ( ) 4 |

| 102A LBPL Reletive 5/6 ( ) 4 |

| 102B LBMI Reletive 5/6 ( ) 4 |

| 102C LBGE Reletive 5/6 ( ) 4 |

| 102D LBLT Reletive 5/6 ( ) 4 |

| 102E LBGT Reletive 5/6 ( ) 4 |

| 102F LBLE Reletive 5/6 ( ) 4 |

| \* 1030 ADDR Register 4 3 |

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Opcode and Mnemonics opcode reference table Page 15

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| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| \* 1031 ADCR Register 4 3 |

| \* 1032 SUBR Register 4 3 |

| \* 1033 SBCR Register 4 3 |

| \* 1034 ANDR Register 4 3 |

| \* 1035 ORR Register 4 3 |

| \* 1036 EORR Register 4 3 |

| \* 1037 CMPR Register 4 3 |

| \* 1038 PSHSW Register 6 2 |

| \* 1039 PULSW Register 6 2 |

| \* 103A PSHUW Register 6 2 |

| \* 103B PULUW Register 6 2 |

| 103F SWI2 Inherent 20 (22) 2 |

| \* 1040 NEGD Inherent 3 (2) 2 |

| \* 1043 COMD Inherent 3 (2) 2 |

| \* 1044 LSRD Inherent 3 (2) 2 |

| \* 1046 RORD Inherent 3 (2) 2 |

| \* 1047 ASRD Inherent 3 (2) 2 |

| \* 1048 ASLD/LSLD Inherent 3 (2) 2 |

| \* 1049 ROLD Inherent 3 (2) 2 |

| \* 104A DECD Inherent 3 (2) 2 |

| \* 104C INCD Inherent 3 (2) 2 |

| \* 104D TSTD Inherent 3 (2) 2 |

| \* 104F CLRD Inherent 3 (2) 2 |

| \* 1053 COMW Inherent 3 (2) 2 |

| \* 1054 LSRW Inherent 3 (2) 2 |

| \* 1056 RORW Inherent 3 (2) 2 |

| \* 1059 ROLW Inherent 3 (2) 2 |

| \* 105A DECW Inherent 3 (2) 2 |

| \* 105C INCW Inherent 3 (2) 2 |

| \* 105D TSTW Inherent 3 (2) 2 |

| \* 105F CLRW Inherent 3 (2) 2 |

| \* 1080 SUBW Immediate 5 (4) 4 |

| \* 1081 CMPW Immediate 5 (4) 4 |

| \* 1082 SBCD Immediate 5 (4) 4 |

| 1083 CMPD Immediate 5 (4) 4 |

| \* 1084 ANDD Immediate 5 (4) 4 |

| \* 1085 BITD Immediate 5 (4) 4 |

| \* 1086 LDW Immediate 5 (4) 4 |

| \* 1088 EORD Immediate 5 (4) 4 |

| \* 1089 ADCD Immediate 5 (4) 4 |

| \* 108A ORD Immediate 5 (4) 4 |

| \* 108B ADDW Immediate 5 (4) 4 |

| 108C CMPY Immediate 5 (4) 4 |

| 108E LDY Immediate 5 (4) 4 |

| \* 1090 SUBW Direct 7 (5) 3 |

| \* 1091 CMPW Direct 7 (5) 3 |

| \* 1092 SBCD Direct 7 (5) 3 |

| 1093 CMPD Direct 7 (5) 3 |

| \* 1094 ANDD Direct 7 (5) 3 |

| \* 1095 BITD Direct 7 (5) 3 |

| \* 1096 LDW Direct 6 (5) 3 |

| \* 1097 STW Direct 6 (5) 3 |

| \* 1098 EORD Direct 7 (5) 3 |

| \* 1099 ADCD Direct 7 (5) 3 |

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Opcode and Mnemonics opcode reference table Page 16

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| \* 109A ORD Direct 7 (5) 3 |

