

NASM 2.05 based x86 Instruction Reference

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Appendix A: x86 Instruction Reference

This appendix provides a complete list of the machine instructions which NASM will assemble, and a short description of the function of each one.

It is not intended to be an exhaustive documentation on the fine details of the instructions' function, such as which exceptions they can trigger: for such documentation, you should go to Intel's Web site, <http://developer.intel.com/design/Pentium4/manuals/>.

Instead, this appendix is intended primarily to provide documentation on the way the instructions may be used within NASM. For example, looking up `LOOP` will tell you that NASM allows `CX` or `ECX` to be specified as an optional second argument to the `LOOP` instruction, to enforce which of the two possible counter registers should be used if the default is not the one desired.

The instructions are not quite listed in alphabetical order, since groups of instructions with similar functions are lumped together in the same entry. Most of them don't move very far from their alphabetic position because of this.

A.1 Key to Operand Specifications

The instruction descriptions in this appendix specify their operands using the following notation:

- Registers: `reg8` denotes an 8-bit general purpose register, `reg16` denotes a 16-bit general purpose register, `reg32` a 32-bit one and `reg64` a 64-bit one. `fpureg` denotes one of the eight FPU stack registers, `mmxreg` denotes one of the eight 64-bit MMX registers, and `segreg` denotes a segment register. `xmmreg` denotes one of the 8, or 16 in x64 long mode, SSE XMM registers. In addition, some registers (such as `AL`, `DX`, `ECX` or `RAX`) may be specified explicitly.
- Immediate operands: `imm` denotes a generic immediate operand. `imm8`, `imm16` and `imm32` are used when the operand is intended to be a specific size. For some of these instructions, NASM allows an explicit specifier: for example, `ADD ESP, 16` could be interpreted as either `ADD r/m32, imm32` or `ADD r/m32, imm8`. If the immediate value is known during the assembling of that instruction, and fits in the range of a signed byte, then recent versions of NASM automatically optimise the instruction by choosing the latter form. It is allowed to specify `ADD ESP, BYTE 16` explicitly, which is needed to indicate that optimisation in case the immediate value is not known by NASM. (Eg, if it is a symbol reference only resolved by the linker.) Conversely, using the qualifiers `STRICT WORD` or `STRICT DWORD` forces NASM to use the longer forms. There is a special case of the allowance of an `imm64` for particular x64 versions of the `MOV` instruction.
- Memory references: `mem` denotes a generic memory reference; `mem8`, `mem16`, `mem32`, `mem64` and `mem80` are used when the operand needs to be a specific size. Again, a specifier is needed in some cases: `DEC [address]` is ambiguous and will be rejected

by NASM. You must specify `DEC BYTE [address]`, `DEC WORD [address]` or `DEC DWORD [address]` instead.

- Restricted memory references: one form of the `MOV` instruction allows a memory address to be specified *without* allowing the normal range of register combinations and effective address processing. This is denoted by `memoffs8`, `memoffs16`, `memoffs32` or `memoffs64`.
- Register or memory choices: many instructions can accept either a register *or* a memory reference as an operand. `r/m8` is shorthand for `reg8/mem8`; similarly `r/m16` and `r/m32`. On legacy x86 modes, `r/m64` is MMX-related, and is shorthand for `mmxreg/mem64`. When utilizing the x86-64 architecture extension, `r/m64` denotes use of a 64-bit GPR as well, and is shorthand for `reg64/mem64`.

A.2 Key to Opcode Descriptions

This appendix also provides the opcodes which NASM will generate for each form of each instruction. The opcodes are listed in the following way:

- A hex number, such as `3F`, indicates a fixed byte containing that number.
- A hex number followed by `+r`, such as `C8+r`, indicates that one of the operands to the instruction is a register, and the ‘register value’ of that register should be added to the hex number to produce the generated byte. For example, `EDX` has register value 2, so the code `C8+r`, when the register operand is `EDX`, generates the hex byte `CA`. Register values for specific registers are given in section A.2.1.
- A hex number followed by `+cc`, such as `70+cc`, indicates that the instruction name has a condition code suffix, and the numeric representation of the condition code should be added to the hex number to produce the generated byte. For example, the code `70+cc`, when the instruction contains the `NE` condition, generates the hex byte `75`. Condition codes and their numeric representations are given in section A.2.2. In one case, `70+(cc^1)` is given, which means that the inverse condition code is encoded in the byte.
- A slash followed by a digit, such as `/2`, indicates that one of the operands to the instruction is a memory address or register (denoted `mem` or `r/m`, with an optional size). This is to be encoded as an effective address, with a `ModR/M` byte, an optional `SIB` byte, and an optional displacement, and the spare (register) field of the `ModR/M` byte should be the digit given (which will be from 0 to 7, so it fits in three bits). The encoding of effective addresses is given in section A.2.6.
- The code `/r` combines the above two: it indicates that one of the operands is a memory address or `r/m`, and another is a register, and that an effective address should be generated with the spare (register) field in the `ModR/M` byte being equal to the ‘register value’ of the register operand. The encoding of effective addresses is given in section A.2.6; register values are given in section A.2.1.
- The codes `ib`, `iw` and `id` indicate that one of the operands to the instruction is an immediate value, and that this is to be encoded as a byte, little-endian word or little-endian doubleword respectively.
- The codes `rb`, `rw` and `rd` indicate that one of the operands to the instruction is an immediate value, and that the *difference* between this value and the address of the end of the instruction

is to be encoded as a byte, word or doubleword respectively. Where the form rw/rd appears, it indicates that either rw or rd should be used according to whether assembly is being performed in BITS 16 or BITS 32 state respectively.

- The codes ow and od indicate that one of the operands to the instruction is a reference to the contents of a memory address specified as an immediate value: this encoding is used in some forms of the MOV instruction in place of the standard effective-address mechanism. The displacement is encoded as a word or doubleword. Again, ow/od denotes that ow or od should be chosen according to the BITS setting.
- The codes $o16$ and $o32$ indicate that the given form of the instruction should be assembled with operand size 16 or 32 bits. In other words, $o16$ indicates a 66 prefix in BITS 32 state, but generates no code in BITS 16 state; and $o32$ indicates a 66 prefix in BITS 16 state but generates nothing in BITS 32.
- The codes $a16$ and $a32$, similarly to $o16$ and $o32$, indicate the address size of the given form of the instruction. Where this does not match the BITS setting, a 67 prefix is required. Please note that $a16$ is useless in long mode as 16-bit addressing is depreciated on the x86-64 architecture extension.

A.2.1 Register Values

Where an instruction requires a register value, it is already implicit in the encoding of the rest of the instruction what type of register is intended: an 8-bit general-purpose register, a segment register, a debug register, an MMX register, or whatever. Therefore there is no problem with registers of different types sharing an encoding value.

Please note that for the register classes listed below, the register extensions (REX) classes require the use of the REX prefix, which is only available when in long mode on an x86-64 processor. This pretty much goes for any register that has a number higher than 7.

The encodings for the various classes of register are:

- 8-bit general registers: AL is 0, CL is 1, DL is 2, BL is 3, AH is 4, CH is 5, DH is 6 and BH is 7. Please note that AH, BH, CH and DH are not addressable when using the REX prefix in long mode.
- 8-bit general register extensions (REX): SPL is 4, BPL is 5, SIL is 6, DIL is 7, R8B is 8, R9B is 9, R10B is 10, R11B is 11, R12B is 12, R13B is 13, R14B is 14 and R15B is 15.
- 16-bit general registers: AX is 0, CX is 1, DX is 2, BX is 3, SP is 4, BP is 5, SI is 6, and DI is 7.
- 16-bit general register extensions (REX): R8W is 8, R9W is 9, R10w is 10, R11W is 11, R12W is 12, R13W is 13, R14W is 14 and R15W is 15.
- 32-bit general registers: EAX is 0, ECX is 1, EDX is 2, EBX is 3, ESP is 4, EBP is 5, ESI is 6, and EDI is 7.
- 32-bit general register extensions (REX): R8D is 8, R9D is 9, R10D is 10, R11D is 11, R12D is 12, R13D is 13, R14D is 14 and R15D is 15.
- 64-bit general register extensions (REX): RAX is 0, RCX is 1, RDX is 2, RBX is 3, RSP is 4, RBP is 5, RSI is 6, RDI is 7, R8 is 8, R9 is 9, R10 is 10, R11 is 11, R12 is 12, R13 is

13, R14 is 14 and R15 is 15.

- Segment registers: ES is 0, CS is 1, SS is 2, DS is 3, FS is 4, and GS is 5.
- Floating-point registers: ST0 is 0, ST1 is 1, ST2 is 2, ST3 is 3, ST4 is 4, ST5 is 5, ST6 is 6, and ST7 is 7.
- 64-bit MMX registers: MM0 is 0, MM1 is 1, MM2 is 2, MM3 is 3, MM4 is 4, MM5 is 5, MM6 is 6, and MM7 is 7.
- 128-bit XMM (SSE) registers: XMM0 is 0, XMM1 is 1, XMM2 is 2, XMM3 is 3, XMM4 is 4, XMM5 is 5, XMM6 is 6 and XMM7 is 7.
- 128-bit XMM (SSE) register extensions (REX): XMM8 is 8, XMM9 is 9, XMM10 is 10, XMM11 is 11, XMM12 is 12, XMM13 is 13, XMM14 is 14 and XMM15 is 15.
- Control registers: CR0 is 0, CR2 is 2, CR3 is 3, and CR4 is 4.
- Control register extensions: CR8 is 8.
- Debug registers: DR0 is 0, DR1 is 1, DR2 is 2, DR3 is 3, DR6 is 6, and DR7 is 7.
- Test registers: TR3 is 3, TR4 is 4, TR5 is 5, TR6 is 6, and TR7 is 7.

(Note that wherever a register name contains a number, that number is also the register value for that register.)

A.2.2 Condition Codes

The available condition codes are given here, along with their numeric representations as part of opcodes. Many of these condition codes have synonyms, so several will be listed at a time.

In the following descriptions, the word ‘either’, when applied to two possible trigger conditions, is used to mean ‘either or both’. If ‘either but not both’ is meant, the phrase ‘exactly one of’ is used.

- O is 0 (trigger if the overflow flag is set); NO is 1.
- B, C and NAE are 2 (trigger if the carry flag is set); AE, NB and NC are 3.
- E and Z are 4 (trigger if the zero flag is set); NE and NZ are 5.
- BE and NA are 6 (trigger if either of the carry or zero flags is set); A and NBE are 7.
- S is 8 (trigger if the sign flag is set); NS is 9.
- P and PE are 10 (trigger if the parity flag is set); NP and PO are 11.
- L and NGE are 12 (trigger if exactly one of the sign and overflow flags is set); GE and NL are 13.
- LE and NG are 14 (trigger if either the zero flag is set, or exactly one of the sign and overflow flags is set); G and NLE are 15.

Note that in all cases, the sense of a condition code may be reversed by changing the low bit of the numeric representation.

For details of when an instruction sets each of the status flags, see the individual instruction, plus the Status Flags reference in section A.2.4

A.2.3 SSE Condition Predicates

The condition predicates for SSE comparison instructions are the codes used as part of the opcode, to determine what form of comparison is being carried out. In each case, the imm8 value is the final byte of the opcode encoding, and the predicate is the code used as part of the mnemonic for the instruction (equivalent to the "cc" in an integer instruction that used a condition code). The instructions that use this will give details of what the various mnemonics are, this table is used to help you work out details of what is happening.

Predic- cate	imm8 Encod- ing	Description	Relation where: A Is 1st Operand B Is 2nd Operand	Emula- tion	Result if NaN Operand	QNaN Signal Invalid
EQ	000B	equal	A = B		False	No
LT	001B	less-than	A < B		False	Yes
LE	010B	less-than- or-equal	A <= B		False	Yes
---	----	greater than	A > B	Swap Operands, Use LT	False	Yes
---	----	greater- than-or-equal	A >= B	Swap Operands, Use LE	False	Yes
UNORD	011B	unordered	A, B = Unordered		True	No
NEQ	100B	not-equal	A != B		True	No
NLT	101B	not-less- than	NOT(A < B)		True	Yes
NLE	110B	not-less- than-or- equal	NOT(A <= B)		True	Yes
---	----	not-greater than	NOT(A > B)	Swap Operands, Use NLT	True	Yes
---	----	not-greater than- or-equal	NOT(A >= B)	Swap Operands, Use NLE	True	Yes

ORD	111B	ordered	A , B = Ordered	False	No
-----	------	---------	-----------------	-------	----

The unordered relationship is true when at least one of the two values being compared is a NaN or in an unsupported format.

Note that the comparisons which are listed as not having a predicate or encoding can only be achieved through software emulation, as described in the "emulation" column. Note in particular that an instruction such as `greater-than` is not the same as `NLE`, as, unlike with the `CMP` instruction, it has to take into account the possibility of one operand containing a NaN or an unsupported numeric format.

A.2.4 Status Flags

The status flags provide some information about the result of the arithmetic instructions. This information can be used by conditional instructions (such as `JCC` and `CMOVCcC`) as well as by some of the other instructions (such as `ADC` and `INTO`).

There are 6 status flags:

CF - Carry flag.

Set if an arithmetic operation generates a carry or a borrow out of the most-significant bit of the result; cleared otherwise. This flag indicates an overflow condition for unsigned-integer arithmetic. It is also used in multiple-precision arithmetic.

PF - Parity flag.

Set if the least-significant byte of the result contains an even number of 1 bits; cleared otherwise.

AF - Adjust flag.

Set if an arithmetic operation generates a carry or a borrow out of bit 3 of the result; cleared otherwise. This flag is used in binary-coded decimal (BCD) arithmetic.

ZF - Zero flag.

Set if the result is zero; cleared otherwise.

SF - Sign flag.

Set equal to the most-significant bit of the result, which is the sign bit of a signed integer. (0 indicates a positive value and 1 indicates a negative value.)

OF - Overflow flag.

Set if the integer result is too large a positive number or too small a negative number (excluding the sign-bit) to fit in the destination operand; cleared otherwise. This flag indicates an overflow condition for signed-integer (two's complement) arithmetic.

A.2.5 Control Flags

Control Flags control aspects of the CPU's operation. In the 16-bit `FLAGS` register there are 3 such flags supported on all CPUs down to the 8086. They are:

A.2.5.1 IF - Interrupt flag

If set, enables hardware interrupts (IRQs) to be serviced by the CPU. Note that a MOV or POP to SS (see section A.5.156 and section A.5.244) disables hardware interrupt servicing and Trace flag tracing until after the next instruction, to allow atomic setting of both SS and SP at the same time. (There is a bug that makes this interrupt lockout fail on early 8086/8088 CPUs, which is why 8086-compatible code that sets SS and SP usually also clears the Interrupt flag explicitly first.)

A.2.5.2 DF - Direction flag

If set (called DN 'Down'), string operations such as MOVSx (section A.5.178) decrement their index registers, (E)SI and/or (E)DI. If clear (called UP), which is the usual default state, the string operations increment their index registers.

A.2.5.3 TF - Trace flag

If set, the CPU will invoke the Trace interrupt (interrupt 1) after the next instruction. There are a few special cases:

- Other interrupt invocations ignore the prior Trace flag status. That is, interrupts are not traced.
- After an interrupt invocation, the IRET (see section A.5.127) restores TF=1, but the Trace interrupt is then only called after another instruction. That is, the Trace interrupt 'fires too late'.
- When interrupt lockout due to MOV or POP to SS is in effect, no Trace interrupt is invoked.
- When a repeated string operation is invoked, at most one iteration is executed. (E)IP is reset in case more iterations are to be executed.

If (E)CX was greater than 1, and (for CMPSx and SCASx) after the first comparison the Zero flag is set or clear so as to repeat the operation, the (E)IP address is reset to point to the first prefix opcode and then a Trace interrupt is invoked.

When (E)CX was 1 prior to the instruction, or the Zero flag after the comparison indicates to break out of the repetition, then one iteration is executed, (E)IP is not reset, and a Trace interrupt is invoked.

When (E)CX was 0 prior to the instruction, then no iteration is executed, but (E)IP is still incremented to point after the instruction, and a Trace interrupt is invoked.

A.2.6 Effective Address Encoding: ModR/M and SIB

An effective address is encoded in up to three parts: a ModR/M byte, an optional SIB byte, and an optional byte, word or doubleword displacement field.

The ModR/M byte consists of three fields: the mod field, ranging from 0 to 3, in the upper two bits of the byte, the r/m field, ranging from 0 to 7, in the lower three bits, and the spare (register) field in the middle (bit 3 to bit 5). The spare field is not relevant to the effective address being encoded, and either contains an extension to the instruction opcode or the register value of another operand.

A.2.6.1 ModR/M encoding a register

The ModR/M system can be used to encode a direct register reference rather than a memory access. This is always done by setting the `mod` field to 3 and the `r/m` field to the register value of the register in question (it must be a general-purpose register, and the size of the register must already be implicit in the encoding of the rest of the instruction). In this case, the SIB byte and displacement field are both absent.

A.2.6.2 Memory a16 ModR/M encoding

In 16-bit addressing mode (either `BITS 16` with no 67 prefix, or `BITS 32` with a 67 prefix), the SIB byte is never used. The general rules for `mod` and `r/m` (there is an exception, given below) are:

- The `mod` field gives the length of the displacement field: 0 means no displacement, 1 means one byte, and 2 means two bytes.
- The `r/m` field encodes the combination of registers to be added to the displacement to give the accessed address: 0 means `BX+SI`, 1 means `BX+DI`, 2 means `BP+SI`, 3 means `BP+DI`, 4 means `SI` only, 5 means `DI` only, 6 means `BP` only, and 7 means `BX` only.