| \* 109B ADDW Direct 7 (5) 3 |

| 109C CMPY Direct 7 (5) 3 |

| 109E LDY Direct 6 (5) 3 |

| 109F STY Direct 6 (5) 3 |

| \* 10A0 SUBW Indexed 7+ (6+) 3+ |

| \* 10A1 CMPW Indexed 7+ (6+) 3+ |

| \* 10A2 SBCD Indexed 7+ (6+) 3+ |

| 10A3 CMPD Indexed 7+ (6+) 3+ |

| \* 10A4 ANDD Indexed 7+ (6+) 3+ |

| \* 10A5 BITD Indexed 7+ (6+) 3+ |

| \* 10A6 LDW Indexed 6+ 3+ |

| \* 10A7 STW Indexed 6+ 3+ |

| \* 10A8 EORD Indexed 7+ (6+) 3+ |

| \* 10A9 ADCD Indexed 7+ (6+) 3+ |

| \* 10AA ORD Indexed 7+ (6+) 3+ |

| \* 10AB ADDW Indexed 7+ (6+) 3+ |

| 10AC CMPY Indexed 7+ (6+) 3+ |

| 10AE LDY Indexed 6 3+ |

| 10AF STY Indexed 6 3+ |

| \* 10B0 SUBW Extended 8 (6) 4 |

| \* 10B1 CMPW Extended 8 (6) 4 |

| \* 10B2 SBCD Extended 8 (6) 4 |

| 10B3 CMPD Extended 8 (6) 4 |

| \* 10B4 ANDD Extended 8 (6) 4 |

| \* 10B5 BITD Extended 8 (6) 4 |

| \* 10B6 LDW Extended 7 (6) 4 |

| \* 10B7 STW Extended 7 (6) 4 |

| \* 10B8 EORD Extended 8 (6) 4 |

| \* 10B9 ADCD Extended 8 (6) 4 |

| \* 10BA ORD Extended 8 (6) 4 |

| \* 10BB ADDW Extended 8 (6) 4 |

| 10BC CMPY Extended 8 (6) 4 |

| 10BE LDY Extended 7 (6) 4 |

| 10BF STY Extended 7 (6) 4 |

| 10CE LDS Immediate 4 4 |

| \* 10DC LDQ Direct 8 (7) 3 |

| \* 10DD STQ Direct 8 (7) 3 |

| 10DE LDS Direct 6 (5) 3 |

| 10DF STS Direct 6 (5) 3 |

| \* 10DC LDQ Indexed 8+ 3+ |

| \* 10DD STQ Indexed 8+ 3+ |

| 10EE LDS Indexed 6+ 3+ |

| 10EF STS Indexed 6+ 3+ |

| \* 10DC LDQ Extended 9 (8) 4 |

| \* 10DD STQ Extended 9 (8) 4 |

| 10FE LDS Extended 7 (6) 4 |

| 10FF STS Extended 7 (6) 4 |

| \* 1130 BAND Memory 7 (6) 4 |

| \* 1131 BIAND Memory 7 (6) 4 |

| \* 1132 BOR Memory 7 (6) 4 |

| \* 1133 BIOR Memory 7 (6) 4 |

| \* 1134 BEOR Memory 7 (6) 4 |

| \* 1135 BIEOR Memory 7 (6) 4 |

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Opcode and Mnemonics opcode reference table Page 17

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| \* 1136 LDBT Memory 7 (6) 4 |

| \* 1137 STBT Memory 8 (7) 4 |

| \* 1138 TFM R+,R+ Register 6+3n 3 |

| \* 1139 TFM R-,R- Register 6+3n 3 |

| \* 113A TFM R+,R Register 6+3n 3 |

| \* 113B TFM R,R+ Register 6+3n 3 |

| \* 113C BITMD Immediate 4 3 |

| \* 113D LDMD Immediate 5 5 |

| 113F SWI2 Inherent 20 ( ) 2 |

| \* 1143 COME Inherent 3 (2) 2 |

| \* 114A DECE Inherent 3 (2) 2 |

| \* 114C INCE Inherent 3 (2) 2 |

| \* 114D TSTE Inherent 3 (2) 2 |

| \* 114F CLRE Inherent 3 (2) 2 |

| \* 1153 COMF Inherent 3 (2) 2 |

| \* 115A DECF Inherent 3 (2) 2 |

| \* 115C INCF Inherent 3 (2) 2 |

| \* 115D TSTF Inherent 3 (2) 2 |

| \* 115F CLRF Inherent 3 (2) 2 |

| 11AC CMPS Indexed 7 ( ) 3 |

| \* 1180 SUBE Immediate 3 3 |

| \* 1181 CMPE Immediate 3 3 |

| 1183 CMPU Immediate 5 (4) 4 |

| \* 1186 LDE Immediate 3 3 |

| \* 118B ADDE Immediate 3 3 |

| 118C CMPS Immediate 5 (4) 4 |

| \* 118D DIVD Immediate 25 4 |

| \* 118E DIVQ Immediate 36 4 |

| \* 118F MULD Immediate 28 4 |

| \* 1190 SUBE Direct 5 (4) 3 |

| \* 1191 CMPE Direct 5 (4) 3 |

| 1193 CMPU Direct 7 (5) 3 |

| \* 1196 LDE Direct 5 (4) 3 |

| \* 1197 STE Direct 5 (4) 3 |

| \* 119B ADDE Direct 5 (4) 3 |

| 119C CMPS Direct 7 (5) 3 |

| \* 119D DIVD Direct 27 (26) 3 |

| \* 119E DIVQ Direct 36 (35) 3 |

| \* 119F MULD Direct 30 (29) 3 |

| \* 11A0 SUBE Indexed 5+ 3+ |

| \* 11A1 CMPE Indexed 5+ 3+ |

| 11A3 CMPU Indexed 7+ (6+) 3+ |

| \* 11A6 LDE Indexed 5+ 3+ |

| \* 11A7 STE Indexed 5+ 3+ |

| \* 11AB ADDE Indexed 5+ 3+ |

| 11AC CMPS Indexed 7+ (6+) 3+ |

| \* 11AD DIVD Indexed 27+ 3+ |

| \* 11AE DIVQ Indexed 36+ 3+ |

| \* 11AF MULD Indexed 30+ 3+ |

| \* 11B0 SUBE Extended 6 (5) 4 |

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Opcode and Mnemonics opcode reference table Page 18

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| |

| Opcode Mnemonic Mode Cycles Length |

| (\* 6309) |

|----------------------------------------------------------------|

| \* 11B1 CMPE Extended 6 (5) 4 |

| 11B3 CMPU Extended 8 (6) 4 |

| \* 11B6 LDE Extended 6 (5) 4 |

| \* 11B7 STE Extended 6 (5) 4 |

| \* 11BB ADDE Extended 6 (5) 4 |

| 11BC CMPS Extended 8 (6) 4 |

| \* 11BD DIVD Extended 28 (27) 4 |

| \* 11BE DIVQ Extended 37 (36) 4 |

| \* 11BF MULD Extended 31 (30) 4 |

| \* 11C0 SUBF Immediate 3 3 |

| \* 11C1 CMPF Immediate 3 3 |

| \* 11C6 LDF Immediate 3 3 |

| \* 11CB ADDF Immediate 3 3 |

| \* 11D0 SUBF Direct 5 (4) 3 |

| \* 11D1 CMPF Direct 5 (4) 3 |

| \* 11D6 LDF Direct 5 (4) 3 |

| \* 11D7 STF Direct 5 (4) 3 |

| \* 11DB ADDF Direct 5 (4) 3 |

| \* 11E0 SUBF Indexed 5+ 3+ |

| \* 11E1 CMPF Indexed 5+ 3+ |

| \* 11E6 LDF Indexed 5+ 3+ |

| \* 11E7 STF Indexed 5+ 3+ |

| \* 11EB ADDF Indexed 5+ 3+ |

| \* 11F0 SUBF Extended 6 (5) 4 |

| \* 11F1 CMPF Extended 6 (5) 4 |

| \* 11F6 LDF Extended 6 (5) 4 |

| \* 11F7 STF Extended 6 (5) 4 |

| \* 11FB ADDF Extended 6 (5) 4 |

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Mnemonics Reference Table Page 19

Mnemonics Table

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| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ + | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

| ABX | | | | | 3A 3/1 1 |

| ADCA | 89 2 2 | 99 4/3 2 | A9 4+ 2+| B9 5/4 3 | |

| ADCB | C9 2 2 | D9 4/3 2 | E9 4+ 2+| F9 5/3 3 | |

|\*ADCD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 89 | 99 | A9 | B9 | |

|--------+------------+------------+------------+------------+------------|

| ADDA | 8B 2 2 | 9B 4/3 2 | AB 4+ 2+| BB 5/4 3 | |

| ADDB | CB 2 2 | DB 4/3 2 | EB 4+ 2+| FB 5/4 3 | |

| ADDD | C3 4/3 3 | D3 6/4 2 | E3 6+/5+ 2+| F3 7/5 3 | |

|\*ADDE | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | 8B | 9B | AB | BB | |

|\*ADDF | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | CB | DB | EB | FB | |

|\*ADDW | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 8B | 9B | AB | BB | |

|--------+------------+------------+------------+------------+------------|

|\*AIM | | 02 6 3 | 62 7+ 3+| 72 7 4 | |

|--------+------------+------------+------------+------------+------------|

| ANDA | 84 2 2 | 94 4/3 2 | A4 4+ 2 | B4 5/4 3 | |

| ANDB | C4 2 2 | D4 4/3 2 | E4 4+ 2 | F4 5/4 3 | |

| ANDCC | 1C 3 2 | | | | |

|\*ANDD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 84 | 94 | A4 | B4 | |

|--------+------------+------------+------------+------------+------------|

| ASLA | | | | | 48 2/1 1 |

| ASLB | | | | | 58 2/1 1 |

|\*ASLD | | | | | 10 3/2 2 |

| | | | | | 48 |

| ASL | | 08 6/5 2 | 68 6+ 2+| 78 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| ASRA | | | | | 47 2/1 1 |

| ASRB | | | | | 57 2/1 1 |

|\*ASRD | | | | | 10 3/2 1 |

| | | | | | 47 |

| ASR | | 07 6/6 2 | 67 6+ 2+| 77 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| BITA | 85 2 2 | 95 4/3 2 | A5 4+ 2+| B5 5/4 3 | |

| BITB | C5 2 2 | D5 4/3 2 | E5 4+ 2+| F5 5/4 3 | |

| BITD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 85 | 95 | A5 | B5 | |

| BITMD | 11 4 3 | | | | |

| | 3C | | | | |

|--------+------------+------------+------------+------------+------------|

| CLRA | | | | | 4F 2/1 1 |

| CLRB | | | | | 5F 2/1 1 |

|\*CLRD | | | | | 10 3/2 2 |

| | | | | | 4F |

|\*CLRE | | | | | 11 3/2 2 |

| | | | | | 4F |

|\*CLRF | | | | | 11 3/2 2 |

| | | | | | 5F |

|\*CLRW | | | | | 10 3/2 2 |

| | | | | | 5F |

| CLR | | 0F 6/5 2 | 6F 6+ 2+| 7F 7/6 3 | |

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Mnemonics Reference Table Page 20

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| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ + | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

| CMPA | 81 2 2 | 91 4/3 2 | A1 4+ 2+| B1 5/4 3 | |

| CMPB | C1 2 2 | D1 4/3 2 | E1 4+ 2+| F1 5/4 3 | |

| CMPD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 83 | 93 | A3 | B3 | |

|\*CMPE | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | 81 | 91 | A1 | B1 | |

|\*CMPF | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | C1 | D1 | E1 | F1 | |

| CMPS | 11 5/4 4 | 11 7/5 3 | 11 7+/6+ 3+| 11 8/6 4 | |

| | 8C | 9C | AC | BC | |

| CMPU | 11 5/4 4 | 11 7/5 3 | 11 7+/6+ 3+| 11 8/6 4 | |

| | 83 | 93 | A3 | B3 | |

|\*CMPW | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 81 | 91 | A1 | B1 | |

| CMPX | 8C 4/3 3 | 9C 6/4 2 | AC 6+/5+ 2+| BC 7/5 3 | |

| CMPY | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 8C | 9C | AC | BC | |

|--------+------------+------------+------------+------------+------------|

| COMA | | | | | 43 2/1 1 |

| COMB | | | | | 53 2/1 1 |

|\*COMD | | | | | 10 3/2 2 |

| | | | | | 43 |

|\*COME | | | | | 11 3/2 2 |

| | | | | | 43 |

|\*COMF | | | | | 11 3/2 2 |

| | | | | | 53 |

|\*COMW | | | | | 10 3/2 2 |

| | | | | | 53 |

| COM | | 03 6/5 2 | 63 6+ 2+| 73 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| CWAI | 3C 22/20 2 | | | | |