However, there is a special case:

- If `mod` is 0 and `r/m` is 6, the effective address encoded is not `[BP]` as the above rules would suggest, but instead `[disp16]`: the displacement field is present and is two bytes long, and no registers are added to the displacement.

Therefore the effective address `[BP]` cannot be encoded as efficiently as `[BX]`; so if you code `[BP]` in a program, NASM adds a notional 8-bit zero displacement, and sets `mod` to 1, `r/m` to 6, and the one-byte displacement field to 0.

If `BP` is used in an address then the default segment register is `SS`. Otherwise, it is `DS`.

A.2.6.3 Memory a32 ModR/M and SIB encoding

In 32-bit addressing mode (either `BITS 16` with a 67 prefix, or `BITS 32` with no 67 prefix) the general rules (again, there are exceptions) for `mod` and `r/m` are:

- The `mod` field gives the length of the displacement field: 0 means no displacement, 1 means one byte, and 2 means four bytes.
- If only one register is to be added to the displacement, and it is not `ESP`, the `r/m` field gives its register value, and the SIB byte is absent. If the `r/m` field is 4 (which would encode `ESP`), the SIB byte is present and gives the combination and scaling of registers to be added to the displacement.

If the SIB byte is present, it describes the combination of registers (an optional base register, and an optional index register scaled by multiplication by 1, 2, 4 or 8) to be added to the displacement. The SIB byte is divided into the `scale` field, in the top two bits, the `index` field in the next three, and the `base` field in the bottom three. The general rules are:

- The `base` field encodes the register value of the base register.
- The `index` field encodes the register value of the index register, unless it is 4, in which case no index register is used (so `ESP` cannot be used as an index register). If a 4 is encoded

then the `scale` field is ignored.

- The `scale` field encodes the multiplier by which the index register is scaled before adding it to the base and displacement: 0 encodes a multiplier of 1, 1 encodes 2, 2 encodes 4 and 3 encodes 8.

The exceptions to the 32-bit encoding rules are:

- If `mod` is 0 and `r/m` is 5, the effective address encoded is not `[EBP]` as the above rules would suggest, but instead `[disp32]`: the displacement field is present and is four bytes long, and no registers are added to the displacement.
- If `mod` is 0, `r/m` is 4 (meaning the SIB byte is present) and `base` is 5, the effective address encoded is not `[EBP+index]` as the above rules would suggest, but instead `[disp32+index]`: the displacement field is present and is four bytes long, and there is no base register (but the index register is still processed in the normal way).
- Note that if the prior exception applies, then the `index` register field can also be encoded as 4. This combines the two special cases, resulting in a longer encoding of `[disp32]` without any registers. (This longer encoding differs only in a 64-bit code segment from the short `mod=0 r/m=5` encoding of `[disp32]`.)

If `EBP` or `ESP` is used as the base register in an address then the default segment register is `SS`. Otherwise, it is `DS`. (The use of these registers corresponds to `r/m = 5` or `base = 5` or 4, except for the special cases with `mod = 0`.)

A.2.7 Register Extensions: The REX Prefix

The Register Extensions, or REX for short, prefix is the means of accessing extended registers on the x86-64 architecture. REX is considered an instruction prefix, but is required to be after all other prefixes and thus immediately before the first instruction opcode itself. So overall, REX can be thought of as an "Opcode Prefix" instead. The REX prefix itself is indicated by a value of `0x4X`, where `X` is one of 16 different combinations of the actual REX flags.

The REX prefix flags consist of four 1-bit extensions fields. These flags are found in the lower nibble of the actual REX prefix opcode. Below is the list of REX prefix flags, from high bit to low bit.

REX.W: When set, this flag indicates the use of a 64-bit operand, as opposed to the default of using 32-bit operands as found in 32-bit Protected Mode.

REX.R: When set, this flag extends the `reg` (spare) field of the ModR/M byte. Overall, this raises the amount of addressable registers in this field from 8 to 16.

REX.X: When set, this flag extends the `index` field of the SIB byte. Overall, this raises the amount of addressable registers in this field from 8 to 16.

REX.B: When set, this flag extends the `r/m` field of the ModR/M byte. This flag can also represent an extension to the opcode register (`/r`) field. The determination of which is used varies depending on which instruction is used. Overall, this raises the amount of addressable registers in these fields from 8 to 16.

Internal use of the REX prefix by the processor is consistent, yet non-trivial. Most instructions use the REX prefix as indicated by the above flags. Some instructions require the REX prefix to

be present even if the flags are empty. Some instructions default to a 64-bit operand and require the REX prefix only for actual register extensions, and thus ignores the REX.W field completely.

At any rate, NASM is designed to handle, and fully supports, the REX prefix internally. Please read the appropriate processor documentation for further information on the REX prefix.

You may have noticed that opcodes 0x40 through 0x4F are actually opcodes for the INC/DEC instructions for each General Purpose Register. This is, of course, correct... for legacy x86. While in long mode, opcodes 0x40 through 0x4F are reserved for use as the REX prefix. The other opcode forms of the INC/DEC instructions are used instead.

A.3 Key to Instruction Flags

Given along with each instruction in this appendix is a set of flags, denoting the type of the instruction. The types are as follows:

- 8086, 186, 286, 386, 486, PENT and P6 denote the lowest processor type that supports the instruction. Most instructions run on all processors above the given type; those that do not are documented. The Pentium II contains no additional instructions beyond the P6 (Pentium Pro); from the point of view of its instruction set, it can be thought of as a P6 with MMX capability.
- 3DNOW indicates that the instruction is a 3DNow! one, and will run on the AMD K6-2 and later processors. ATHLON extensions to the 3DNow! instruction set are documented as such.
- CYRIX indicates that the instruction is specific to Cyrix processors, for example the extra MMX instructions in the Cyrix extended MMX instruction set.
- FPU indicates that the instruction is a floating-point one, and will only run on machines with a coprocessor (automatically including 486DX, Pentium and above).
- KATMAI indicates that the instruction was introduced as part of the Katmai New Instruction set. These instructions are available on the Pentium III and later processors. Those which are not specifically SSE instructions are also available on the AMD Athlon.
- MMX indicates that the instruction is an MMX one, and will run on MMX-capable Pentium processors and the Pentium II.
- PRIV indicates that the instruction is a protected-mode management instruction. Many of these may only be used in protected mode, or only at privilege level zero.
- SSE and SSE2 indicate that the instruction is a Streaming SIMD Extension instruction. These instructions operate on multiple values in a single operation. SSE was introduced with the Pentium III and SSE2 was introduced with the Pentium 4.
- UNDOC indicates that the instruction is an undocumented one, and not part of the official Intel Architecture; it may or may not be supported on any given machine.
- WILLAMETTE indicates that the instruction was introduced as part of the new instruction set in the Pentium 4 and Intel Xeon processors. These instructions are also known as SSE2 instructions.
- X64 indicates that the instruction was introduced as part of the new instruction set in the x86-64 architecture extension, commonly referred to as x64, AMD64 or EM64T.

A.4 Emulator notes

A.4.1 Common corner cases

- POP to CS is invalid, and used by 286+ CPUs as prefix byte for two-byte instructions. Some 8086s may actually implement it however. It is unclear how this interacts with the prefetch queue, which is known to be purged by every JMP, CALL, interrupt, or return instruction.
- LEA has to encode a memory reference as source operand, and thus not a register.
- MOV to and from segregs can encode invalid non-existent segment registers beyond DS, or (on a 386+) beyond GS.
- MOV to a segreg mustn't encode CS as destination. Like POP to CS, the prefetch queue behaviour is uncertain.
- HLT should cause the machine to halt, ideally until the next hardware interrupt occurs. It may however simply cause the machine to sleep or give up a timeslice in a multitasker. Failing even that is in error.
- SHL and other shift and rotate instructions mask the shift count (either from CL or the immediate operand) with 31 on 186+ machines, except NEC V20/V30. The latter, and 8088/8086, use the entire shift count.
- On the 8088/8086, the divide by zero interrupt points behind the instruction that caused the exception. Otherwise, it points at the instruction.
- AAD and AAM accept immediate bytes other than 10 on some machines, but not on the NEC V20/V30.
- Interrupt 6 (Invalid opcode) didn't exist on the 8088/8086. Unsupported instructions may behave as one- or two-byte no-ops or otherwise oddly.
- Interrupt lockout after MOV or POP to SS is described in the Control Flags description of the Interrupt Flag, section A.2.5.1.
- Proper repeated string operations tracing is described in the Control Flags description of the Trace Flag, section A.2.5.3.

A.4.2 Emulator call encodings

- NTVDM uses C4 C4 (LEA with a register source) followed by one or two callback identifier bytes.
- DOSBox uses FE 38 (invalid encoding with /7) followed by a callback identifier word.
- dosemu2 uses HLT and dispatches based on the address of the HLT.
- 8086tiny uses 0F followed by one identifier byte, currently in the range 00 to 04.

A.5 x86 Instruction Set

A.5.1 AAA, AAS, AAM, AAD: ASCII Adjustments

AAA

; 37

[8086]

AAS	; 3F	[8086]
AAD	; D5 0A	[8086]
AAD imm	; D5 ib	[8086]
AAM	; D4 0A	[8086]
AAM imm	; D4 ib	[8086]

These instructions are used in conjunction with the add, subtract, multiply and divide instructions to perform binary-coded decimal arithmetic in *unpacked* (one BCD digit per byte - easy to translate to and from ASCII, hence the instruction names) form. There are also packed BCD instructions DAA and DAS: see section A.5.57.

- AAA (ASCII Adjust After Addition) should be used after a one-byte ADD instruction whose destination was the AL register: by means of examining the value in the low nibble of AL and also the auxiliary carry flag AF, it determines whether the addition has overflowed, and adjusts it (and sets the carry flag) if so. You can add long BCD strings together by doing ADD/AAA on the low digits, then doing ADC/AAA on each subsequent digit.
- AAS (ASCII Adjust AL After Subtraction) works similarly to AAA, but is for use after SUB instructions rather than ADD.
- AAM (ASCII Adjust AX After Multiply) is for use after you have multiplied two decimal digits together and left the result in AL: it divides AL by ten and stores the quotient in AH, leaving the remainder in AL. The divisor 10 can be changed by specifying an operand to the instruction: a particularly handy use of this is AAM 16, causing the two nibbles in AL to be separated into AH and AL. Note that the divisor immediate byte is ignored by some implementations such as the NEC V20/V30, which always use 10 as divisor.
- AAD (ASCII Adjust AX Before Division) performs the inverse operation to AAM: it multiplies AH by ten, adds it to AL, and sets AH to zero. Again, the multiplier 10 can be changed on some implementations.

A.5.2 ADC: Add with Carry

ADC r/m8,reg8	; 10 /r	[8086]
ADC r/m16,reg16	; 016 11 /r	[8086]
ADC r/m32,reg32	; 032 11 /r	[386]
ADC reg8,r/m8	; 12 /r	[8086]
ADC reg16,r/m16	; 016 13 /r	[8086]
ADC reg32,r/m32	; 032 13 /r	[386]
ADC r/m8,imm8	; 80 /2 ib	[8086]
ADC r/m16,imm16	; 016 81 /2 iw	[8086]
ADC r/m32,imm32	; 032 81 /2 id	[386]
ADC r/m16,imm8	; 016 83 /2 ib	[8086]
ADC r/m32,imm8	; 032 83 /2 ib	[386]
ADC AL,imm8	; 14 ib	[8086]
ADC AX,imm16	; 016 15 iw	[8086]

```
ADC EAX,imm32 ; 032 15 id [386]
```

ADC performs integer addition: it adds its two operands together, plus the value of the carry flag, and leaves the result in its destination (first) operand. The destination operand can be a register or a memory location. The source operand can be a register, a memory location or an immediate value.

The flags are set according to the result of the operation: in particular, the carry flag is affected and can be used by a subsequent ADC instruction.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The `BYTE` qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the `STRICT WORD` or `STRICT DWORD` qualifier.

To add two numbers without also adding the contents of the carry flag, use `ADD` (section A.5.3).

A.5.3 ADD: Add Integers

```
ADD r/m8,reg8 ; 00 /r [8086]
ADD r/m16,reg16 ; 016 01 /r [8086]
ADD r/m32,reg32 ; 032 01 /r [386]

ADD reg8,r/m8 ; 02 /r [8086]
ADD reg16,r/m16 ; 016 03 /r [8086]
ADD reg32,r/m32 ; 032 03 /r [386]

ADD r/m8,imm8 ; 80 /7 ib [8086]
ADD r/m16,imm16 ; 016 81 /7 iw [8086]
ADD r/m32,imm32 ; 032 81 /7 id [386]

ADD r/m16,imm8 ; 016 83 /7 ib [8086]
ADD r/m32,imm8 ; 032 83 /7 ib [386]

ADD AL,imm8 ; 04 ib [8086]
ADD AX,imm16 ; 016 05 iw [8086]
ADD EAX,imm32 ; 032 05 id [386]
```

ADD performs integer addition: it adds its two operands together, and leaves the result in its destination (first) operand. The destination operand can be a register or a memory location. The source operand can be a register, a memory location or an immediate value.

The flags are set according to the result of the operation: in particular, the carry flag is affected and can be used by a subsequent ADC instruction.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The `BYTE` qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the `STRICT WORD` or `STRICT DWORD` qualifier.

A.5.4 ADDPD: ADD Packed Double-Precision FP Values

ADDPD xmm1, xmm2/mem128 ; 66 0F 58 /r [WILLAMETTE, SSE2]

ADDPD performs addition on each of two packed double-precision FP value pairs.

$$\begin{aligned} \text{dst}[0-63] &:= \text{dst}[0-63] + \text{src}[0-63], \\ \text{dst}[64-127] &:= \text{dst}[64-127] + \text{src}[64-127]. \end{aligned}$$

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.5 ADDPS: ADD Packed Single-Precision FP Values

ADDPS xmm1, xmm2/mem128 ; 0F 58 /r [KATMAI, SSE]

ADDPS performs addition on each of four packed single-precision FP value pairs

$$\begin{aligned} \text{dst}[0-31] &:= \text{dst}[0-31] + \text{src}[0-31], \\ \text{dst}[32-63] &:= \text{dst}[32-63] + \text{src}[32-63], \\ \text{dst}[64-95] &:= \text{dst}[64-95] + \text{src}[64-95], \\ \text{dst}[96-127] &:= \text{dst}[96-127] + \text{src}[96-127]. \end{aligned}$$

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.6 ADDSD: ADD Scalar Double-Precision FP Values

ADDSD xmm1, xmm2/mem64 ; F2 0F 58 /r [KATMAI, SSE]

ADDSD adds the low double-precision FP values from the source and destination operands and stores the double-precision FP result in the destination operand.

$$\begin{aligned} \text{dst}[0-63] &:= \text{dst}[0-63] + \text{src}[0-63], \\ \text{dst}[64-127] &\text{ remains unchanged.} \end{aligned}$$

The destination is an XMM register. The source operand can be either an XMM register or a 64-bit memory location.

A.5.7 ADDSS: ADD Scalar Single-Precision FP Values

ADDSS xmm1, xmm2/mem32 ; F3 0F 58 /r [WILLAMETTE, SSE2]

ADDSS adds the low single-precision FP values from the source and destination operands and stores the single-precision FP result in the destination operand.

$$\begin{aligned} \text{dst}[0-31] &:= \text{dst}[0-31] + \text{src}[0-31], \\ \text{dst}[32-127] &\text{ remains unchanged.} \end{aligned}$$

The destination is an XMM register. The source operand can be either an XMM register or a 32-bit memory location.

A.5.8 AND: Bitwise AND

AND r/m8, reg8 ; 20 /r [8086]

AND r/m16,reg16	; o16 21 /r	[8086]
AND r/m32,reg32	; o32 21 /r	[386]
AND reg8,r/m8	; 22 /r	[8086]
AND reg16,r/m16	; o16 23 /r	[8086]
AND reg32,r/m32	; o32 23 /r	[386]
AND r/m8,imm8	; 80 /4 ib	[8086]
AND r/m16,imm16	; o16 81 /4 iw	[8086]
AND r/m32,imm32	; o32 81 /4 id	[386]
AND r/m16,imm8	; o16 83 /4 ib	[8086]
AND r/m32,imm8	; o32 83 /4 ib	[386]
AND AL,imm8	; 24 ib	[8086]
AND AX,imm16	; o16 25 iw	[8086]
AND EAX,imm32	; o32 25 id	[386]

AND performs a bitwise AND operation between its two operands (i.e. each bit of the result is 1 if and only if the corresponding bits of the two inputs were both 1), and stores the result in the destination (first) operand. The destination operand can be a register or a memory location. The source operand can be a register, a memory location or an immediate value.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the STRICT WORD or STRICT DWORD qualifier.

The Carry Flag is cleared by AND. The Zero Flag is set according to whether the result is zero.

The TEST (see section A.5.317) instruction performs the same operation as AND but without writing to the destination operand. That is, it only reads the operands and writes the status flags.

The MMX instruction PAND (see section A.5.202) performs the same operation on the 64-bit MMX registers.