|--------+------------+------------+------------+------------+------------|

| DAA | | | | | 19 2/1 1 |

|--------+------------+------------+------------+------------+------------|

| DECA | | | | | 4A 2/1 1 |

| DECB | | | | | 5A 2/1 1 |

|\*DECD | | | | | 10 3/2 2 |

| | | | | | 4A |

|\*DECE | | | | | 11 3/2 2 |

| | | | | | 4A |

|\*DECF | | | | | 11 3/2 2 |

| | | | | | 5A |

|\*DECW | | | | | 10 3/2 2 |

| | | | | | 5A |

| DEC | | 0A 6/5 2 | 6A 6+ 2+| 7A 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

|\*DIVD | 11 25 3 | 11 27/26 3 | 11 27+ 3+| 11 28/27 4 | |

| | 8D | 9D | AD | BD | |

|\*DIVQ | 11 34 4 | 11 36/35 3 | 11 36+ 3+| 11 37/36 4 | |

| | 8E | 9E | AE | BE | |

|--------+------------+------------+------------+------------+------------|

|\*EIM | | 05 6 3 | 65 7+ 3+| 75 7 4 | |

|--------+------------+------------+------------+------------+------------|

| EORA | 88 2 2 | 98 4/3 2 | A8 4+ 2+| B8 5/4 3 | |

| EORB | C8 2 # | D8 4/3 2 | E8 4+ 2+| F8 5/4 3 | |

|\*EORD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 88 | 98 | A8 | B8 | |

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Mnemonics Reference Table Page 21

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| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ + | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

| EXG | 1E 8/5 2 | | | | |

|--------+------------+------------+------------+------------+------------|

| INCA | | | | | 4C 2/1 1 |

| INCB | | | | | 5C 2/1 1 |

|\*INCD | | | | | 10 3/2 2 |

| | | | | | 4C |

|\*INCE | | | | | 11 3/2 2 |

| | | | | | 4C |

|\*INCF | | | | | 11 3/2 2 |

| | | | | | 5C |

|\*INCW | | | | | 10 3/2 2 |

| | | | | | 5C |

| INC | | 0C 6/5 2 | 6C 6+ 2+| 7C 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| JMP | | 0E 3/2 2 | 6E 3+ 2+| 7E 4/3 3 | |

|--------+------------+------------+------------+------------+------------|

| JSR | | 9D 7/6 2 | AD 7+/6+ 2+| BD 8/7 3 | |

|--------+------------+------------+------------+------------+------------|

| LDA | 86 2 2 | 96 4/3 2 | A6 4+ 2+| B6 5/4 3 | |

| LDB | C6 2 2 | D6 4/3 2 | E6 4+ 2+| F6 5/4 3 | |

| LDD | CC 3 3 | DC 5/4 2 | EC 5+ 2+| FC 6/5 3 | |

|\*LDE | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | 86 | 96 | A6 | B6 | |

|\*LDF | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | C6 | D6 | E6 | F6 | |

|\*LDQ | CD 5 5 | 10 8/7 3 | 10 8+ 3+| 10 9/8 4 | |

| | | DC | EC | FC | |

| LDS | 10 4 4 | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | CE | DE | EE | FE | |

| LDU | CE 3 3 | DE 5/4 2 | EE 5+ 2+| FE 6/5 3 | |

|\*LDW | 10 4 4 | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | 86 | 96 | A6 | B6 | |

| LDX | 8E 3 3 | 9E 5/4 2 | AE 5+ 2+| BE 6/5 3 | |

| LDY | 10 4 4 | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | 8E | 9E | AE | BE | |

|\*LDMD | 11 5 3 | | | | |

| | 3D | | | | |

|--------+------------+------------+------------+------------+------------|

| LEAS | | | 32 4+ 2+| | |

| LEAU | | | 33 4+ 2+| | |

| LEAX | | | 30 4+ 2+| | |

| LEAY | | | 31 4+ 2+| | |

|--------+------------+------------+------------+------------+------------|

| LSLA/LSLB/LSLD/LSL - Same as ASL |

|--------+------------+------------+------------+------------+------------|

| LSRA | | | | | 44 2/1 1 |

| LSRB | | | | | 54 2/1 1 |

|\*LSRD | | | | | 10 3/2 2 |

| | | | | | 44 |

|\*LSRW | | | | | 10 3/2 2 |

| | | | | | 54 |

| LSR | | 04 6/5 2 | 64 6+ 2+| 74 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| MUL | | | | | 3D 11/10 1 |

|\*MULD | 11 28 4 | 11 30/29 3 | 11 30+ 3+| 11 31/30 4 | |

| | 8F | 9F | AF | BF | |

-------------------------------------------------------------------------

Mnemonics Reference Table Page 22

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ + | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

| NEGA | | | | | 40 2/1 1 |

| NEGB | | | | | 50 2/1 1 |

|\*NEGD | | | | | 10 3/2 2 |

| | | | | | 40 |

| NEG | | 00 6/5 2 | 60 6+ 2+| 70 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| NOP | | | | | 12 2/1 1 |

|--------+------------+------------+------------+------------+------------|

|\*OIM | | 01 6 3 | 61 7+ 3+| 71 7 4 | |

|--------+------------+------------+------------+------------+------------|

| ORA | 8A 2 2 | 9A 4/3 2 | AA 4+ 2 | BA 5/4 3 | |

| ORB | CA 2 2 | DA 4/3 2 | EA 4+ 2 | FA 5/4 3 | |

| ORCC | 1A 3/2 2 | | | | |

|\*ORD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 8A | 9A | AA | BA | |