A.5.9 ANDNPD: Bitwise Logical AND NOT of Packed Double-Precision FP Values

ANDNPD xmm1,xmm2/mem128	; 66 0F 55 /r	[WILLAMETTE,SSE2]
-------------------------	---------------	-------------------

ANDNPD inverts the bits of the two double-precision floating-point values in the destination register, and then performs a logical AND between the two double-precision floating-point values in the source operand and the temporary inverted result, storing the result in the destination register.

```
dst[0-63] := src[0-63] AND NOT dst[0-63],
dst[64-127] := src[64-127] AND NOT dst[64-127].
```

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.10 **ANDNPS: Bitwise Logical AND NOT of Packed Single-Precision FP Values**

```
ANDNPS xmm1, xmm2/mem128 ; 0F 55 /r [KATMAI, SSE]
```

ANDNPS inverts the bits of the four single-precision floating-point values in the destination register, and then performs a logical AND between the four single-precision floating-point values in the source operand and the temporary inverted result, storing the result in the destination register.

```
dst[0-31] := src[0-31] AND NOT dst[0-31],
dst[32-63] := src[32-63] AND NOT dst[32-63],
dst[64-95] := src[64-95] AND NOT dst[64-95],
dst[96-127] := src[96-127] AND NOT dst[96-127].
```

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.11 **ANDPD: Bitwise Logical AND For Single FP**

```
ANDPD xmm1, xmm2/mem128 ; 66 0F 54 /r [WILLAMETTE, SSE2]
```

ANDPD performs a bitwise logical AND of the two double-precision floating point values in the source and destination operand, and stores the result in the destination register.

```
dst[0-63] := src[0-63] AND dst[0-63],
dst[64-127] := src[64-127] AND dst[64-127].
```

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.12 **ANDPS: Bitwise Logical AND For Single FP**

```
ANDPS xmm1, xmm2/mem128 ; 0F 54 /r [KATMAI, SSE]
```

ANDPS performs a bitwise logical AND of the four single-precision floating point values in the source and destination operand, and stores the result in the destination register.

```
dst[0-31] := src[0-31] AND dst[0-31],
dst[32-63] := src[32-63] AND dst[32-63],
dst[64-95] := src[64-95] AND dst[64-95],
dst[96-127] := src[96-127] AND dst[96-127].
```

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

A.5.13 **ARPL: Adjust RPL Field of Selector**

```
ARPL r/m16, reg16 ; 63 /r [286, PRIV]
```

ARPL expects its two word operands to be segment selectors. It adjusts the RPL (requested privilege level - stored in the bottom two bits of the selector) field of the destination (first) operand to ensure that it is no less (i.e. no more privileged than) the RPL field of the source operand. The zero flag is set if and only if a change had to be made.

A.5.14 BOUND: Check Array Index against Bounds

```
BOUND reg16,mem          ; o16 62 /r          [186]
BOUND reg32,mem          ; o32 62 /r          [386]
```

BOUND expects its second operand to point to an area of memory containing two signed values of the same size as its first operand (i.e. two words for the 16-bit form; two doublewords for the 32-bit form). It performs two signed comparisons: if the value in the register passed as its first operand is less than the first of the in-memory values, or is greater than or equal to the second, it throws a BR exception. Otherwise, it does nothing.

A.5.15 BSF, BSR: Bit Scan

```
BSF reg16,r/m16          ; o16 0F BC /r          [386]
BSF reg32,r/m32          ; o32 0F BC /r          [386]

BSR reg16,r/m16          ; o16 0F BD /r          [386]
BSR reg32,r/m32          ; o32 0F BD /r          [386]
```

- BSF searches for the least significant set bit in its source (second) operand, and if it finds one, stores the index in its destination (first) operand. If no set bit is found, the contents of the destination operand are undefined. If the source operand is zero, the zero flag is set.
- BSR performs the same function, but searches from the top instead, so it finds the most significant set bit.

Bit indices are from 0 (least significant) to 15 or 31 (most significant). The destination operand can only be a register. The source operand can be a register or a memory location.

A.5.16 BSWAP: Byte Swap

```
BSWAP reg32              ; o32 0F C8+r          [486]
```

BSWAP swaps the order of the four bytes of a 32-bit register: bits 0-7 exchange places with bits 24-31, and bits 8-15 swap with bits 16-23. There is no explicit 16-bit equivalent: to byte-swap AX, BX, CX or DX, XCHG can be used. When BSWAP is used with a 16-bit register, the result is undefined.

A.5.17 BT, BTC, BTR, BTS: Bit Test

```
BT r/m16,reg16          ; o16 0F A3 /r          [386]
BT r/m32,reg32          ; o32 0F A3 /r          [386]
BT r/m16,imm8           ; o16 0F BA /4 ib       [386]
BT r/m32,imm8           ; o32 0F BA /4 ib       [386]

BTC r/m16,reg16         ; o16 0F BB /r          [386]
BTC r/m32,reg32         ; o32 0F BB /r          [386]
BTC r/m16,imm8          ; o16 0F BA /7 ib       [386]
BTC r/m32,imm8          ; o32 0F BA /7 ib       [386]

BTR r/m16,reg16         ; o16 0F B3 /r          [386]
BTR r/m32,reg32         ; o32 0F B3 /r          [386]
BTR r/m16,imm8          ; o16 0F BA /6 ib       [386]
```

BTR r/m32,imm8	; 032 0F BA /6 ib	[386]
BTS r/m16,reg16	; 016 0F AB /r	[386]
BTS r/m32,reg32	; 032 0F AB /r	[386]
BTS r/m16,imm	; 016 0F BA /5 ib	[386]
BTS r/m32,imm	; 032 0F BA /5 ib	[386]

These instructions all test one bit of their first operand, whose index is given by the second operand, and store the value of that bit into the carry flag. Bit indices are from 0 (least significant) to 15 or 31 (most significant).

In addition to storing the original value of the bit into the carry flag, BTR also resets (clears) the bit in the operand itself. BTS sets the bit, and BTC complements the bit. BT does not modify its operands.

The destination can be a register or a memory location. The source can be a register or an immediate value.

If the destination operand is a register, the bit offset should be in the range 0-15 (for 16-bit operands) or 0-31 (for 32-bit operands). An immediate value outside these ranges will be taken modulo 16/32 by the processor.

If the destination operand is a memory location, then an immediate bit offset follows the same rules as for a register. If the bit offset is in a register, then it can be anything within the signed range of the register used (ie, for a 32-bit operand, it can be (-2^{31}) to $(2^{31} - 1)$).

A.5.18 CALL: Call Subroutine

CALL imm	; E8 rw/rd	[8086]
CALL imm:imm16	; 016 9A iw iw	[8086]
CALL imm:imm32	; 032 9A id iw	[386]
CALL FAR mem16	; 016 FF /3	[8086]
CALL FAR mem32	; 032 FF /3	[386]
CALL r/m16	; 016 FF /2	[8086]
CALL r/m32	; 032 FF /2	[386]

CALL calls a subroutine, by means of pushing the current instruction pointer (IP) and optionally CS as well on the stack, and then jumping to a given address.

CS is pushed as well as IP if and only if the call is a far call, i.e. a destination segment address is specified in the instruction. The forms involving two colon-separated arguments are far calls; so are the CALL FAR mem forms.

The immediate near call takes one of two forms (CALL imm16/imm32), determined by the current segment size limit. For 16-bit operands, you would use CALL 0x1234, and for 32-bit operands you would use CALL 0x12345678. The value passed as an operand is a relative offset.

You can choose between the two immediate far call forms (CALL imm:imm) by the use of the WORD and DWORD keywords: CALL WORD 0x1234:0x5678) or CALL DWORD 0x1234:0x56789abc.

The CALL FAR mem forms execute a far call by loading the destination address out of memory. The address loaded consists of 16 or 32 bits of offset (depending on the operand size), and

16 bits of segment. The operand size may be overridden using `CALL WORD FAR mem` or `CALL DWORD FAR mem`.

The `CALL r/m` forms execute a near call (within the same segment), loading the destination address out of memory or out of a register. The keyword `NEAR` may be specified, for clarity, in these forms, but is not necessary. Again, operand size can be overridden using `CALL WORD mem` or `CALL DWORD mem`.

As a convenience, NASM does not require you to call a far procedure symbol by coding the cumbersome `CALL SEG routine:routine`, but instead allows the easier synonym `CALL FAR routine`.

A.5.19 CBW, CWD, CDQ, CWDE: Sign Extensions

<code>CBW</code>	<code>; 016 98</code>	<code>[8086]</code>
<code>CWDE</code>	<code>; 032 98</code>	<code>[386]</code>
<code>CWD</code>	<code>; 016 99</code>	<code>[8086]</code>
<code>CDQ</code>	<code>; 032 99</code>	<code>[386]</code>

All these instructions sign-extend a short value into a longer one, by replicating the top bit of the original value to fill the extended one.

`CBW` extends `AL` into `AX` by repeating the top bit of `AL` in every bit of `AH`. `CWDE` extends `AX` into `EAX`. `CWD` extends `AX` into `DX:AX` by repeating the top bit of `AX` throughout `DX`, and `CDQ` extends `EAX` into `EDX:EAX`.

A.5.20 CLC, CLD, CLI, CLTS: Clear Flags

<code>CLC</code>	<code>; F8</code>	<code>[8086]</code>
<code>CLD</code>	<code>; FC</code>	<code>[8086]</code>
<code>CLI</code>	<code>; FA</code>	<code>[8086]</code>
<code>CLTS</code>	<code>; 0F 06</code>	<code>[286, PRIV]</code>

These instructions clear various flags. `CLC` clears the carry flag; `CLD` clears the direction flag; `CLI` clears the interrupt flag (thus disabling interrupts); and `CLTS` clears the task-switched (TS) flag in `CR0`.

To set the carry, direction, or interrupt flags, use the `STC`, `STD` and `STI` instructions (section A.5.301). To invert the carry flag, use `CMC` (section A.5.22).

A.5.21 CLFLUSH: Flush Cache Line

<code>CLFLUSH mem</code>	<code>; 0F AE /7</code>	<code>[WILLAMETTE, SSE2]</code>
--------------------------	-------------------------	---------------------------------

`CLFLUSH` invalidates the cache line that contains the linear address specified by the source operand from all levels of the processor cache hierarchy (data and instruction). If, at any level of the cache hierarchy, the line is inconsistent with memory (dirty) it is written to memory before invalidation. The source operand points to a byte-sized memory location.

Although `CLFLUSH` is flagged SSE2 and above, it may not be present on all processors which have SSE2 support, and it may be supported on other processors; the `CPUID` instruction (section A.5.34) will return a bit which indicates support for the `CLFLUSH` instruction.

A.5.22 CMC: Complement Carry Flag

CMC ; F5 [8086]

CMC changes the value of the carry flag: if it was 0, it sets it to 1, and vice versa.

A.5.23 CMOVcc: Conditional Move

CMOVcc reg16,r/m16 ; 016 0F 40+cc /r [P6]

CMOVcc reg32,r/m32 ; 032 0F 40+cc /r [P6]

CMOV moves its source (second) operand into its destination (first) operand if the given condition code is satisfied; otherwise it does nothing.

For a list of condition codes, see section A.2.2.

Although the CMOV instructions are flagged P6 and above, they may not be supported by all Pentium Pro processors; the CPUID instruction (section A.5.34) will return a bit which indicates whether conditional moves are supported.

A.5.24 CMP: Compare Integers

CMP r/m8,reg8 ; 38 /r [8086]

CMP r/m16,reg16 ; 016 39 /r [8086]

CMP r/m32,reg32 ; 032 39 /r [386]

CMP reg8,r/m8 ; 3A /r [8086]

CMP reg16,r/m16 ; 016 3B /r [8086]

CMP reg32,r/m32 ; 032 3B /r [386]

CMP r/m8,imm8 ; 80 /7 ib [8086]

CMP r/m16,imm16 ; 016 81 /7 iw [8086]

CMP r/m32,imm32 ; 032 81 /7 id [386]

CMP r/m16,imm8 ; 016 83 /7 ib [8086]

CMP r/m32,imm8 ; 032 83 /7 ib [386]

CMP AL,imm8 ; 3C ib [8086]

CMP AX,imm16 ; 016 3D iw [8086]

CMP EAX,imm32 ; 032 3D id [386]

CMP performs a ‘mental’ subtraction of its second operand from its first operand, and affects the flags as if the subtraction had taken place, but does not store the result of the subtraction anywhere. (For subtraction that does store the result, see section A.5.305.)

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the STRICT WORD or STRICT DWORD qualifier.

The destination operand can be a register or a memory location. The source can be a register, memory location or an immediate value of the same size as the destination.

A.5.25 **CMPCCPD: Packed Double-Precision FP Compare**

```
CMPDPD xmm1, xmm2/mem128, imm8 ; 66 0F C2 /r ib [WILLAMETTE, SSE2]
CMPEQPD xmm1, xmm2/mem128 ; 66 0F C2 /r 00 [WILLAMETTE, SSE2]
CMPLTPD xmm1, xmm2/mem128 ; 66 0F C2 /r 01 [WILLAMETTE, SSE2]
CMPLEPD xmm1, xmm2/mem128 ; 66 0F C2 /r 02 [WILLAMETTE, SSE2]
CMPUNORDPD xmm1, xmm2/mem128 ; 66 0F C2 /r 03 [WILLAMETTE, SSE2]
CMPNEQPD xmm1, xmm2/mem128 ; 66 0F C2 /r 04 [WILLAMETTE, SSE2]
CMPNLTPD xmm1, xmm2/mem128 ; 66 0F C2 /r 05 [WILLAMETTE, SSE2]
CMPNLEPD xmm1, xmm2/mem128 ; 66 0F C2 /r 06 [WILLAMETTE, SSE2]
CMPORDPD xmm1, xmm2/mem128 ; 66 0F C2 /r 07 [WILLAMETTE, SSE2]
```

The **CMPCCPD** instructions compare the two packed double-precision FP values in the source and destination operands, and returns the result of the comparison in the destination register. The result of each comparison is a quadword mask of all 1s (comparison true) or all 0s (comparison false).

The destination is an XMM register. The source can be either an XMM register or a 128-bit memory location.

The third operand is an 8-bit immediate value, of which the low 3 bits define the type of comparison. For ease of programming, the 8 two-operand pseudo-instructions are provided, with the third operand already filled in. The **Condition Predicates** are:

EQ	0	Equal
LT	1	Less-than
LE	2	Less-than-or-equal
UNORD	3	Unordered
NE	4	Not-equal
NLT	5	Not-less-than
NLE	6	Not-less-than-or-equal
ORD	7	Ordered

For more details of the comparison predicates, and details of how to emulate the "greater-than" equivalents, see section A.2.3

A.5.26 **CMPCCPS: Packed Single-Precision FP Compare**

```
CMPSPS xmm1, xmm2/mem128, imm8 ; 0F C2 /r ib [KATMAI, SSE]
CMPEQPS xmm1, xmm2/mem128 ; 0F C2 /r 00 [KATMAI, SSE]
CMPLTPS xmm1, xmm2/mem128 ; 0F C2 /r 01 [KATMAI, SSE]
CMPLEPS xmm1, xmm2/mem128 ; 0F C2 /r 02 [KATMAI, SSE]
CMPUNORDPS xmm1, xmm2/mem128 ; 0F C2 /r 03 [KATMAI, SSE]
CMPNEQPS xmm1, xmm2/mem128 ; 0F C2 /r 04 [KATMAI, SSE]
CMPNLTPS xmm1, xmm2/mem128 ; 0F C2 /r 05 [KATMAI, SSE]
CMPNLEPS xmm1, xmm2/mem128 ; 0F C2 /r 06 [KATMAI, SSE]
CMPORDPS xmm1, xmm2/mem128 ; 0F C2 /r 07 [KATMAI, SSE]
```

The **CMPCCPS** instructions compare the two packed single-precision FP values in the source and destination operands, and returns the result of the comparison in the destination register. The

result of each comparison is a doubleword mask of all 1s (comparison true) or all 0s (comparison false).

The destination is an XMM register. The source can be either an XMM register or a 128-bit memory location.

The third operand is an 8-bit immediate value, of which the low 3 bits define the type of comparison. For ease of programming, the 8 two-operand pseudo-instructions are provided, with the third operand already filled in. The `Condition Predicates` are:

EQ	0	Equal
LT	1	Less-than
LE	2	Less-than-or-equal
UNORD	3	Unordered
NE	4	Not-equal
NLT	5	Not-less-than
NLE	6	Not-less-than-or-equal
ORD	7	Ordered

For more details of the comparison predicates, and details of how to emulate the "greater-than" equivalents, see section A.2.3

A.5.27 **CMPSB, CMPSW, CMPSD: Compare Strings**

CMPSB	; A6	[8086]
CMPSW	; o16 A7	[8086]
CMPSD	; o32 A7	[386]

CMPSB compares the byte at `[DS:SI]` or `[DS:ESI]` with the byte at `[ES:DI]` or `[ES:EDI]`, and sets the flags accordingly. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) `SI` and `DI` (or `ESI` and `EDI`).

The registers used are `SI` and `DI` if the address size is 16 bits, and `ESI` and `EDI` if it is 32 bits. If you need to use an address size not equal to the current `BITS` setting, you can use an explicit `a16` or `a32` prefix.

The segment register used to load from `[SI]` or `[ESI]` can be overridden by using a segment register name as a prefix (for example, `ES CMPSB`). The use of `ES` for the load from `[DI]` or `[EDI]` cannot be overridden.

CMPSW and CMPSD work in the same way, but they compare a word or a doubleword instead of a byte, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The `REPE` and `REPNE` prefixes (equivalently, `REPZ` and `REPNZ`) may be used to repeat the instruction up to `CX` (or `ECX` - again, the address size chooses which) times until the first unequal or equal element is found. To NASM, `REP` is an alias for `REPE`.

A.5.27.1 **Pseudo-code examples**

`a16 CMPSB` without segment override and with Direction Flag clear (`UP`) is equal to

```
CMP BYTE [SI], BYTE [ES:DI]
LEA SI, [SI + 1]
```

```
LEA DI, [DI + 1]
```

a16 REPE CMPSW without segment override and with Direction Flag clear (UP) is equal to

```
JCXZ @FF
@@:
CMP WORD [SI], WORD [ES:DI]
LEA SI, [SI + 2]
LEA DI, [DI + 2]
a16 LOOPE @B
@@:
```

a32 ES CMPSD with Direction Flag set (DN) is equal to

```
CMP DWORD [ES:ESI], DWORD [ES:EDI]
LEA ESI, [ESI - 4]
LEA EDI, [EDI - 4]
```

A.5.28 CMPCCSD: Scalar Double-Precision FP Compare

```
CMPSD xmm1, xmm2/mem64, imm8 ; F2 0F C2 /r ib [WILLAMETTE, SSE2]
CMPEQSD xmm1, xmm2/mem64 ; F2 0F C2 /r 00 [WILLAMETTE, SSE2]
CMPLTSD xmm1, xmm2/mem64 ; F2 0F C2 /r 01 [WILLAMETTE, SSE2]
CMPLESD xmm1, xmm2/mem64 ; F2 0F C2 /r 02 [WILLAMETTE, SSE2]
CMPUNORDSD xmm1, xmm2/mem64 ; F2 0F C2 /r 03 [WILLAMETTE, SSE2]
CMPNEQSD xmm1, xmm2/mem64 ; F2 0F C2 /r 04 [WILLAMETTE, SSE2]
CMPNLTSD xmm1, xmm2/mem64 ; F2 0F C2 /r 05 [WILLAMETTE, SSE2]
CMPNLESD xmm1, xmm2/mem64 ; F2 0F C2 /r 06 [WILLAMETTE, SSE2]
CMPORDSD xmm1, xmm2/mem64 ; F2 0F C2 /r 07 [WILLAMETTE, SSE2]
```

The CMPCCSD instructions compare the low-order double-precision FP values in the source and destination operands, and returns the result of the comparison in the destination register. The result of each comparison is a quadword mask of all 1s (comparison true) or all 0s (comparison false).

The destination is an XMM register. The source can be either an XMM register or a 128-bit memory location.

The third operand is an 8-bit immediate value, of which the low 3 bits define the type of comparison. For ease of programming, the 8 two-operand pseudo-instructions are provided, with the third operand already filled in. The Condition Predicates are:

EQ	0	Equal
LT	1	Less-than
LE	2	Less-than-or-equal
UNORD	3	Unordered
NE	4	Not-equal
NLT	5	Not-less-than
NLE	6	Not-less-than-or-equal
ORD	7	Ordered

For more details of the comparison predicates, and details of how to emulate the "greater-than" equivalents, see section A.2.3

A.5.29 CMPccSS: Scalar Single-Precision FP Compare

```
CMPSS xmm1,xmm2/mem32,imm8 ; F3 0F C2 /r ib [KATMAI,SSE]
CMPEQSS xmm1,xmm2/mem32 ; F3 0F C2 /r 00 [KATMAI,SSE]
CMPLTSS xmm1,xmm2/mem32 ; F3 0F C2 /r 01 [KATMAI,SSE]
CMPLESS xmm1,xmm2/mem32 ; F3 0F C2 /r 02 [KATMAI,SSE]
CMPUNORDSS xmm1,xmm2/mem32 ; F3 0F C2 /r 03 [KATMAI,SSE]
CMPNEQSS xmm1,xmm2/mem32 ; F3 0F C2 /r 04 [KATMAI,SSE]
CMPNLTSS xmm1,xmm2/mem32 ; F3 0F C2 /r 05 [KATMAI,SSE]
CMPNLESS xmm1,xmm2/mem32 ; F3 0F C2 /r 06 [KATMAI,SSE]
CMPORDSS xmm1,xmm2/mem32 ; F3 0F C2 /r 07 [KATMAI,SSE]
```

The CMPccSS instructions compare the low-order single-precision FP values in the source and destination operands, and returns the result of the comparison in the destination register. The result of each comparison is a doubleword mask of all 1s (comparison true) or all 0s (comparison false).

The destination is an XMM register. The source can be either an XMM register or a 128-bit memory location.

The third operand is an 8-bit immediate value, of which the low 3 bits define the type of comparison. For ease of programming, the 8 two-operand pseudo-instructions are provided, with the third operand already filled in. The Condition Predicates are:

EQ	0	Equal
LT	1	Less-than
LE	2	Less-than-or-equal
UNORD	3	Unordered
NE	4	Not-equal
NLT	5	Not-less-than
NLE	6	Not-less-than-or-equal
ORD	7	Ordered

For more details of the comparison predicates, and details of how to emulate the "greater-than" equivalents, see section A.2.3

A.5.30 CMPXCHG, CMPXCHG486: Compare and Exchange

```
CMPXCHG r/m8,reg8 ; 0F B0 /r [PENT]
CMPXCHG r/m16,reg16 ; 016 0F B1 /r [PENT]
CMPXCHG r/m32,reg32 ; 032 0F B1 /r [PENT]

CMPXCHG486 r/m8,reg8 ; 0F A6 /r [486,UNDOC]
CMPXCHG486 r/m16,reg16 ; 016 0F A7 /r [486,UNDOC]
CMPXCHG486 r/m32,reg32 ; 032 0F A7 /r [486,UNDOC]
```

These two instructions perform exactly the same operation; however, apparently some (not all) 486 processors support it under a non-standard opcode, so NASM provides the undocumented CMPXCHG486 form to generate the non-standard opcode.

CMPXCHG compares its destination (first) operand to the value in AL, AX or EAX (depending on the operand size of the instruction). If they are equal, it copies its source (second) operand into

the destination and sets the zero flag. Otherwise, it clears the zero flag and copies the destination register to AL, AX or EAX.

The destination can be either a register or a memory location. The source is a register.

CMPXCHG is intended to be used for atomic operations in multitasking or multiprocessor environments. To safely update a value in shared memory, for example, you might load the value into EAX, load the updated value into EBX, and then execute the instruction `LOCK CMPXCHG [value],EBX`. If `value` has not changed since being loaded, it is updated with your desired new value, and the zero flag is set to let you know it has worked. (The `LOCK` prefix prevents another processor doing anything in the middle of this operation: it guarantees atomicity.) However, if another processor has modified the value in between your load and your attempted store, the store does not happen, and you are notified of the failure by a cleared zero flag, so you can go round and try again.

A.5.31 **CMPXCHG8B: Compare and Exchange Eight Bytes**

```
CMPXCHG8B mem ; 0F C7 /1 [PENT]
```

This is a larger and more unwieldy version of `CMPXCHG`: it compares the 64-bit (eight-byte) value stored at `[mem]` with the value in `EDX:EAX`. If they are equal, it sets the zero flag and stores `ECX:EBX` into the memory area. If they are unequal, it clears the zero flag and stores the memory contents into `EDX:EAX`.

`CMPXCHG8B` can be used with the `LOCK` prefix, to allow atomic execution. This is useful in multi-processor and multi-tasking environments.

A.5.32 **COMISD: Scalar Ordered Double-Precision FP Compare and Set EFLAGS**

```
COMISD xmm1,xmm2/mem64 ; 66 0F 2F /r [WILLAMETTE,SSE2]
```

`COMISD` compares the low-order double-precision FP value in the two source operands. `ZF`, `PF` and `CF` are set according to the result. `OF`, `AF` and `AF` are cleared. The unordered result is returned if either source is a NaN (QNaN or SNaN).

The destination operand is an XMM register. The source can be either an XMM register or a memory location.

The flags are set according to the following rules:

Result	Flags	Values
UNORDERED:	<code>ZF,PF,CF</code>	<code><-- 111;</code>
GREATER_THAN:	<code>ZF,PF,CF</code>	<code><-- 000;</code>
LESS_THAN:	<code>ZF,PF,CF</code>	<code><-- 001;</code>
EQUAL:	<code>ZF,PF,CF</code>	<code><-- 100;</code>

A.5.33 **COMISS: Scalar Ordered Single-Precision FP Compare and Set EFLAGS**

```
COMISS xmm1,xmm2/mem32 ; 66 0F 2F /r [KATMAI,SSE]
```

`COMISS` compares the low-order single-precision FP value in the two source operands. `ZF`, `PF` and `CF` are set according to the result. `OF`, `AF` and `AF` are cleared. The unordered result is

returned if either source is a NaN (QNaN or SNaN).

The destination operand is an XMM register. The source can be either an XMM register or a memory location.

The flags are set according to the following rules:

Result	Flags	Values
UNORDERED:	ZF, PF, CF	<-- 111;
GREATER_THAN:	ZF, PF, CF	<-- 000;
LESS_THAN:	ZF, PF, CF	<-- 001;
EQUAL:	ZF, PF, CF	<-- 100;

A.5.34 CPUID: Get CPU Identification Code

```
CPUID                                ; 0F A2                                [PENT]
```

CPUID returns various information about the processor it is being executed on. It fills the four registers EAX, EBX, ECX and EDX with information, which varies depending on the input contents of EAX.

CPUID also acts as a barrier to serialize instruction execution: executing the CPUID instruction guarantees that all the effects (memory modification, flag modification, register modification) of previous instructions have been completed before the next instruction gets fetched.

The information returned is as follows:

- If EAX is zero on input, EAX on output holds the maximum acceptable input value of EAX, and EBX:EDX:ECX contain the string 'GenuineIntel' (or not, if you have a clone processor). That is to say, EBX contains 'Genu' (in NASM's own sense of character constants), EDX contains 'ineI' and ECX contains 'ntel'.
- If EAX is one on input, EAX on output contains version information about the processor, and EDX contains a set of feature flags, showing the presence and absence of various features. For example, bit 8 is set if the CMPXCHG8B instruction (section A.5.31) is supported, bit 15 is set if the conditional move instructions (section A.5.23 and section A.5.72) are supported, and bit 23 is set if MMX instructions are supported.
- If EAX is two on input, EAX, EBX, ECX and EDX all contain information about caches and TLBs (Translation Lookahead Buffers).

For more information on the data returned from CPUID, see the documentation from Intel and other processor manufacturers.

A.5.35 CVTDQ2PD: Packed Signed INT32 to Packed Double-Precision FP Conversion

```
CVTDQ2PD xmm1, xmm2/mem64          ; F3 0F E6 /r          [WILLAMETTE, SSE2]
```

CVTDQ2PD converts two packed signed doublewords from the source operand to two packed double-precision FP values in the destination operand.

The destination operand is an XMM register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the packed integers are in the low quadword.

A.5.36 CVTQ2PS: Packed Signed INT32 to Packed Single-Precision FP Conversion

CVTQ2PS *xmm1, xmm2/mem128* ; 0F 5B /r [WILLAMETTE, SSE2]

CVTQ2PS converts four packed signed doublewords from the source operand to four packed single-precision FP values in the destination operand.

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.37 CVTDP2DQ: Packed Double-Precision FP to Packed Signed INT32 Conversion

CVTDP2DQ *xmm1, xmm2/mem128* ; F2 0F E6 /r [WILLAMETTE, SSE2]

CVTDP2DQ converts two packed double-precision FP values from the source operand to two packed signed doublewords in the low quadword of the destination operand. The high quadword of the destination is set to all 0s.

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.38 CVTDP2PI: Packed Double-Precision FP to Packed Signed INT32 Conversion

CVTDP2PI *mm, xmm/mem128* ; 66 0F 2D /r [WILLAMETTE, SSE2]

CVTDP2PI converts two packed double-precision FP values from the source operand to two packed signed doublewords in the destination operand.

The destination operand is an MMX register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.39 CVTDP2PS: Packed Double-Precision FP to Packed Single-Precision FP Conversion

CVTDP2PS *xmm1, xmm2/mem128* ; 66 0F 5A /r [WILLAMETTE, SSE2]

CVTDP2PS converts two packed double-precision FP values from the source operand to two packed single-precision FP values in the low quadword of the destination operand. The high quadword of the destination is set to all 0s.

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.40 CVTPI2PD: Packed Signed INT32 to Packed Double-Precision FP Conversion

CVTPI2PD xmm,mm/mem64 ; 66 0F 2A /r [WILLAMETTE,SSE2]

CVTPI2PD converts two packed signed doublewords from the source operand to two packed double-precision FP values in the destination operand.

The destination operand is an XMM register. The source can be either an MMX register or a 64-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.41 CVTPI2PS: Packed Signed INT32 to Packed Single-FP Conversion

CVTPI2PS xmm,mm/mem64 ; 0F 2A /r [KATMAI,SSE]

CVTPI2PS converts two packed signed doublewords from the source operand to two packed single-precision FP values in the low quadword of the destination operand. The high quadword of the destination remains unchanged.

The destination operand is an XMM register. The source can be either an MMX register or a 64-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.42 CVTPS2DQ: Packed Single-Precision FP to Packed Signed INT32 Conversion

CVTPS2DQ xmm1,xmm2/mem128 ; 66 0F 5B /r [WILLAMETTE,SSE2]

CVTPS2DQ converts four packed single-precision FP values from the source operand to four packed signed doublewords in the destination operand.

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.43 CVTPS2PD: Packed Single-Precision FP to Packed Double-Precision FP Conversion

CVTPS2PD xmm1,xmm2/mem64 ; 0F 5A /r [WILLAMETTE,SSE2]

CVTPS2PD converts two packed single-precision FP values from the source operand to two packed double-precision FP values in the destination operand.

The destination operand is an XMM register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input values are in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.44 CVTPS2PI: Packed Single-Precision FP to Packed Signed INT32 Conversion

CVTPS2PI mm,xmm/mem64 ; 0F 2D /r [KATMAI,SSE]

CVTPS2PI converts two packed single-precision FP values from the source operand to two packed signed doublewords in the destination operand.

The destination operand is an MMX register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input values are in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.45 CVTSD2SI: Scalar Double-Precision FP to Signed INT32 Conversion

CVTSD2SI *reg32, xmm/mem64* ; F2 0F 2D /r [WILLAMETTE, SSE2]

CVTSD2SI converts a double-precision FP value from the source operand to a signed doubleword in the destination operand.

The destination operand is a general purpose register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input value is in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.46 CVTSD2SS: Scalar Double-Precision FP to Scalar Single-Precision FP Conversion

CVTSD2SS *xmm1, xmm2/mem64* ; F2 0F 5A /r [KATMAI, SSE]

CVTSD2SS converts a double-precision FP value from the source operand to a single-precision FP value in the low doubleword of the destination operand. The upper 3 doublewords are left unchanged.

The destination operand is an XMM register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input value is in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.47 CVTSI2SD: Signed INT32 to Scalar Double-Precision FP Conversion

CVTSI2SD *xmm, r/m32* ; F2 0F 2A /r [WILLAMETTE, SSE2]

CVTSI2SD converts a signed doubleword from the source operand to a double-precision FP value in the low quadword of the destination operand. The high quadword is left unchanged.

The destination operand is an XMM register. The source can be either a general purpose register or a 32-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.48 CVTSI2SS: Signed INT32 to Scalar Single-Precision FP Conversion

CVTSI2SS *xmm, r/m32* ; F3 0F 2A /r [KATMAI, SSE]

CVTSI2SS converts a signed doubleword from the source operand to a single-precision FP value in the low doubleword of the destination operand. The upper 3 doublewords are left unchanged.

The destination operand is an XMM register. The source can be either a general purpose register or a 32-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.49 CVTSS2SD: Scalar Single-Precision FP to Scalar Double-Precision FP Conversion

`CVTSS2SD xmm1, xmm2/mem32 ; F3 0F 5A /r [WILLAMETTE, SSE2]`

CVTSS2SD converts a single-precision FP value from the source operand to a double-precision FP value in the low quadword of the destination operand. The upper quadword is left unchanged.

The destination operand is an XMM register. The source can be either an XMM register or a 32-bit memory location. If the source is a register, the input value is contained in the low doubleword.

For more details of this instruction, see the Intel Processor manuals.

A.5.50 CVTSS2SI: Scalar Single-Precision FP to Signed INT32 Conversion

`CVTSS2SI reg32, xmm/mem32 ; F3 0F 2D /r [KATMAI, SSE]`

CVTSS2SI converts a single-precision FP value from the source operand to a signed doubleword in the destination operand.

The destination operand is a general purpose register. The source can be either an XMM register or a 32-bit memory location. If the source is a register, the input value is in the low doubleword.

For more details of this instruction, see the Intel Processor manuals.

A.5.51 CVTTPD2DQ: Packed Double-Precision FP to Packed Signed INT32 Conversion with Truncation

`CVTTPD2DQ xmm1, xmm2/mem128 ; 66 0F E6 /r [WILLAMETTE, SSE2]`

CVTTPD2DQ converts two packed double-precision FP values in the source operand to two packed single-precision FP values in the destination operand. If the result is inexact, it is truncated (rounded toward zero). The high quadword is set to all 0s.

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.52 CVTTPD2PI: Packed Double-Precision FP to Packed Signed INT32 Conversion with Truncation

`CVTTPD2PI mm, xmm/mem128 ; 66 0F 2C /r [WILLAMETTE, SSE2]`

CVTTPD2PI converts two packed double-precision FP values in the source operand to two packed single-precision FP values in the destination operand. If the result is inexact, it is truncated (rounded toward zero).

The destination operand is an MMX register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.53 **CVTTPS2DQ: Packed Single-Precision FP to Packed Signed INT32 Conversion with Truncation**

CVTTPS2DQ *xmm1, xmm2/mem128* ; F3 0F 5B /r [WILLAMETTE, SSE2]

CVTTPS2DQ converts four packed single-precision FP values in the source operand to four packed signed doublewords in the destination operand. If the result is inexact, it is truncated (rounded toward zero).

The destination operand is an XMM register. The source can be either an XMM register or a 128-bit memory location.

For more details of this instruction, see the Intel Processor manuals.

A.5.54 **CVTTPS2PI: Packed Single-Precision FP to Packed Signed INT32 Conversion with Truncation**

CVTTPS2PI *mm, xmm/mem64* ; 0F 2C /r [KATMAI, SSE]

CVTTPS2PI converts two packed single-precision FP values in the source operand to two packed signed doublewords in the destination operand. If the result is inexact, it is truncated (rounded toward zero). If the source is a register, the input values are in the low quadword.