|--------+------------+------------+------------+------------+------------|

| PSHS | 34 5+/4+ 2 | | | | |

| PSHU | 36 5+/4+ 2 | | | | |

|\*PSHSW | 10 6 2 | | | | |

| | 38 6 2 | | | | |

|\*PSHUW | 10 6 2 | | | | |

| | 3A 6 2 | | | | |

|--------+------------+------------+------------+------------+------------|

| PULS | 35 5+/4+ 2 | | | | |

| PULU | 37 5+/4+ 2 | | | | |

|\*PULSW | 10 6 2 | | | | |

| | 39 | | | | |

|\*PULUW | 10 6 2 | | | | |

| | 3B | | | | |

|--------+------------+------------+------------+------------+------------|

| ROLA | | | | | 49 2/1 1 |

| ROLB | | | | | 59 2/1 1 |

|\*ROLD | | | | | 10 3/2 2 |

| | | | | | 49 |

|\*ROLW | | | | | 10 3/2 2 |

| | | | | | 59 |

| ROL | | 09 6/5 2 | 69 6+ 2+| 79 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| RORA | | | | | 46 2/1 1 |

| RORB | | | | | 56 2/1 1 |

|\*RORD | | | | | 10 3/2 2 |

| | | | | | 46 |

|\*RORW | | | | | 10 3/2 2 |

| | | | | | 56 |

| ROR | | 06 6/5 2 | 66 6+ 2+| 76 7/6 3 | |

|--------+------------+------------+------------+------------+------------|

| RTI | | | | | 3B 6/17 1 |

| | | | | | 15/17 |

|--------+------------+------------+------------+------------+------------|

| RTS | | | | | 39 5/4 1 |

|--------+------------+------------+------------+------------+------------|

| SBCA | 82 2 2 | 92 4/3 2 | A2 4+ 2+| B2 5/4 3 | |

| SBCB | C2 2 2 | D2 4/3 2 | E2 4+ 2+| F2 5/2 3 | |

|\*SBCD | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 82 | 92 | A2 | B2 | |

|--------+------------+------------+------------+------------+------------|

| SEX | | | | | 1D 2/1 1 |

|\*SEXW | | | | | 14 4 1 |

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Mnemonics Reference Table Page 23

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ + | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

| STA | | 97 4/3 2 | A7 4+ 2+| B7 5/4 3 | |

| STB | | D7 4/3 2 | E7 4+ 2+| F7 5/4 3 | |

| STD | | DD 5/4 2 | ED 5+ 2+| FD 6/5 3 | |

|\*STE | | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | | 97 | A7 | B7 | |

|\*STF | | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | | D7 | E7 | F7 | |

|\*STQ | | 10 8/7 3 | 10 8+ 3+| 10 9/8 4 | |

| | | DD | ED | FD | |

|\*STS | | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | | DF | EF | FF | |

| STU | | DF 5/4 2 | EF 5+ 2+| FF 6/5 3 | |

|\*STW | | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | | 97 | A7 | B7 | |

| STX | | 9F 5/4 2 | AF 5+ 2+| BF 6/5 3 | |

| STY | | 10 6/5 3 | 10 6+ 3+| 10 7/6 4 | |

| | | 9F | AF | BF | |

|--------+------------+------------+------------+------------+------------|

| SUBA | 80 2 2 | 90 4/3 2 | A0 4+ 2+| B0 5/4 3 | |

| SUBB | C0 2 2 | D0 4/3 2 | E0 4+ 2+| F0 5/4 3 | |

| SUBD | 83 4/3 3 | 93 6/4 3 | A3 6+/5+ 2+| B3 7/5 3 | |

|\*SUBE | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | 80 | 90 | A0 | B0 | |

|\*SUBF | 11 3 3 | 11 5/4 3 | 11 5+ 3+| 11 6/5 4 | |

| | C0 | D0 | E0 | F0 | |

|\*SUBW | 10 5/4 4 | 10 7/5 3 | 10 7+/6+ 3+| 10 8/6 4 | |

| | 80 | 90 | A0 | B0 | |

|--------+------------+------------+------------+------------+------------|

| SWI | | | | | 3F 19/21 1 |

| SWI2 | | | | | 10 20/22 2 |

| | | | | | 3F |

| SWI3 | | | | | 11 20/22 2 |

| | | | | | 3F |

|--------+------------+------------+------------+------------+------------|

| SYNC | | | | | 13 2+/1+ 1 |

|--------+------------+------------+------------+------------+------------|

| TFR 1| 1F 6/4 2 | | | | |

|--------+------------+------------+------------+------------+------------|

|\*TIM | | 0B 6 3 | 6B 7+ 3+| 7B 5 4 | |

|--------+------------+------------+------------+------------+------------|

| TSTA | | | | | 4D 2/1 1 |

| TSTB | | | | | 5D 2/1 1 |

|\*TSTD | | | | | 10 3/2 2 |

| | | | | | 4D |

|\*TSTE | | | | | 11 3/2 2 |

| | | | | | 4D |

|\*TSTF | | | | | 11 3/2 2 |

| | | | | | 5D |

|\*TSTW | | | | | 10 3/2 2 |

| | | | | | 5D |

| TST | | 0D 6/4 2 | 6D 6+/5+ 2+| 7D 7/5 3 | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Mnemonics Reference Table Page 24