The destination operand is an MMX register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input value is in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.55 **CVTTSD2SI: Scalar Double-Precision FP to Signed INT32 Conversion with Truncation**

CVTTSD2SI *reg32, xmm/mem64* ; F2 0F 2C /r [WILLAMETTE, SSE2]

CVTTSD2SI converts a double-precision FP value in the source operand to a signed doubleword in the destination operand. If the result is inexact, it is truncated (rounded toward zero).

The destination operand is a general purpose register. The source can be either an XMM register or a 64-bit memory location. If the source is a register, the input value is in the low quadword.

For more details of this instruction, see the Intel Processor manuals.

A.5.56 **CVTTSS2SI: Scalar Single-Precision FP to Signed INT32 Conversion with Truncation**

CVTTSS2SI *reg32, xmm/mem32* ; F3 0F 2C /r [KATMAI, SSE]

CVTTSS2SI converts a single-precision FP value in the source operand to a signed doubleword in the destination operand. If the result is inexact, it is truncated (rounded toward zero).

The destination operand is a general purpose register. The source can be either an XMM register or a 32-bit memory location. If the source is a register, the input value is in the low doubleword.

For more details of this instruction, see the Intel Processor manuals.

A.5.57 DAA, DAS: Decimal Adjustments

DAA	; 27	[8086]
DAS	; 2F	[8086]

These instructions are used in conjunction with the add and subtract instructions to perform binary-coded decimal arithmetic in *packed* (one BCD digit per nibble) form. For the unpacked equivalents, see section A.5.1.

DAA should be used after a one-byte ADD instruction whose destination was the AL register: by means of examining the value in the AL and also the auxiliary carry flag AF, it determines whether either digit of the addition has overflowed, and adjusts it (and sets the carry and auxiliary-carry flags) if so. You can add long BCD strings together by doing ADD/DAA on the low two digits, then doing ADC/DAA on each subsequent pair of digits.

DAS works similarly to DAA, but is for use after SUB instructions rather than ADD.

A.5.58 DEC: Decrement Integer

DEC reg16	; 016 48+r	[8086]
DEC reg32	; 032 48+r	[386]
DEC r/m8	; FE /1	[8086]
DEC r/m16	; 016 FF /1	[8086]
DEC r/m32	; 032 FF /1	[386]

DEC subtracts 1 from its operand. It does *not* affect the carry flag: to affect the carry flag, use SUB something, 1 (see section A.5.305). DEC affects all the other flags according to the result.

This instruction can be used with a LOCK prefix to allow atomic execution.

See also INC (section A.5.120).

A.5.59 DIV: Unsigned Integer Divide

DIV r/m8	; F6 /6	[8086]
DIV r/m16	; 016 F7 /6	[8086]
DIV r/m32	; 032 F7 /6	[386]

DIV performs unsigned integer division. The explicit operand provided is the divisor; the dividend and destination operands are implicit, in the following way:

- For DIV r/m8, AX is divided by the given operand; the quotient is stored in AL and the remainder in AH.
- For DIV r/m16, DX:AX is divided by the given operand; the quotient is stored in AX and the remainder in DX.
- For DIV r/m32, EDX:EAX is divided by the given operand; the quotient is stored in EAX and the remainder in EDX.

Signed integer division is performed by the IDIV instruction: see section A.5.117.

A.5.60 DIVPD: Packed Double-Precision FP Divide

`DIVPD xmm1, xmm2/mem128 ; 66 0F 5E /r [WILLAMETTE, SSE2]`

DIVPD divides the two packed double-precision FP values in the destination operand by the two packed double-precision FP values in the source operand, and stores the packed double-precision results in the destination register.

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

```
dst[0-63] := dst[0-63] / src[0-63],
dst[64-127] := dst[64-127] / src[64-127].
```

A.5.61 DIVPS: Packed Single-Precision FP Divide

`DIVPS xmm1, xmm2/mem128 ; 0F 5E /r [KATMAI, SSE]`

DIVPS divides the four packed single-precision FP values in the destination operand by the four packed single-precision FP values in the source operand, and stores the packed single-precision results in the destination register.

The destination is an XMM register. The source operand can be either an XMM register or a 128-bit memory location.

```
dst[0-31] := dst[0-31] / src[0-31],
dst[32-63] := dst[32-63] / src[32-63],
dst[64-95] := dst[64-95] / src[64-95],
dst[96-127] := dst[96-127] / src[96-127].
```

A.5.62 DIVSD: Scalar Double-Precision FP Divide

`DIVSD xmm1, xmm2/mem64 ; F2 0F 5E /r [WILLAMETTE, SSE2]`

DIVSD divides the low-order double-precision FP value in the destination operand by the low-order double-precision FP value in the source operand, and stores the double-precision result in the destination register.

The destination is an XMM register. The source operand can be either an XMM register or a 64-bit memory location.

```
dst[0-63] := dst[0-63] / src[0-63],
dst[64-127] remains unchanged.
```

A.5.63 DIVSS: Scalar Single-Precision FP Divide

`DIVSS xmm1, xmm2/mem32 ; F3 0F 5E /r [KATMAI, SSE]`

DIVSS divides the low-order single-precision FP value in the destination operand by the low-order single-precision FP value in the source operand, and stores the single-precision result in the destination register.

The destination is an XMM register. The source operand can be either an XMM register or a 32-bit memory location.

```
dst[0-31] := dst[0-31] / src[0-31],
dst[32-127] remains unchanged.
```

A.5.64 EMMS: Empty MMX State

```
EMMS ; 0F 77 [PENT,MMX]
```

EMMS sets the FPU tag word (marking which floating-point registers are available) to all ones, meaning all registers are available for the FPU to use. It should be used after executing MMX instructions and before executing any subsequent floating-point operations.

A.5.65 ENTER: Create Stack Frame

```
ENTER imm,imm ; C8 iw ib [186]
```

ENTER constructs a stack frame for a high-level language procedure call. The first operand (the *iw* in the opcode definition above refers to the first operand) gives the amount of stack space to allocate for local variables; the second (the *ib* above) gives the nesting level of the procedure (for languages like Pascal, with nested procedures).

The function of ENTER, with a nesting level of zero, is equivalent to

```
PUSH EBP ; or PUSH BP in 16 bits
MOV EBP, ESP ; or MOV BP, SP in 16 bits
LEA ESP, [ESP - op1] ; or LEA SP, [BP - op1] in 16 bits
```

This creates a stack frame with the procedure parameters accessible upwards from EBP, and local variables accessible downwards from EBP. Note that the flags are not modified by the calculation.

With a nesting level of one, the stack frame created is 4 (or 2) bytes bigger, and the value of the final frame pointer EBP is accessible in memory at [EBP-4].

This allows ENTER, when called with a nesting level of two, to look at the stack frame described by the *previous* value of EBP, find the frame pointer at offset -4 from that, and push it along with its new frame pointer, so that when a level-two procedure is called from within a level-one procedure, [EBP-4] holds the frame pointer of the most recent level-one procedure call and [EBP-8] holds that of the most recent level-two call. And so on, for nesting levels up to 31. The nesting level is determined by bitwise AND-masking the second operand with 31.

Stack frames created by ENTER can be destroyed by the LEAVE instruction: see section A.5.136.

A.5.66 F2XM1: Calculate 2**X-1

```
F2XM1 ; D9 F0 [8086,FPU]
```

F2XM1 raises 2 to the power of ST0, subtracts one, and stores the result back into ST0. The initial contents of ST0 must be a number in the range -1.0 to +1.0.

A.5.67 FABS: Floating-Point Absolute Value

```
FABS ; D9 E1 [8086,FPU]
```

FABS computes the absolute value of ST0, by clearing the sign bit, and stores the result back in ST0.

A.5.68 FADD, FADDP: Floating-Point Addition

FADD mem32	; D8 /0	[8086,FPU]
FADD mem64	; DC /0	[8086,FPU]
FADD fpureg	; D8 C0+r	[8086,FPU]
FADD ST0,fpureg	; D8 C0+r	[8086,FPU]
FADD TO fpureg	; DC C0+r	[8086,FPU]
FADD fpureg,ST0	; DC C0+r	[8086,FPU]
FADDP fpureg	; DE C0+r	[8086,FPU]
FADDP fpureg,ST0	; DE C0+r	[8086,FPU]

- FADD, given one operand, adds the operand to ST0 and stores the result back in ST0. If the operand has the TO modifier, the result is stored in the register given rather than in ST0.
- FADDP performs the same function as FADD TO, but pops the register stack after storing the result.

The given two-operand forms are synonyms for the one-operand forms.

To add an integer value to ST0, use the FIADD instruction (section A.5.80).

A.5.69 FBLD, FBSTP: BCD Floating-Point Load and Store

FBLD mem80	; DF /4	[8086,FPU]
FBSTP mem80	; DF /6	[8086,FPU]

FBLD loads an 80-bit (ten-byte) packed binary-coded decimal number from the given memory address, converts it to a real, and pushes it on the register stack. FBSTP stores the value of ST0, in packed BCD, at the given address and then pops the register stack.

A.5.70 FCHS: Floating-Point Change Sign

FCHS	; D9 E0	[8086,FPU]
------	---------	------------

FCHS negates the number in ST0, by inverting the sign bit: negative numbers become positive, and vice versa.

A.5.71 FCLEX, FNCLEX: Clear Floating-Point Exceptions

FCLEX	; 9B DB E2	[8086,FPU]
FNCLEX	; DB E2	[8086,FPU]

FCLEX clears any floating-point exceptions which may be pending. FNCLEX does the same thing but doesn't wait for previous floating-point operations (including the *handling* of pending exceptions) to finish first.

A.5.72 FCMOVCc: Floating-Point Conditional Move

FCMOVB fpureg	; DA C0+r	[P6,FPU]
FCMOVB ST0,fpureg	; DA C0+r	[P6,FPU]
FCMOVE fpureg	; DA C8+r	[P6,FPU]
FCMOVE ST0,fpureg	; DA C8+r	[P6,FPU]

FCMOVBE fpureg	; DA D0+r	[P6, FPU]
FCMOVBE ST0, fpureg	; DA D0+r	[P6, FPU]
FCMOVU fpureg	; DA D8+r	[P6, FPU]
FCMOVU ST0, fpureg	; DA D8+r	[P6, FPU]
FCMOVNB fpureg	; DB C0+r	[P6, FPU]
FCMOVNB ST0, fpureg	; DB C0+r	[P6, FPU]
FCMOVNE fpureg	; DB C8+r	[P6, FPU]
FCMOVNE ST0, fpureg	; DB C8+r	[P6, FPU]
FCMOVNBE fpureg	; DB D0+r	[P6, FPU]
FCMOVNBE ST0, fpureg	; DB D0+r	[P6, FPU]
FCMOVNU fpureg	; DB D8+r	[P6, FPU]
FCMOVNU ST0, fpureg	; DB D8+r	[P6, FPU]

The U instructions perform conditional move operations: each of them moves the contents of the given register into ST0 if its condition is satisfied, and does nothing if not.

The conditions are not the same as the standard condition codes used with conditional jump instructions. The conditions B, BE, NB, NBE, E and NE are exactly as normal, but none of the other standard ones are supported. Instead, the condition U and its counterpart NU are provided; the U condition is satisfied if the last two floating-point numbers compared were *unordered*, i.e. they were not equal but neither one could be said to be greater than the other, for example if they were NaNs. (The flag state which signals this is the setting of the parity flag: so the U condition is notionally equivalent to PE, and NU is equivalent to PO.)

The FCMOV conditions test the main processor's status flags, not the FPU status flags, so using FCMOV directly after FCOM will not work. Instead, you should either use FCOMI which writes directly to the main CPU flags word, or use FSTSW to extract the FPU flags.

Although the FCMOV instructions are flagged P6 above, they may not be supported by all Pentium Pro processors; the CPUID instruction (section A.5.34) will return a bit which indicates whether conditional moves are supported.

A.5.73 FCOM, FCOMP, FCOMPP, FCOMI, FCOMIP: Floating-Point Compare

FCOM mem32	; D8 /2	[8086, FPU]
FCOM mem64	; DC /2	[8086, FPU]
FCOM fpureg	; D8 D0+r	[8086, FPU]
FCOM ST0, fpureg	; D8 D0+r	[8086, FPU]
FCOMP mem32	; D8 /3	[8086, FPU]
FCOMP mem64	; DC /3	[8086, FPU]
FCOMP fpureg	; D8 D8+r	[8086, FPU]
FCOMP ST0, fpureg	; D8 D8+r	[8086, FPU]
FCOMPP	; DE D9	[8086, FPU]
FCOMI fpureg	; DB F0+r	[P6, FPU]
FCOMI ST0, fpureg	; DB F0+r	[P6, FPU]
FCOMIP fpureg	; DF F0+r	[P6, FPU]

FCOMIP ST0,fpureg ; DF F0+r [P6,FPU]

FCOM compares ST0 with the given operand, and sets the FPU flags accordingly. ST0 is treated as the left-hand side of the comparison, so that the carry flag is set (for a 'less-than' result) if ST0 is less than the given operand.

FCOMP does the same as FCOM, but pops the register stack afterwards. FCOMPP compares ST0 with ST1 and then pops the register stack twice.

FCOMI and FCOMIP work like the corresponding forms of FCOM and FCOMP, but write their results directly to the CPU flags register rather than the FPU status word, so they can be immediately followed by conditional jump or conditional move instructions.

The FCOM instructions differ from the FUCOM instructions (section A.5.108) only in the way they handle quiet NaNs: FUCOM will handle them silently and set the condition code flags to an 'unordered' result, whereas FCOM will generate an exception.

A.5.74 FCOS: Cosine

FCOS ; D9 FF [386,FPU]

FCOS computes the cosine of ST0 (in radians), and stores the result in ST0. The absolute value of ST0 must be less than 2**63.

See also FSINCOS (section A.5.100).

A.5.75 FDECSTP: Decrement Floating-Point Stack Pointer

FDECSTP ; D9 F6 [8086,FPU]

FDECSTP decrements the 'top' field in the floating-point status word. This has the effect of rotating the FPU register stack by one, as if the contents of ST7 had been pushed on the stack. See also FINCSTP (section A.5.85).

A.5.76 FxDISI, FxENI: Disable and Enable Floating-Point Interrupts

FDISI ; 9B DB E1 [8086,FPU]

FNDISI ; DB E1 [8086,FPU]

FENI ; 9B DB E0 [8086,FPU]

FNENI ; DB E0 [8086,FPU]

FDISI and FENI disable and enable floating-point interrupts. These instructions are only meaningful on original 8087 processors: the 287 and above treat them as no-operation instructions.

FNDISI and FNENI do the same thing as FDISI and FENI respectively, but without waiting for the floating-point processor to finish what it was doing first.

A.5.77 FDIV, FDIVP, FDIVR, FDIVRP: Floating-Point Division

FDIV mem32 ; D8 /6 [8086,FPU]

FDIV mem64 ; DC /6 [8086,FPU]

FDIV fpureg ; D8 F0+r [8086,FPU]

FDIV ST0,fpureg ; D8 F0+r [8086,FPU]

FDIV TO fpureg	; DC F8+r	[8086,FPU]
FDIV fpureg,ST0	; DC F8+r	[8086,FPU]
FDIVR mem32	; D8 /7	[8086,FPU]
FDIVR mem64	; DC /7	[8086,FPU]
FDIVR fpureg	; D8 F8+r	[8086,FPU]
FDIVR ST0,fpureg	; D8 F8+r	[8086,FPU]
FDIVR TO fpureg	; DC F0+r	[8086,FPU]
FDIVR fpureg,ST0	; DC F0+r	[8086,FPU]
FDIVP fpureg	; DE F8+r	[8086,FPU]
FDIVP fpureg,ST0	; DE F8+r	[8086,FPU]
FDIVRP fpureg	; DE F0+r	[8086,FPU]
FDIVRP fpureg,ST0	; DE F0+r	[8086,FPU]

- FDIV divides ST0 by the given operand and stores the result back in ST0, unless the TO qualifier is given, in which case it divides the given operand by ST0 and stores the result in the operand.
- FDIVR does the same thing, but does the division the other way up: so if TO is not given, it divides the given operand by ST0 and stores the result in ST0, whereas if TO is given it divides ST0 by its operand and stores the result in the operand.
- FDIVP operates like FDIV TO, but pops the register stack once it has finished.
- FDIVRP operates like FDIVR TO, but pops the register stack once it has finished.

For FP/Integer divisions, see FIDIV (section A.5.82).

A.5.78 FEMMS: Faster Enter/Exit of the MMX or floating-point state

FEMMS ; 0F 0E [PENT,3DNow]

FEMMS can be used in place of the EMMS instruction on processors which support the 3DNow! instruction set. Following execution of FEMMS, the state of the MMX/FP registers is undefined, and this allows a faster context switch between FP and MMX instructions. The FEMMS instruction can also be used *before* executing MMX instructions.

A.5.79 FFREE: Flag Floating-Point Register as Unused

FFREE fpureg ; DD C0+r [8086,FPU]
 FFREEP fpureg ; DF C0+r [286,FPU,UNDOC]

FFREE marks the given register as being empty.

FFREEP marks the given register as being empty, and then pops the register stack.

A.5.80 FIADD: Floating-Point/Integer Addition

FIADD mem16 ; DE /0 [8086,FPU]
 FIADD mem32 ; DA /0 [8086,FPU]

FIADD adds the 16-bit or 32-bit integer stored in the given memory location to ST0, storing

the result in ST0.

A.5.81 FICOM, FICOMP: Floating-Point/Integer Compare

FICOM mem16	; DE /2	[8086,FPU]
FICOM mem32	; DA /2	[8086,FPU]
FICOMP mem16	; DE /3	[8086,FPU]
FICOMP mem32	; DA /3	[8086,FPU]

FICOM compares ST0 with the 16-bit or 32-bit integer stored in the given memory location, and sets the FPU flags accordingly. FICOMP does the same, but pops the register stack afterwards.

A.5.82 FIDIV, FIDIVR: Floating-Point/Integer Division

FIDIV mem16	; DE /6	[8086,FPU]
FIDIV mem32	; DA /6	[8086,FPU]
FIDIVR mem16	; DE /7	[8086,FPU]
FIDIVR mem32	; DA /7	[8086,FPU]

FIDIV divides ST0 by the 16-bit or 32-bit integer stored in the given memory location, and stores the result in ST0. FIDIVR does the division the other way up: it divides the integer by ST0, but still stores the result in ST0.

A.5.83 FILD, FIST, FISTP: Floating-Point/Integer Conversion

FILD mem16	; DF /0	[8086,FPU]
FILD mem32	; DB /0	[8086,FPU]
FILD mem64	; DF /5	[8086,FPU]
FIST mem16	; DF /2	[8086,FPU]
FIST mem32	; DB /2	[8086,FPU]
FISTP mem16	; DF /3	[8086,FPU]
FISTP mem32	; DB /3	[8086,FPU]
FISTP mem64	; DF /7	[8086,FPU]

FILD loads an integer out of a memory location, converts it to a real, and pushes it on the FPU register stack. FIST converts ST0 to an integer and stores that in memory; FISTP does the same as FIST, but pops the register stack afterwards.

A.5.84 FIMUL: Floating-Point/Integer Multiplication

FIMUL mem16	; DE /1	[8086,FPU]
FIMUL mem32	; DA /1	[8086,FPU]

FIMUL multiplies ST0 by the 16-bit or 32-bit integer stored in the given memory location, and stores the result in ST0.

A.5.85 FINCSTP: Increment Floating-Point Stack Pointer

FINCSTP	; D9 F7	[8086,FPU]
---------	---------	------------

FINCSTP increments the 'top' field in the floating-point status word. This has the effect of rotating the FPU register stack by one, as if the register stack had been popped; however, unlike

the popping of the stack performed by many FPU instructions, it does not flag the new ST7 (previously ST0) as empty. See also FDECSTP (section A.5.75).

A.5.86 FINIT, FNINIT: initialize Floating-Point Unit

```
FINIT                ; 9B DB E3                [8086,FPU]
FNINIT              ; DB E3                  [8086,FPU]
```

FINIT initializes the FPU to its default state. It flags all registers as empty, without actually change their values, clears the top of stack pointer. FNINIT does the same, without first waiting for pending exceptions to clear.

A.5.87 FISUB: Floating-Point/Integer Subtraction

```
FISUB mem16         ; DE /4                [8086,FPU]
FISUB mem32         ; DA /4                [8086,FPU]

FISUBR mem16       ; DE /5                [8086,FPU]
FISUBR mem32       ; DA /5                [8086,FPU]
```

FISUB subtracts the 16-bit or 32-bit integer stored in the given memory location from ST0, and stores the result in ST0. FISUBR does the subtraction the other way round, i.e. it subtracts ST0 from the given integer, but still stores the result in ST0.

A.5.88 FLD: Floating-Point Load

```
FLD mem32          ; D9 /0                [8086,FPU]
FLD mem64          ; DD /0                [8086,FPU]
FLD mem80          ; DB /5                [8086,FPU]
FLD fpureg         ; D9 C0+r            [8086,FPU]
```

FLD loads a floating-point value out of the given register or memory location, and pushes it on the FPU register stack.

A.5.89 FLDxx: Floating-Point Load Constants

```
FLD1               ; D9 E8                [8086,FPU]
FLDL2E             ; D9 EA                [8086,FPU]
FLDL2T             ; D9 E9                [8086,FPU]
FLDLG2             ; D9 EC                [8086,FPU]
FLDLN2             ; D9 ED                [8086,FPU]
FLDPI              ; D9 EB                [8086,FPU]
FLDZ               ; D9 EE                [8086,FPU]
```

These instructions push specific standard constants on the FPU register stack.

Instruction	Constant pushed
FLD1	1
FLDL2E	base-2 logarithm of e
FLDL2T	base-2 log of 10
FLDLG2	base-10 log of 2
FLDLN2	base-e log of 2
FLDPI	pi
FLDZ	zero

A.5.90 FLDCW: Load Floating-Point Control Word

FLDCW mem16 ; D9 /5 [8086,FPU]

FLDCW loads a 16-bit value out of memory and stores it into the FPU control word (governing things like the rounding mode, the precision, and the exception masks). See also FSTCW (section A.5.103). If exceptions are enabled and you don't want to generate one, use FCLEX or FNCLEX (section A.5.71) before loading the new control word.

A.5.91 FLDENV: Load Floating-Point Environment

FLDENV mem ; D9 /4 [8086,FPU]

FLDENV loads the FPU operating environment (control word, status word, tag word, instruction pointer, data pointer and last opcode) from memory. The memory area is 14 or 28 bytes long, depending on the CPU mode at the time. See also FSTENV (section A.5.104).

A.5.92 FMUL, FMULP: Floating-Point Multiply

FMUL mem32 ; D8 /1 [8086,FPU]

FMUL mem64 ; DC /1 [8086,FPU]

FMUL fpureg ; D8 C8+r [8086,FPU]

FMUL ST0,fpureg ; D8 C8+r [8086,FPU]

FMUL TO fpureg ; DC C8+r [8086,FPU]

FMUL fpureg,ST0 ; DC C8+r [8086,FPU]

FMULP fpureg ; DE C8+r [8086,FPU]

FMULP fpureg,ST0 ; DE C8+r [8086,FPU]

FMUL multiplies ST0 by the given operand, and stores the result in ST0, unless the TO qualifier is used in which case it stores the result in the operand. FMULP performs the same operation as FMUL TO, and then pops the register stack.

A.5.93 FNOP: Floating-Point No Operation

FNOP ; D9 D0 [8086,FPU]

FNOP does nothing.

A.5.94 FPATAN, FPTAN: Arctangent and Tangent

FPATAN ; D9 F3 [8086,FPU]

FPTAN ; D9 F2 [8086,FPU]

FPATAN computes the arctangent, in radians, of the result of dividing ST1 by ST0, stores the result in ST1, and pops the register stack. It works like the C atan2 function, in that changing the sign of both ST0 and ST1 changes the output value by pi (so it performs true rectangular-to-polar coordinate conversion, with ST1 being the Y coordinate and ST0 being the X coordinate, not merely an arctangent).

FPTAN computes the tangent of the value in ST0 (in radians), and stores the result back into ST0.

The absolute value of ST0 must be less than 2**63.

A.5.95 **FPREM, FPREM1: Floating-Point Partial Remainder**

FPREM	; D9 F8	[8086 ,FPU]
FPREM1	; D9 F5	[386 ,FPU]

These instructions both produce the remainder obtained by dividing ST0 by ST1. This is calculated, notionally, by dividing ST0 by ST1, rounding the result to an integer, multiplying by ST1 again, and computing the value which would need to be added back on to the result to get back to the original value in ST0.

The two instructions differ in the way the notional round-to-integer operation is performed. FPREM does it by rounding towards zero, so that the remainder it returns always has the same sign as the original value in ST0; FPREM1 does it by rounding to the nearest integer, so that the remainder always has at most half the magnitude of ST1.

Both instructions calculate *partial* remainders, meaning that they may not manage to provide the final result, but might leave intermediate results in ST0 instead. If this happens, they will set the C2 flag in the FPU status word; therefore, to calculate a remainder, you should repeatedly execute FPREM or FPREM1 until C2 becomes clear.

A.5.96 **FRNDINT: Floating-Point Round to Integer**

FRNDINT	; D9 FC	[8086 ,FPU]
---------	---------	--------------

FRNDINT rounds the contents of ST0 to an integer, according to the current rounding mode set in the FPU control word, and stores the result back in ST0.

A.5.97 **FSAVE, FRSTOR: Save/Restore Floating-Point State**

FSAVE mem	; 9B DD /6	[8086 ,FPU]
FNSAVE mem	; DD /6	[8086 ,FPU]
FRSTOR mem	; DD /4	[8086 ,FPU]

FSAVE saves the entire floating-point unit state, including all the information saved by FSTENV (section A.5.104) plus the contents of all the registers, to a 94 or 108 byte area of memory (depending on the CPU mode). FRSTOR restores the floating-point state from the same area of memory.

FNSAVE does the same as FSAVE, without first waiting for pending floating-point exceptions to clear.

A.5.98 **FSCALE: Scale Floating-Point Value by Power of Two**

FSCALE	; D9 FD	[8086 ,FPU]
--------	---------	--------------

FSCALE scales a number by a power of two: it rounds ST1 towards zero to obtain an integer, then multiplies ST0 by two to the power of that integer, and stores the result in ST0.

A.5.99 **FSETPM: Set Protected Mode**

FSETPM	; DB E4	[286 ,FPU]
--------	---------	-------------

This instruction initializes protected mode on the 287 floating-point coprocessor. It is only meaningful on that processor: the 387 and above treat the instruction as a no-operation.

A.5.100 FSIN, FSINCOS: Sine and Cosine

FSIN	; D9 FE	[386 ,FPU]
FSINCOS	; D9 FB	[386 ,FPU]

FSIN calculates the sine of ST0 (in radians) and stores the result in ST0. FSINCOS does the same, but then pushes the cosine of the same value on the register stack, so that the sine ends up in ST1 and the cosine in ST0. FSINCOS is faster than executing FSIN and FCOS (see section A.5.74) in succession.

The absolute value of ST0 must be less than $2^{*}63$.

A.5.101 FSQRT: Floating-Point Square Root

FSQRT	; D9 FA	[8086 ,FPU]
-------	---------	--------------

FSQRT calculates the square root of ST0 and stores the result in ST0.

A.5.102 FST, FSTP: Floating-Point Store

FST mem32	; D9 /2	[8086 ,FPU]
FST mem64	; DD /2	[8086 ,FPU]
FST fpureg	; DD D0+r	[8086 ,FPU]
FSTP mem32	; D9 /3	[8086 ,FPU]
FSTP mem64	; DD /3	[8086 ,FPU]
FSTP mem80	; DB /7	[8086 ,FPU]
FSTP fpureg	; DD D8+r	[8086 ,FPU]

FST stores the value in ST0 into the given memory location or other FPU register. FSTP does the same, but then pops the register stack.

A.5.103 FSTCW: Store Floating-Point Control Word

FSTCW mem16	; 9B D9 /7	[8086 ,FPU]
FNSTCW mem16	; D9 /7	[8086 ,FPU]

FSTCW stores the FPU control word (governing things like the rounding mode, the precision, and the exception masks) into a 2-byte memory area. See also FLDCW (section A.5.90).

FNSTCW does the same thing as FSTCW, without first waiting for pending floating-point exceptions to clear.

A.5.104 FSTENV: Store Floating-Point Environment

FSTENV mem	; 9B D9 /6	[8086 ,FPU]
FNSTENV mem	; D9 /6	[8086 ,FPU]

FSTENV stores the FPU operating environment (control word, status word, tag word, instruction pointer, data pointer and last opcode) into memory. The memory area is 14 or 28 bytes long, depending on the CPU mode at the time. See also FLDENV (section A.5.91).

FNSTENV does the same thing as FSTENV, without first waiting for pending floating-point exceptions to clear.

A.5.105 FSTSW: Store Floating-Point Status Word

FSTSW mem16	; 9B DD /7	[8086,FPU]
FSTSW AX	; 9B DF E0	[286,FPU]
FNSTSW mem16	; DD /7	[8086,FPU]
FNSTSW AX	; DF E0	[286,FPU]

FSTSW stores the FPU status word into AX or into a 2-byte memory area.

FNSTSW does the same thing as FSTSW, without first waiting for pending floating-point exceptions to clear.

A.5.106 FSUB, FSUBP, FSUBR, FSUBRP: Floating-Point Subtract

FSUB mem32	; D8 /4	[8086,FPU]
FSUB mem64	; DC /4	[8086,FPU]
FSUB fpureg	; D8 E0+r	[8086,FPU]
FSUB ST0,fpureg	; D8 E0+r	[8086,FPU]
FSUB TO fpureg	; DC E8+r	[8086,FPU]
FSUB fpureg,ST0	; DC E8+r	[8086,FPU]
FSUBR mem32	; D8 /5	[8086,FPU]
FSUBR mem64	; DC /5	[8086,FPU]
FSUBR fpureg	; D8 E8+r	[8086,FPU]
FSUBR ST0,fpureg	; D8 E8+r	[8086,FPU]
FSUBR TO fpureg	; DC E0+r	[8086,FPU]
FSUBR fpureg,ST0	; DC E0+r	[8086,FPU]
FSUBP fpureg	; DE E8+r	[8086,FPU]
FSUBP fpureg,ST0	; DE E8+r	[8086,FPU]
FSUBRP fpureg	; DE E0+r	[8086,FPU]
FSUBRP fpureg,ST0	; DE E0+r	[8086,FPU]

- FSUB subtracts the given operand from ST0 and stores the result back in ST0, unless the TO qualifier is given, in which case it subtracts ST0 from the given operand and stores the result in the operand.
- FSUBR does the same thing, but does the subtraction the other way up: so if TO is not given, it subtracts ST0 from the given operand and stores the result in ST0, whereas if TO is given it subtracts its operand from ST0 and stores the result in the operand.
- FSUBP operates like FSUB TO, but pops the register stack once it has finished.
- FSUBRP operates like FSUBR TO, but pops the register stack once it has finished.

A.5.107 FTST: Test ST0 Against Zero

FTST	; D9 E4	[8086,FPU]
------	---------	------------

FTST compares ST0 with zero and sets the FPU flags accordingly. ST0 is treated as the left-

hand side of the comparison, so that a ‘less-than’ result is generated if ST0 is negative.

A.5.108 **FUCOMxx: Floating-Point Unordered Compare**

FUCOM fpureg	; DD E0+r	[386,FPU]
FUCOM ST0,fpureg	; DD E0+r	[386,FPU]
FUCOMP fpureg	; DD E8+r	[386,FPU]
FUCOMP ST0,fpureg	; DD E8+r	[386,FPU]
FUCOMPP	; DA E9	[386,FPU]
FUCOMI fpureg	; DB E8+r	[P6,FPU]
FUCOMI ST0,fpureg	; DB E8+r	[P6,FPU]
FUCOMIP fpureg	; DF E8+r	[P6,FPU]
FUCOMIP ST0,fpureg	; DF E8+r	[P6,FPU]

- FUCOM compares ST0 with the given operand, and sets the FPU flags accordingly. ST0 is treated as the left-hand side of the comparison, so that the carry flag is set (for a ‘less-than’ result) if ST0 is less than the given operand.
- FUCOMP does the same as FUCOM, but pops the register stack afterwards. FUCOMPP compares ST0 with ST1 and then pops the register stack twice.
- FUCOMI and FUCOMIP work like the corresponding forms of FUCOM and FUCOMP, but write their results directly to the CPU flags register rather than the FPU status word, so they can be immediately followed by conditional jump or conditional move instructions.

The FUCOM instructions differ from the FCOM instructions (section A.5.73) only in the way they handle quiet NaNs: FUCOM will handle them silently and set the condition code flags to an ‘unordered’ result, whereas FCOM will generate an exception.

A.5.109 **FXAM: Examine Class of Value in ST0**

FXAM	; D9 E5	[8086,FPU]
------	---------	------------

FXAM sets the FPU flags C3, C2 and C0 depending on the type of value stored in ST0:

Register contents	Flags
Unsupported format	000
NaN	001
Finite number	010
Infinity	011
Zero	100
Empty register	101
Denormal	110

Additionally, the C1 flag is set to the sign of the number.

A.5.110 **FXCH: Floating-Point Exchange**

FXCH	; D9 C9	[8086,FPU]
FXCH fpureg	; D9 C8+r	[8086,FPU]

```
FXCH fpureg,ST0           ; D9 C8+r           [8086,FPU]
FXCH ST0,fpureg          ; D9 C8+r           [8086,FPU]
```

FXCH exchanges ST0 with a given FPU register. The no-operand form exchanges ST0 with ST1.

A.5.111 FXRSTOR: Restore FP, MMX and SSE State

```
FXRSTOR memory           ; 0F AE /1           [P6,SSE,FPU]
```

The FXRSTOR instruction reloads the FPU, MMX and SSE state (environment and registers), from the 512 byte memory area defined by the source operand. This data should have been written by a previous FXSAVE.

A.5.112 FXSAVE: Store FP, MMX and SSE State

```
FXSAVE memory           ; 0F AE /0           [P6,SSE,FPU]
```

The FXSAVE instruction writes the current FPU, MMX and SSE technology states (environment and registers), to the 512 byte memory area defined by the destination operand. It does this without checking for pending unmasked floating-point exceptions (similar to the operation of FNSAVE).

Unlike the FSAVE/FNSAVE instructions, the processor retains the contents of the FPU, MMX and SSE state in the processor after the state has been saved. This instruction has been optimized to maximize floating-point save performance.

A.5.113 FXTRACT: Extract Exponent and Significand

```
FXTRACT                 ; D9 F4           [8086,FPU]
```

FXTRACT separates the number in ST0 into its exponent and significand (mantissa), stores the exponent back into ST0, and then pushes the significand on the register stack (so that the significand ends up in ST0, and the exponent in ST1).

A.5.114 FYL2X, FYL2XP1: Compute Y times Log2(X) or Log2(X+1)

```
FYL2X                  ; D9 F1           [8086,FPU]
FYL2XP1                ; D9 F9           [8086,FPU]
```

FYL2X multiplies ST1 by the base-2 logarithm of ST0, stores the result in ST1, and pops the register stack (so that the result ends up in ST0). ST0 must be non-zero and positive.