Branch Instructions

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Mnem | Immed. | | Mnem | Immed. | | Mnem | Immed. |

| | | | | | | | |

| | OP ~/~ # | | | OP ~/~ # | | | OP ~/~ # |

|--------+------------+ |--------+------------+ |--------+------------+

| BCC | 24 3 2 | | BLE | 2F 3 2 | | BPL | 2A 3 2 |

| LBCC | 10 5/6 4 | | LBLE | 10 5/6 4 | | LBPL | 10 5/6 4 |

| | 24 | | | 2F | | | 2A |

| BCS | 25 3 2 | | BLO | 25 3 2 | | BRA | 20 3 2 |

| LBCS | 10 5/6 4 | | LBLO | 10 5/6 4 | | LBRA | 16 5/4 3 |

| | 25 | | | 25 | | | |

| BEQ | 27 3 2 | | BLS | 23 3 2 | | BRN | 21 3 2 |

| LBEQ | 10 5/6 4 | | LBLS | 10 5/6 4 | | LBRN | 10 5/6 4 |

| | 27 | | | 23 | | | 21 |

| BGE | 2C 3 2 | | BLT | 2D 3 2 | | BSR | 8D 7/6 2 |

| LBGE | 10 5/6 4 | | LBLT | 10 5/6 4 | | LBSR | 17 9/7 3 |

| | 2C | | | 2D | | | |

| BGT | 2E 3 2 | | BMI | 28 3 2 | | BVC | 28 3 2 |

| LBGT | 10 5/6 4 | | LBMI | 10 5/6 4 | | LBVC | 10 5/6 4 |

| | 2E | | | 28 | | | 28 |

| BHI | 22 3 2 | | BNE | 26 3 2 | | BVS | 29 3 2 |

| LBHI | 10 5/6 4 | | LBNE | 10 5/6 4 | | LBVS | 10 5/6 4 |

| | 22 | | | 26 | | | 29 |

| BHS | 2F 3 2 | --------------------- ---------------------

| LBHS | 10 5/6 4 |

| | 2F |

---------------------

Bit Transfer/Manipulation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Mnem | Direct | Post-Byte

| | |

| | OP ~/~ # | --------------------------

|--------+------------| | 7 6 | 5 4 3 | 2 1 0 |

|\*BAND | 11 7/6 4 | --------------------------

| | 30 |

|\*BIAND | 11 7/6 4 | Bits 7 and 6: Register

| | 31 |

|\*BOR | 11 7/6 4 | 00 - CC 10 - B

| | 32 | 01 - A 11 - Unused

|\*BIOR | 11 7/6 4 |

| | 33 | Bits 5, 4 and 3: Source Bit

|\*BEOR | 11 7/6 4 |

| | 34 | Bits 2, 1 and 0: Destination bit

|\*BIEOR | 11 7/6 4 |

| | 35 |

|\*LDBT | 11 7/6 4 | Source/Destination Bit in binary form:

| | 36 |

|\*STBT | 11 8/7 4 | 0 - 000 2 - 010 5 - 100 6 - 110

| | 37 | 1 - 001 3 - 011 5 - 101 7 - 111

---------------------

Both the source and destination bit portions of the post-byte are

looked at by the 6309 as the actual bit NUMBER to transfer/store. Use the

binary equivalent of the numbers (0 thru 7) and position them into the bit

area of the post byte.

Mnemonics Reference Table Page 25

Logical Memory Operations

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Mnem | Immed. | Direct | Indexed | Extended | Inherent |

| | | | | | |

| | OP ~/~ # | OP ~/~ # | OP ~/~ # | OP ~/~ # | OP ~/~ # |

|--------+------------+------------+------------+------------+------------|

|\*AIM | | 02 6 3 | 62 7+ 3+| 72 7 4 | |

|\*EIM | | 05 6 3 | 65 7+ 3+| 75 7 4 | |

|\*OIM | | 01 6 3 | 61 7+ 3+| 71 7 4 | |

|\*TIM | | 0B 6 3 | 6B 7+ 3+| 7B 5 4 | |

-------------------------------------------------------------------------

Inter-Register Instructions Transfer/Exchange and

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Inter-Register Post Byte

| Mnem | Forms | Register |

| | | | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| | | OP ~/~ + | | | | | | | | | |

|--------+------------+------------| | SOURCE | DESTINATION |

|\*ADCR | R0,R1 | 10 4 3 | |\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|

| | | 31 | HI NIBBLE | LOW NIBBLE

|\*ADDR | R0,R1 | 10 4 3 |

| | | 30 |

|\*ANDR | R0,R1 | 10 4 3 | Register Field

| | | 34 | (source or destination)

|\*CMPR | R0,R1 | 10 4 3 |

| | | 37 | 0000 - D (A:B) 1000 - A

|\*EORR | R0,R1 | 10 4 3 | 0001 - X 1001 - B

| | | 36 | 0010 - Y 1010 - CCR

| EXG | R0,R1 | 1E 8/5 2 | 0011 - U 1011 - DPR

|\*ORR | R0,R1 | 10 4 3 | 0100 - S 1100 - 0

| | | 35 | 0101 - PC 1101 - 0

|\*SBCR | R0,R1 | 10 4 3 | 0110 - W 1110 - E

| | | 33 | 0111 - V 1111 - F

|\*SUBR | R0,R1 | 10 4 3 |

| | | 32 |

| TFR | R0,R1 | 1F 6/4 2 | The results of all Inter-Register

|\*TFM | R0+,R1+ | 11 6+3n 3 | operations are passed into R1 with

| | | 38 | the exception of EXG which exchanges

|\*TFM | R0-,R1- | 11 6+3n 3 | the values of registers and the TFR

| | | 39 | block transfers.

|\*TFM | R0+,R1 | 11 6+3n 3 |

| | | 3A | The register field codes %1100 and

|\*TFM | R0,R1+ | 11 6+3n 3 | %1101 are both zero registers. They

| | | 3B | can be used as source or destination.