FYL2XP1 works the same way, but replacing the base-2 log of ST0 with that of ST0 plus one. This time, ST0 must have magnitude no greater than 1 minus half the square root of two.

A.5.115 HLT: Halt Processor

```
HLT                    ; F4           [8086,PRIV]
```

HLT puts the processor into a halted state, where it will perform no more operations until restarted by an interrupt or a reset.

On the 286 and later processors, this is a privileged instruction.

This instruction, when supported, generally causes the CPU to idle, either by sleeping a certain

amount of time, releasing a time slice in a multitasker, or actually halting until the next hardware interrupt occurs. Thus, executing HLT within an input loop after not receiving any new inputs allows to idle the system.

DPMI environments may fault when trying to execute HLT, if the host does not support this usage. Calls such as interrupt 2Fh with AX=1680h must be used instead then.

A.5.116 IBTS: Insert Bit String

```
IBTS r/m16,reg16          ; 016 0F A7 /r          [386,UNDOC]
IBTS r/m32,reg32         ; 032 0F A7 /r          [386,UNDOC]
```

The implied operation of this instruction is:

```
IBTS r/m16,AX,CL,reg16
IBTS r/m32,EAX,CL,reg32
```

Writes a bit string from the source operand to the destination. CL indicates the number of bits to be copied, from the low bits of the source. (E)AX indicates the low order bit offset in the destination that is written to. For example, if CL is set to 4 and AX (for 16-bit code) is set to 5, bits 0-3 of *src* will be copied to bits 5-8 of *dst*. This instruction is very poorly documented, and I have been unable to find any official source of documentation on it.

IBTS is supported only on the early Intel 386s, and conflicts with the opcodes for CMPXCHG486 (on early Intel 486s). NASM supports it only for completeness. Its counterpart is XBTS (see section A.5.332).

A.5.117 IDIV: Signed Integer Divide

```
IDIV r/m8                ; F6 /7          [8086]
IDIV r/m16               ; 016 F7 /7          [8086]
IDIV r/m32               ; 032 F7 /7          [386]
```

IDIV performs signed integer division. The explicit operand provided is the divisor; the dividend and destination operands are implicit, in the following way:

- For IDIV *r/m8*, AX is divided by the given operand; the quotient is stored in AL and the remainder in AH.
- For IDIV *r/m16*, DX:AX is divided by the given operand; the quotient is stored in AX and the remainder in DX.
- For IDIV *r/m32*, EDX:EAX is divided by the given operand; the quotient is stored in EAX and the remainder in EDX.

Unsigned integer division is performed by the DIV instruction: see section A.5.59.

A.5.118 IMUL: Signed Integer Multiply

```
IMUL r/m8                ; F6 /5          [8086]
IMUL r/m16               ; 016 F7 /5          [8086]
IMUL r/m32               ; 032 F7 /5          [386]

IMUL reg16,r/m16        ; 016 0F AF /r          [386]
IMUL reg32,r/m32       ; 032 0F AF /r          [386]
```

IMUL reg16,imm8	; o16 6B /r ib	[186]
IMUL reg16,imm16	; o16 69 /r iw	[186]
IMUL reg32,imm8	; o32 6B /r ib	[386]
IMUL reg32,imm32	; o32 69 /r id	[386]
IMUL reg16,r/m16,imm8	; o16 6B /r ib	[186]
IMUL reg16,r/m16,imm16	; o16 69 /r iw	[186]
IMUL reg32,r/m32,imm8	; o32 6B /r ib	[386]
IMUL reg32,r/m32,imm32	; o32 69 /r id	[386]

IMUL performs signed integer multiplication. For the single-operand form, the other operand and destination are implicit, in the following way:

- For IMUL r/m8, AL is multiplied by the given operand; the product is stored in AX.
- For IMUL r/m16, AX is multiplied by the given operand; the product is stored in DX:AX.
- For IMUL r/m32, EAX is multiplied by the given operand; the product is stored in EDX:EAX.

The two-operand form multiplies its two operands and stores the result in the destination (first) operand. The three-operand form multiplies its last two operands and stores the result in the first operand.

The two-operand form with an immediate second operand is in fact a shorthand for the three-operand form, as can be seen by examining the opcode descriptions: in the two-operand form, the code /r takes both its register and r/m parts from the same operand (the first one).

In the forms with an 8-bit immediate operand and another longer source operand, the immediate operand is considered to be signed, and is sign-extended to the length of the other source operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the STRICT WORD or STRICT DWORD qualifier.

Unsigned integer multiplication is performed by the MUL instruction: see section A.5.184.

A.5.119 IN: Input from I/O Port

IN AL,imm8	; E4 ib	[8086]
IN AX,imm8	; o16 E5 ib	[8086]
IN EAX,imm8	; o32 E5 ib	[386]
IN AL,DX	; EC	[8086]
IN AX,DX	; o16 ED	[8086]
IN EAX,DX	; o32 ED	[386]

IN reads a byte, word or doubleword from the specified I/O port, and stores it in the given destination register. The port number may be specified as an immediate value if it is between 0 and 255, and otherwise must be stored in DX. See also OUT (section A.5.194).

A.5.120 INC: Increment Integer

INC reg16	; o16 40+r	[8086]
INC reg32	; o32 40+r	[386]

INC r/m8	; FE /0	[8086]
INC r/m16	; 016 FF /0	[8086]
INC r/m32	; 032 FF /0	[386]

INC adds 1 to its operand. It does *not* affect the carry flag: to affect the carry flag, use `ADD something, 1` (see section A.5.3). INC affects all the other flags according to the result.

This instruction can be used with a LOCK prefix to allow atomic execution.

See also DEC (section A.5.58).

A.5.121 INSB, INSW, INSD: Input String from I/O Port

INSB	; 6C	[186]
INSW	; 016 6D	[186]
INSD	; 032 6D	[386]

INSB inputs a byte from the I/O port specified in DX and stores it at [ES:DI] or [ES:EDI]. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) DI or EDI.

The register used is DI if the address size is 16 bits, and EDI if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit `a16` or `a32` prefix.

Segment override prefixes have no effect for this instruction: the use of ES for the load from [DI] or [EDI] cannot be overridden.

INSW and INSD work in the same way, but they input a word or a doubleword instead of a byte, and increment or decrement the addressing register by 2 or 4 instead of 1.

The REP prefix may be used to repeat the instruction CX (or ECX - again, the address size chooses which) times. The REP alias REPE, as well as the differently-encoded REPNE, are both allowed as well. They behave in the same way as REP.

See also OUTSB, OUTSW and OUTSD (section A.5.195).

A.5.121.1 Pseudo-code examples

`a16 INSB` and with Direction Flag clear (UP) is equal to

```
IN BYTE [ES:DI], DX
LEA DI, [DI + 1]
```

`a16 REP INSW` and with Direction Flag clear (UP) is equal to

```
JCXZ @FF
@@:
IN WORD [ES:DI], DX
LEA DI, [DI + 2]
a16 LOOP @B
@@:
```

`a32 INSD` with Direction Flag set (DN) is equal to

```
IN DWORD [ES:EDI], DX
LEA EDI, [EDI - 4]
```

A.5.122 INT: Software Interrupt

INT imm8 ; CD ib [8086]

INT causes a software interrupt through a specified vector number from 0 to 255.

The code generated by the INT instruction is always two bytes long: although there are short forms for some INT instructions, NASM does not generate them when it sees the INT mnemonic. In order to generate single-byte breakpoint instructions, use the INT3 or INT1 instructions (see section A.5.123) instead.

A.5.123 INT3, INT1, ICEBP, INT01: Breakpoints

INT1 ; F1 [P6]
ICEBP ; F1 [P6]
INT01 ; F1 [P6]
INT3 ; CC [8086]
INT03 ; CC [8086]

INT1 and INT3 are short one-byte forms of the instructions INT 1 and INT 3 (see section A.5.122). They perform a similar function to their longer counterparts, but take up less code space. They are used as breakpoints by debuggers.

- INT1, and its alternative synonyms INT01 and ICEBP, is an instruction used by in-circuit emulators (ICEs). It is present, though not documented, on some processors down to the 286, but is only documented for the Pentium Pro. INT3 is the instruction normally used as a breakpoint by debuggers.
- INT3, and its synonym INT03, is not precisely equivalent to INT 3: the short form, since it is designed to be used as a breakpoint, bypasses the normal IOPL checks in virtual-8086 mode, and also does not go through interrupt redirection.

A.5.124 INTO: Interrupt if Overflow

INTO ; CE [8086]

INTO performs an INT 4 software interrupt (see section A.5.122) if and only if the overflow flag is set.

A.5.125 INVD: Invalidate Internal Caches

INVD ; 0F 08 [486]

INVD invalidates and empties the processor's internal caches, and causes the processor to instruct external caches to do the same. It does not write the contents of the caches back to memory first: any modified data held in the caches will be lost. To write the data back first, use WBINVD (section A.5.328).

A.5.126 INVLPG: Invalidate TLB Entry

INVLPG mem ; 0F 01 /7 [486]

INVLPG invalidates the translation lookahead buffer (TLB) entry associated with the supplied memory address.

A.5.127 IRET, IRETW, IRETD: Return from Interrupt

IRET	; CF	[8086]
IRETW	; 016 CF	[8086]
IRETD	; 032 CF	[386]

IRET returns from an interrupt (hardware or software) by means of popping IP (or EIP), CS and the flags off the stack and then continuing execution from the new CS:IP.

IRETW pops IP, CS and the flags as 2 bytes each, taking 6 bytes off the stack in total. IRETD pops EIP as 4 bytes, pops a further 4 bytes of which the top two are discarded and the bottom two go into CS, and pops the flags as 4 bytes as well, taking 12 bytes off the stack.

IRET is a shorthand for either IRETW or IRETD, depending on the default BITS setting at the time.

A.5.128 Jcc: Conditional Branch

Jcc imm	; 70+cc rb	[8086]
Jcc NEAR imm	; 0F 80+cc rw/rd	[386]
Jcc NEAR imm	; 70+(cc^1) 03 E9 rw	[8086]

The conditional jump instructions execute a near (same segment) jump if and only if their conditions are satisfied. For example, JNZ jumps only if the zero flag is not set.

The ordinary form of the instructions has only a 128-byte range. The single-instruction NEAR form is a 386 extension to the instruction set, and can span the full size of a segment. When CPU is set to 386, NASM will automatically choose the single-instruction NEAR form when the jump exceeds the SHORT range.

When CPU is set to below 386 (any of 286, 186, 8086), recent versions of NASM will generate two instructions to work around the range limitation. The first instruction will be a short conditional jump of the opposite condition code as the one desired. This first jump will (if taken) jump to behind the second instruction, which is an unconditional near jump. (Only the 16-bit variant is shown for this, because 32-bit assembly means that the single-instruction form is available.)

You can override the choice of jump instruction using an explicit SHORT keyword, which will cause an error if the jump target is out of range. Also, an explicit STRICT NEAR qualifier makes NASM always use the single-instruction near jump, even if not needed. (If CPU is set to below 386, this will result in an error.) There is no way to force the work around pair of instructions; if you want these unconditionally, you have to code them manually.

For details of the condition codes, see section A.2.2.

A.5.129 JCXZ, JECXZ: Jump if CX/ECX Zero

JCXZ imm	; a16 E3 rb	[8086]
JECXZ imm	; a32 E3 rb	[386]

JCXZ performs a short jump (with maximum range 128 bytes) if and only if the contents of the CX register is 0. JECXZ does the same thing, but with ECX.

A.5.130 JMP: Jump

JMP imm	; E9 rw/rd	[8086]
JMP SHORT imm	; EB rb	[8086]
JMP imm:imm16	; 016 EA iw iw	[8086]
JMP imm:imm32	; 032 EA id iw	[386]
JMP FAR mem	; 016 FF /5	[8086]
JMP FAR mem32	; 032 FF /5	[386]
JMP r/m16	; 016 FF /4	[8086]
JMP r/m32	; 032 FF /4	[386]

JMP jumps to a given address. The address may be specified as an absolute segment and offset, or as a relative jump within the current segment.

JMP SHORT imm has a maximum range of 128 bytes, since the displacement is specified as only 8 bits, but takes up less code space. Recent versions of NASM automatically generate a JMP SHORT for you when the target is in range and known during assembling (ie, before linking). Specifying the SHORT keyword explicitly will cause an error if the jump target is out of range. Specifying a STRICT NEAR qualifier forces NASM to assemble a near jump, even if the target is in range of a short jump.

You can choose between the two immediate far jump forms (JMP imm:imm) by the use of the WORD and DWORD keywords: JMP WORD 0x1234:0x5678 or JMP DWORD 0x1234:0x56789abc.

The JMP FAR mem forms execute a far jump by loading the destination address out of memory. The address loaded consists of 16 or 32 bits of offset (depending on the operand size), and 16 bits of segment. The operand size may be overridden using JMP WORD FAR mem or JMP DWORD FAR mem.

The JMP r/m forms execute a near jump (within the same segment), loading the destination address out of memory or out of a register. The keyword NEAR may be specified, for clarity, in these forms, but is not necessary. Again, operand size can be overridden using JMP WORD mem or JMP DWORD mem.

As a convenience, NASM does not require you to jump to a far symbol by coding the cumbersome JMP SEG routine:routine, but instead allows the easier synonym JMP FAR routine.

A.5.131 LAHF: Load AH from Flags

LAHF	; 9F	[8086]
------	------	--------

LAHF sets the AH register according to the contents of the low byte of the flags word.

The operation of LAHF is:

```
AH <-- SF:ZF:0:AF:0:PF:1:CF
```

See also SAHF (section A.5.282).

A.5.132 LAR: Load Access Rights

```
LAR reg16,r/m16 ; 016 0F 02 /r [286,PRIV]
LAR reg32,r/m32 ; 032 0F 02 /r [386,PRIV]
```

LAR takes the segment selector specified by its source (second) operand, finds the corresponding segment descriptor in the GDT or LDT, and loads the access-rights byte of the descriptor into its destination (first) operand.

A.5.133 LDMXCSR: Load Streaming SIMD Extension Control/Status

```
LDMXCSR mem32 ; 0F AE /2 [KATMAI,SSE]
```

LDMXCSR loads 32-bits of data from the specified memory location into the MXCSR control/status register. MXCSR is used to enable masked/unmasked exception handling, to set rounding modes, to set flush-to-zero mode, and to view exception status flags.

For details of the MXCSR register, see the Intel processor docs.

See also STMXCSR (section A.5.302)

A.5.134 LDS, LES, LFS, LGS, LSS: Load Far Pointer

```
LDS reg16,mem ; 016 C5 /r [8086]
LDS reg32,mem ; 032 C5 /r [386]

LES reg16,mem ; 016 C4 /r [8086]
LES reg32,mem ; 032 C4 /r [386]

LFS reg16,mem ; 016 0F B4 /r [386]
LFS reg32,mem ; 032 0F B4 /r [386]

LGS reg16,mem ; 016 0F B5 /r [386]
LGS reg32,mem ; 032 0F B5 /r [386]

LSS reg16,mem ; 016 0F B2 /r [386]
LSS reg32,mem ; 032 0F B2 /r [386]
```

These instructions load an entire far pointer (16 or 32 bits of offset, plus 16 bits of segment) out of memory in one go. LDS, for example, loads 16 or 32 bits from the given memory address into the given register (depending on the size of the register), then loads the *next* 16 bits from memory into DS. LES, LFS, LGS and LSS work in the same way but use the other segment registers.

A.5.135 LEA: Load Effective Address

```
LEA reg16,mem ; 016 8D /r [8086]
LEA reg32,mem ; 032 8D /r [386]
```

LEA, despite its syntax, does not access memory. It calculates the effective address specified by its second operand as if it were going to load or store data from it, but instead it stores the calculated address into the register specified by its first operand. This can be used to perform quite complex calculations (e.g. `LEA EAX, [EBX+ECX*4+100]`) in one instruction.

LEA, despite being a purely arithmetic instruction which accesses no memory, still requires

square brackets around its second operand, as if it were a memory reference.

The size of the calculation is the current *address* size, and the size that the result is stored as is the current *operand* size. If the address and operand size are not the same, then if the addressing mode was 32-bits, the low 16-bits are stored, and if the address was 16-bits, it is zero-extended to 32-bits before storing.

The ModR/M byte (see section A.2.6) can encode a register as source operand, but this is an invalid instruction.

A.5.136 LEAVE: Destroy Stack Frame

LEAVE ; C9 [186]

LEAVE destroys a stack frame of the form created by the ENTER instruction (see section A.5.65). It is functionally equivalent to MOV ESP,EBP followed by POP EBP (or MOV SP,BP followed by POP BP in 16-bit mode).

A.5.137 LFENCE: Load Fence

LFENCE ; 0F AE /5 [WILLAMETTE,SSE2]

LFENCE performs a serialising operation on all loads from memory that were issued before the LFENCE instruction. This guarantees that all memory reads before the LFENCE instruction are visible before any reads after the LFENCE instruction.

LFENCE is ordered relative to other LFENCE instruction, MFENCE, any memory read and any other serialising instruction (such as CPUID).

Weakly ordered memory types can be used to achieve higher processor performance through such techniques as out-of-order issue and speculative reads. The degree to which a consumer of data recognizes or knows that the data is weakly ordered varies among applications and may be unknown to the producer of this data. The LFENCE instruction provides a performance-efficient way of ensuring load ordering between routines that produce weakly-ordered results and routines that consume that data.

LFENCE uses the following ModR/M encoding:

Mod (7:6)	=	11B
Reg/Opcode (5:3)	=	101B
R/M (2:0)	=	000B

All other ModR/M encodings are defined to be reserved, and use of these encodings risks incompatibility with future processors.