----------------------------------

Mnemonics Reference Table Page 26

Indexed Address Modes and Post byte Information

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| Non-Indirect Modes |

|--------------------------------------------------------------------------|

| Type | Forms | Assembler | PostByte | +/+ | + |

| | | form | OP code | ~/~ | # |

|-------------------------+---------------+-----------+----------+-----+---|

| Constant offset from R | No offset | ,R | 1rr00100 | 0 | 0 |

| | 5 bit offset | n,R | 0rrnnnnn | 1 | 0 |

| | 8 bit offset | n,R | 1rr01000 | 1 | 1 |

| | 16 bit offset | n,R | 1rr01001 | 4/3 | 2 |

|-------------------------+---------------+-----------+----------+-----+---|

| Accumulator offset | A - Register | A,R | 1rr00110 | 1 | 0 |

| from R (Twos complement | B - Register | B,R | 1rr00101 | 1 | 0 |

|\*offset) | E - Register | E,R | 1rr00111 | 1 | 0 |

|\* | F - Register | F,R | 1rr01010 | 1 | 0 |

| | D - Register | D,R | 1rr01011 | 4/2 | 0 |

|\* | W - Register | W,R | 1rr01110 | 4/1 | 0 |

|-------------------------+---------------+-----------+----------+-----+---|

| Auto increment and | Increment 1 | ,R+ | 1rr00000 | 2/1 | 0 |

| decrement of R | Increment 2 | ,R++ | 1rr00001 | 3/2 | 0 |

| | Decrement 1 | ,-R | 1rr00010 | 2/1 | 0 |

| | Decrement 2 | ,--R | 1rr00011 | 3/2 | 0 |

|-------------------------+---------------+-----------+----------+-----+---|

| Constant offset from PC | 8 bit offset | n,PC | 1xx01100 | 1 | 1 |

| (Twos complement offset)| 16 bit offset | n,PC | 1xx01101 | 5/3 | 2 |

|-------------------------+---------------+-----------+----------+-----+---|

|\*Relative to W | No Offset | ,W | 10001111 | 0 | 0 |

|\*(Twos complement offset)| 16 bit offset | n,W | 10101111 | 5/2 | 2 |

|\* AutoIncrement W | Increment 2 | ,W++ | 11001111 | 3/1 | 0 |

|\* AutoDecrement W | Decrement 2 | ,--W | 11101111 | 3/1 | 0 |

|--------------------------------------------------------------------------|

| Indirect Modes |

|-------------------------+---------------+-----------+------------+---+---|

| Constant offset from R | No offset | [ ,R] | 1rr10100 | 3 | 0 |

| | 5 bit offset | [n,R] | Defaults to 8 bit |

| | 8 bit offset | [n,R] | 1rr11000 | 4 | 1 |

| | 16 bit offset | [n,R] | 1rr11001 | 7 | 2 |

|-------------------------+---------------+-----------+------------+---+---|

| Accumulator offset | A - Register | [A,R] | 1rr10110 | 4 | 0 |

| from R (Twos complement | B - Register | [B,R] | 1rr10101 | 4 | 0 |

|\*offset) | E - Register | [E,R] | 1rr10111 | 1 | 0 |

|\* | F - Register | [F,R] | 1rr11010 | 1 | 0 |

| | D - Register | [D,R] | 1rr11011 | 4 | 0 |

|\* | W - Register | [W,R] | 1rr11110 | 4 | 0 |

|-------------------------+---------------+-----------+------------+---+---|

| Auto Increment and | Increment 2 | [,R++] | 1rr10001 | 6 | 0 |

| decrement of R | Decrement 2 | [,--R] | 1rr10011 | 6 | 0 |

|-------------------------+---------------+-----------+------------+---+---|

| Constant offset from PC | 8 bit offset | [n,PC] | 1xx11100 | 4 | 1 |

| (Twos complement offset)| 16 bit offset | [n,PC] | 1xx11101 | 8 | 2 |

|-------------------------+---------------+-----------+------------+---+---|

| Extended indirect | 16 bit address| [n] | 10011111 | 5 | 2 |

|-------------------------+---------------+-----------+------------+---+---|

|\*Relative to W | No Offset | [,W] | 10010000 | 0 | 0 |

|\*(Twos complement offset)| 16 bit offset | [n,W] | 10110000 | 5 | 2 |

|\* AutoIncrement W | Increment 2 | [,W++] | 11010000 | 3 | 0 |

|\* AutoDecrement W | Decrement 2 | [,--W] | 11110000 | 3 | 0 |

--------------------------------------------------------------------------

rr = X, Y, U or S X = 00 Y = 01

xx = Doesn't care U = 10 S = 11

+ and + indicates the additional number of cycles and bytes for the

~ # particular variation

Mnemonics Reference Table Page 27

Register Descriptions

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| X - 16 bit index register |

| Y - 16 bit index register |

| U - 16 bit user-stack pointer |

| S - 16 bit system-stack pointer |

| PC - 16 bit program counter register |

|\*V - 16 bit variable register (inter-register instructions only) |

|\*0 - 8/16 bit zero register (inter-register instructions only) |

|-------------------------------------------------------------------------|

| A - 8 bit accumulator | |

| B - 8 bit accumulator | Accumulator structure map: |

|\*E - 8 bit accumulator | ----- ----- ----- ----- |

|\*F - 8 bit accumulator | | A | B | E | F | |

| D - 16 bit concatenated reg.(A B) | -----------+----------- |

|\*W - 16 bit concatenated reg.(E F) | | D | W | |

|\*Q - 32 bit concatenated reg.(D W) | ----------------------- |

|------------------------------------| | Q | |

|\*MD - 8 bit mode/error register | ----------------------- |

| CC - 8 bit condition code register | bit 31 24 15 8 0 |

| DP - 8 bit direct page register | |

-------------------------------------------------------------------------

\* Indicates new registers in 6309 CPU.

Push/Pull Order of Stack

Pull order Push/Pull Post byte

| -------------------------------

\|/ | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

' -------------------------------

CC | | | | | | | |\_\_\_\_CCr

A\ | | | | | | |\_\_\_\_\_\_\_\_A

B/ D\ Q | | | | | |\_\_\_\_\_\_\_\_\_\_\_\_B

E\ W/ | | | | |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_DPr

F/ | | | |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_X

DP | | |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Y

X-hi | |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_S/U

X-low |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_PC

Y-hi

Y-low

U/S-hi

U/S-low

PC-hi

PC-low

.

/|\

|

Push order

Condition Code Register

-------------------------------

| E | F | H | I | N | Z | V | C |

-------------------------------

Entire flag\_\_\_\_| | | | | | | |\_\_\_\_Carry flag

FIRQ mask\_\_\_\_\_\_\_\_| | | | | |\_\_\_\_\_\_\_\_Overflow

Half carry\_\_\_\_\_\_\_\_\_\_\_\_| | | |\_\_\_\_\_\_\_\_\_\_\_\_Zero

IRQ mask\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_| |\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Negative

The PSH(s,u) and PUL(s,u) instructions require one additional cycle for each byte pushed or pulled.

Alan DeKok's addition to the above Page 28

The new features of the 6309 are closely related to the changes in design from the 6809. The 6309 is micro-coded, which allowed the designers to easily add new instructions and registers. It also has a one byte pre-fetch 'cache', and an internal pipeline. The 'cache' enables the 6309 to execute instructions like 'lsld' (2-bytes) in one clock cycle. The design of the 6809 series allows them to read one byte per clock cycle MAXIMUM, but there is a catch. Most instructions take more clock cycles to execute than bytes they contain. While the 6309 is performing internal calculations, the 'cache' hardware goes and reads the next instruction byte, leaving only one additional byte to be read to execute the 'lsld'. Reading this byte requires one clock cycle, and then the instruction is executed while the CPU fetches the next instruction.

The 6309 has a true 16-bit internal design. e.g. the EXG instruction operates as

6809: read op-code

read inter-register byte (r0,r1)

r0\_high -> temp\_high

r0\_low -> temp\_low

r1\_high -> r0\_high

r1\_low -> r0\_low

r0\_high -> r1\_high

r0\_low -> r1\_low

8 actions, 8 clock cycles.

6809: read op-code

read inter-register byte (r0,r1)

r0 -> temp

r1 -> r0

r0 -> r1

5 actions, 5 clock cycles.

The 6309 native mode instruction execution clock lengths can be mostly accounted for by accounting for the pre-fetch cache and the internal 16-bit ALU.

TFM has some caveats. TFM r1-,r2- should NOT be used to setup the stack, as it's a POST-decrement instruction, not PRE-decrement.

Watch out for TFM r1,r2+ if you're reading from a peripheral. Why? The TFM uses the 1-byte 'cache' as an internal buffer for the byte that it's currently moving. The TFM instruction is interruptible (the only instruction that is), and code execution during the interrupt will destroy the byte in the cache.

On returning from the interrupt, the TFM will read the FROM address again to get the lost byte, which may be the wrong one. The visible effect of this is that block moves sometimes have a byte missing from the middle, and everything after that byte shifted down one address.

The W,E, and F registers do not have the full immediate addressing mode capabilities that D,A, and B do. SBC, AND, BIT, EOR, ADC, OR with E,F,W are available only in register-register mode. LSR, ROR, ROL are available for W but not for E,F. ASR, ASL, LSL, NEG do not exist at all for W,E,F.

ASL can sort of be implemented by doing a ADDR R1,R1. (see later)

You can also do things like 'leax u,x' by doing a ADDR u,x.

Sadly, many of the new 6309 instructions are useless in everyday life. The bit manipulation instructions are interesting, but slow and mostly of limited value. Same with much of the DIV/MUL higher math. The AIM, etc. are very useful, though.

Recommendations Page 29

Programmer recommendations

Try to stay away from using the W register. It's got another pre-byte (like instructions using 'Y' or 'S'), and is correspondingly larger and slower. E and F are best used mainly instead of pushing loop counters onto the stack when you're running out of registers.

The V register is mostly pointless. If you're doing context switches, it isn't saved across interrupts unless you do so manually. Shuffling data back and forth between other registers and V is a lot of trouble. Any math, etc. involving V is generally done much faster using a real register. After going through 1meg+ of 6309 assembly code which is everything from an OS kernel to serial drivers to graphics drivers, I've never seen a use for the V register.

Of course, you could put '$FFFF' into V, and have registers for reg-reg addressing modes with bits all zero (0), and another with bits all 1 (V).

Pseudo-nops: tfr 0,0; exg 0,0

Extremely small software timing loops with large delays may be generated by performing a 'LDW',and then 'TFM 0+,0+'.

Many programs can be executed in 6309 native mode by patching only the IRQ code, if it accesses the stack. A 'LDMD #$01' may be performed as soon as your program starts executing, and will see an immediate 10-15% speed increase. Software timing loops must be checked!

Opcodes Hitachi left out of the 6309: and some round-about equivalents:

E/F/W

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ADCr: ADCR 0,r

ANDr: ; ANDR V,r

ASLr/LSLr: ADDR r,r

ASRr

BITr

EORr

NEGr: COMr INCr

ORr

SBCr: SBCR Z,r

E/F

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LSRr

ROLr: ADCR r,r

RORr

Q (Long word =W1:W0)

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ADDQ: ADDW W0; ADCD W1

SUBQ: SUBW W0; SBCD W1

ASLQ: ASLW ; ROLD

ROLQ: ROLW ; ROLD

LSRQ: LSRD ; RORW

RORQ: RORD ; RORW

ASRQ: ASRD ; RORW

COMQ: COMD ; COMW

NEGQ: COMD ; COMW ; SBCR 0,D