See also SFENCE (section A.5.288) and MFENCE (section A.5.151).

A.5.138 LGDT, LIDT, LLDT: Load Descriptor Tables

LGDT mem	; 0F 01 /2	[286,PRIV]
LIDT mem	; 0F 01 /3	[286,PRIV]
LLDT r/m16	; 0F 00 /2	[286,PRIV]

LGDT and LIDT both take a 6-byte memory area as an operand: they load a 16-bit size limit and a 32-bit linear address from that area (limit word first, then linear address dword) into the

GDT (global descriptor table register) or IDTR (interrupt descriptor table register). The GDT and IDT instructions are the only instructions which directly use *linear* addresses, rather than segment/offset pairs.

LLDT takes a segment selector as an operand. The processor looks up that selector in the GDT and stores the limit and base address given there into the LDTR (local descriptor table register).

See also SGDT, SIDT and SLDT (section A.5.289).

A.5.139 LMSW: Load/Store Machine Status Word

LMSW *r/m16* ; 0F 01 /6 [286, PRIV]

LMSW loads the bottom four bits of the source operand into the bottom four bits of the CR0 control register (or the Machine Status Word, on 286 processors). See also SMSW (section A.5.296).

A.5.140 LOADALL, LOADALL286: Load Processor State

LOADALL ; 0F 07 [386, UNDOC]
LOADALL286 ; 0F 05 [286, UNDOC]

This instruction, in its two different-opcode forms, is apparently supported on most 286 processors, some 386 and possibly some 486. The opcode differs between the 286 and the 386.

The function of the instruction is to load all information relating to the state of the processor out of a block of memory: on the 286, this block is located implicitly at absolute address 0x800, and on the 386 and 486 it is at [ES : EDI].

A.5.141 LODSB, LODSW, LODSD: Load from String

LODSB ; AC [8086]
LODSW ; 016 AD [8086]
LODSD ; 032 AD [386]

LODSB loads a byte from [DS : SI] or [DS : ESI] into AL. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) SI or ESI.

The register used is SI if the address size is 16 bits, and ESI if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit a16 or a32 prefix.

The segment register used to load from [SI] or [ESI] can be overridden by using a segment register name as a prefix (for example, ES LODSB).

LODSW and LODSD work in the same way, but they load a word or a doubleword instead of a byte, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The REP prefix may be used to repeat the instruction CX (or ECX - again, the address size chooses which) times. The REP alias REPE, as well as the differently-encoded REPNE, are both allowed as well. They behave in the same way as REP.

A.5.141.1 Pseudo-code examples

a16 LODSB without segment override and with Direction Flag clear (UP) is equal to

```
MOV AL, BYTE [SI]
LEA SI, [SI + 1]
```

a32 ES LODSD with Direction Flag set (DN) is equal to

```
MOV EAX, DWORD [ES:ESI]
LEA ESI, [ESI - 4]
```

A.5.142 LOOP, LOOPE, LOOPZ, LOOPNE, LOOPNZ: Loop with Counter

```
LOOP imm                ; E2 rb                [8086]
LOOP imm,CX             ; a16 E2 rb                [8086]
LOOP imm,ECX           ; a32 E2 rb                [386]

LOOPE imm              ; E1 rb                [8086]
LOOPE imm,CX          ; a16 E1 rb                [8086]
LOOPE imm,ECX        ; a32 E1 rb                [386]
LOOPZ imm              ; E1 rb                [8086]
LOOPZ imm,CX          ; a16 E1 rb                [8086]
LOOPZ imm,ECX        ; a32 E1 rb                [386]

LOOPNE imm             ; E0 rb                [8086]
LOOPNE imm,CX         ; a16 E0 rb                [8086]
LOOPNE imm,ECX       ; a32 E0 rb                [386]
LOOPNZ imm            ; E0 rb                [8086]
LOOPNZ imm,CX        ; a16 E0 rb                [8086]
LOOPNZ imm,ECX      ; a32 E0 rb                [386]
```

LOOP decrements its counter register (either CX or ECX - if one is not specified explicitly, the BITS setting dictates which is used) by one, and if the counter does not become zero as a result of this operation, it jumps to the given label. The jump has a range of 128 bytes.

LOOPE (or its synonym LOOPZ) adds the additional condition that it only jumps if the counter is nonzero *and* the zero flag is set. Similarly, LOOPNE (and LOOPNZ) jumps only if the counter is nonzero and the zero flag is clear.

A.5.143 LSL: Load Segment Limit

```
LSL reg16,r/m16        ; 016 0F 03 /r          [286,PRIV]
LSL reg32,r/m32        ; 032 0F 03 /r          [386,PRIV]
```

LSL is given a segment selector in its source (second) operand; it computes the segment limit value by loading the segment limit field from the associated segment descriptor in the GDT or LDT. (This involves shifting left by 12 bits if the segment limit is page-granular, and not if it is byte-granular; so you end up with a byte limit in either case.) The segment limit obtained is then loaded into the destination (first) operand.

A.5.144 LTR: Load Task Register

```
LTR r/m16              ; 0F 00 /3              [286,PRIV]
```

LTR looks up the segment base and limit in the GDT or LDT descriptor specified by the segment selector given as its operand, and loads them into the Task Register.

A.5.145 MASKMOVDQU: Byte Mask Write

MASKMOVDQU *xmm1*, *xmm2* ; 66 0F F7 /r [WILLAMETTE, SSE2]

MASKMOVDQU stores data from *xmm1* to the location specified by ES: (E)DI. The size of the store depends on the address-size attribute. The most significant bit in each byte of the mask register *xmm2* is used to selectively write the data (0 = no write, 1 = write) on a per-byte basis.

A.5.146 MASKMOVQ: Byte Mask Write

MASKMOVQ *mm1*, *mm2* ; 0F F7 /r [KATMAI, MMX]

MASKMOVQ stores data from *mm1* to the location specified by ES: (E)DI. The size of the store depends on the address-size attribute. The most significant bit in each byte of the mask register *mm2* is used to selectively write the data (0 = no write, 1 = write) on a per-byte basis.

A.5.147 MAXPD: Return Packed Double-Precision FP Maximum

MAXPD *xmm1*, *xmm2/m128* ; 66 0F 5F /r [WILLAMETTE, SSE2]

MAXPD performs a SIMD compare of the packed double-precision FP numbers from *xmm1* and *xmm2/mem*, and stores the maximum values of each pair of values in *xmm1*. If the values being compared are both zeroes, *source2* (*xmm2/m128*) would be returned. If *source2* (*xmm2/m128*) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned).

A.5.148 MAXPS: Return Packed Single-Precision FP Maximum

MAXPS *xmm1*, *xmm2/m128* ; 0F 5F /r [KATMAI, SSE]

MAXPS performs a SIMD compare of the packed single-precision FP numbers from *xmm1* and *xmm2/mem*, and stores the maximum values of each pair of values in *xmm1*. If the values being compared are both zeroes, *source2* (*xmm2/m128*) would be returned. If *source2* (*xmm2/m128*) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned).

A.5.149 MAXSD: Return Scalar Double-Precision FP Maximum

MAXSD *xmm1*, *xmm2/m64* ; F2 0F 5F /r [WILLAMETTE, SSE2]

MAXSD compares the low-order double-precision FP numbers from *xmm1* and *xmm2/mem*, and stores the maximum value in *xmm1*. If the values being compared are both zeroes, *source2* (*xmm2/m64*) would be returned. If *source2* (*xmm2/m64*) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned). The high quadword of the destination is left unchanged.

A.5.150 MAXSS: Return Scalar Single-Precision FP Maximum

MAXSS *xmm1*, *xmm2/m32* ; F3 0F 5F /r [KATMAI, SSE]

MAXSS compares the low-order single-precision FP numbers from *xmm1* and *xmm2/mem*, and stores the maximum value in *xmm1*. If the values being compared are both zeroes, *source2* (*xmm2/m32*) would be returned. If *source2* (*xmm2/m32*) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned). The high three doublewords of the destination are left unchanged.

A.5.151 MFENCE: Memory Fence

MFENCE ; 0F AE /6 [WILLAMETTE, SSE2]

MFENCE performs a serialising operation on all loads from memory and writes to memory that were issued before the MFENCE instruction. This guarantees that all memory reads and writes before the MFENCE instruction are completed before any reads and writes after the MFENCE instruction.

MFENCE is ordered relative to other MFENCE instructions, LFENCE, SFENCE, any memory read and any other serialising instruction (such as CPUID).

Weakly ordered memory types can be used to achieve higher processor performance through such techniques as out-of-order issue, speculative reads, write-combining, and write-collapsing. The degree to which a consumer of data recognizes or knows that the data is weakly ordered varies among applications and may be unknown to the producer of this data. The MFENCE instruction provides a performance-efficient way of ensuring load and store ordering between routines that produce weakly-ordered results and routines that consume that data.

MFENCE uses the following ModR/M encoding:

Mod (7:6)	=	11B
Reg/Opcode (5:3)	=	110B
R/M (2:0)	=	000B

All other ModR/M encodings are defined to be reserved, and use of these encodings risks incompatibility with future processors.

See also LFENCE (section A.5.137) and SFENCE (section A.5.288).

A.5.152 MINPD: Return Packed Double-Precision FP Minimum

MINPD xmm1, xmm2/m128 ; 66 0F 5D /r [WILLAMETTE, SSE2]

MINPD performs a SIMD compare of the packed double-precision FP numbers from xmm1 and xmm2/mem, and stores the minimum values of each pair of values in xmm1. If the values being compared are both zeroes, source2 (xmm2/m128) would be returned. If source2 (xmm2/m128) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned).

A.5.153 MINPS: Return Packed Single-Precision FP Minimum

MINPS xmm1, xmm2/m128 ; 0F 5D /r [KATMAI, SSE]

MINPS performs a SIMD compare of the packed single-precision FP numbers from xmm1 and xmm2/mem, and stores the minimum values of each pair of values in xmm1. If the values being compared are both zeroes, source2 (xmm2/m128) would be returned. If source2 (xmm2/m128) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned).

A.5.154 MINSD: Return Scalar Double-Precision FP Minimum

MINSD xmm1, xmm2/m64 ; F2 0F 5D /r [WILLAMETTE, SSE2]

MINSD compares the low-order double-precision FP numbers from xmm1 and xmm2/mem, and stores the minimum value in xmm1. If the values being compared are both zeroes, source2 (xmm2/m64) would be returned. If source2 (xmm2/m64) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned). The high quadword of the destination is left unchanged.

A.5.155 MINSS: Return Scalar Single-Precision FP Minimum

```
MINSS xmm1, xmm2/m32 ; F3 0F 5D /r [KATMAI, SSE]
```

MINSS compares the low-order single-precision FP numbers from xmm1 and xmm2/mem, and stores the minimum value in xmm1. If the values being compared are both zeroes, source2 (xmm2/m32) would be returned. If source2 (xmm2/m32) is an SNaN, this SNaN is forwarded unchanged to the destination (i.e., a QNaN version of the SNaN is not returned). The high three doublewords of the destination are left unchanged.

A.5.156 MOV: Move Data

```
MOV r/m8, reg8 ; 88 /r [8086]
MOV r/m16, reg16 ; 016 89 /r [8086]
MOV r/m32, reg32 ; 032 89 /r [386]
MOV reg8, r/m8 ; 8A /r [8086]
MOV reg16, r/m16 ; 016 8B /r [8086]
MOV reg32, r/m32 ; 032 8B /r [386]

MOV reg8, imm8 ; B0+r ib [8086]
MOV reg16, imm16 ; 016 B8+r iw [8086]
MOV reg32, imm32 ; 032 B8+r id [386]
MOV r/m8, imm8 ; C6 /0 ib [8086]
MOV r/m16, imm16 ; 016 C7 /0 iw [8086]
MOV r/m32, imm32 ; 032 C7 /0 id [386]

MOV AL, memoffs8 ; A0 ow/od [8086]
MOV AX, memoffs16 ; 016 A1 ow/od [8086]
MOV EAX, memoffs32 ; 032 A1 ow/od [386]
MOV memoffs8, AL ; A2 ow/od [8086]
MOV memoffs16, AX ; 016 A3 ow/od [8086]
MOV memoffs32, EAX ; 032 A3 ow/od [386]

MOV r/m16, segreg ; 016 8C /r [8086]
MOV r/m32, segreg ; 032 8C /r [386]
MOV segreg, r/m16 ; 016 8E /r [8086]
MOV segreg, r/m32 ; 032 8E /r [386]

MOV reg32, CR0/2/3/4 ; 0F 20 /r [386]
MOV reg32, DR0/1/2/3/6/7 ; 0F 21 /r [386]
MOV reg32, TR3/4/5/6/7 ; 0F 24 /r [386]
MOV CR0/2/3/4, reg32 ; 0F 22 /r [386]
MOV DR0/1/2/3/6/7, reg32 ; 0F 23 /r [386]
MOV TR3/4/5/6/7, reg32 ; 0F 26 /r [386]
```

MOV copies the contents of its source (second) operand into its destination (first) operand.

In all forms of the MOV instruction, the two operands are the same size, except for moving between a segment register and an $r/m32$ operand. These instructions are treated exactly like the corresponding 16-bit equivalent (so that, for example, MOV DS, EAX functions identically to MOV DS, AX but saves a prefix when in 32-bit mode), except that when a segment register is moved into a 32-bit destination, the top two bytes of the result are undefined.

MOV may not use CS as a destination. However, this can be encoded, which is silently accepted by current versions of NASM, and is decoded by NDISASM.

CR4 is only a supported register on the Pentium and above.

Test registers are supported on 386/486 processors and on some non-Intel Pentium class processors.

A.5.157 MOVAPD: Move Aligned Packed Double-Precision FP Values

```
MOVAPD xmm1, xmm2/mem128      ; 66 0F 28 /r      [WILLAMETTE, SSE2]
MOVAPD xmm1/mem128, xmm2      ; 66 0F 29 /r      [WILLAMETTE, SSE2]
```

MOVAPD moves a double quadword containing 2 packed double-precision FP values from the source operand to the destination. When the source or destination operand is a memory location, it must be aligned on a 16-byte boundary.

To move data in and out of memory locations that are not known to be on 16-byte boundaries, use the MOVUPD instruction (section A.5.182).

A.5.158 MOVAPS: Move Aligned Packed Single-Precision FP Values

```
MOVAPS xmm1, xmm2/mem128      ; 0F 28 /r      [KATMAI, SSE]
MOVAPS xmm1/mem128, xmm2      ; 0F 29 /r      [KATMAI, SSE]
```

MOVAPS moves a double quadword containing 4 packed single-precision FP values from the source operand to the destination. When the source or destination operand is a memory location, it must be aligned on a 16-byte boundary.

To move data in and out of memory locations that are not known to be on 16-byte boundaries, use the MOVUPS instruction (section A.5.183).

A.5.159 MOVD: Move Doubleword to/from MMX Register

```
MOVD mm, r/m32                ; 0F 6E /r      [PENT, MMX]
MOVD r/m32, mm                ; 0F 7E /r      [PENT, MMX]
MOVD xmm, r/m32               ; 66 0F 6E /r   [WILLAMETTE, SSE2]
MOVD r/m32, xmm               ; 66 0F 7E /r   [WILLAMETTE, SSE2]
```

MOVD copies 32 bits from its source (second) operand into its destination (first) operand. When the destination is a 64-bit MMX register or a 128-bit XMM register, the input value is zero-extended to fill the destination register.

A.5.160 MOVDQ2Q: Move Quadword from XMM to MMX register.

```
MOVDQ2Q mm, xmm               ; F2 0F D6 /r   [WILLAMETTE, SSE2]
```

MOVDQ2Q moves the low quadword from the source operand to the destination operand.

A.5.161 **MOVDQA: Move Aligned Double Quadword**

```
MOVDQA xmm1, xmm2/m128          ; 66 OF 6F /r      [WILLAMETTE, SSE2]
MOVDQA xmm1/m128, xmm2          ; 66 OF 7F /r      [WILLAMETTE, SSE2]
```

MOVDQA moves a double quadword from the source operand to the destination operand. When the source or destination operand is a memory location, it must be aligned to a 16-byte boundary.

To move a double quadword to or from unaligned memory locations, use the MOVDDQU instruction (section A.5.162).

A.5.162 **MOVDDQU: Move Unaligned Double Quadword**

```
MOVDDQU xmm1, xmm2/m128         ; F3 OF 6F /r      [WILLAMETTE, SSE2]
MOVDDQU xmm1/m128, xmm2         ; F3 OF 7F /r      [WILLAMETTE, SSE2]
```

MOVDDQU moves a double quadword from the source operand to the destination operand. When the source or destination operand is a memory location, the memory may be unaligned.

To move a double quadword to or from known aligned memory locations, use the MOVDQA instruction (section A.5.161).

A.5.163 **MOVHLP: Move Packed Single-Precision FP High to Low**

```
MOVHLP xmm1, xmm2               ; OF 12 /r          [KATMAI, SSE]
```

MOVHLP moves the two packed single-precision FP values from the high quadword of the source register xmm2 to the low quadword of the destination register, xmm1. The upper quadword of xmm1 is left unchanged.

The operation of this instruction is:

```
dst[0-63]    := src[64-127],
dst[64-127]  remains unchanged.
```

A.5.164 **MOVHPD: Move High Packed Double-Precision FP**

```
MOVHPD xmm, m64                 ; 66 OF 16 /r      [WILLAMETTE, SSE2]
MOVHPD m64, xmm                 ; 66 OF 17 /r      [WILLAMETTE, SSE2]
```

MOVHPD moves a double-precision FP value between the source and destination operands. One of the operands is a 64-bit memory location, the other is the high quadword of an XMM register.

The operation of this instruction is:

```
mem[0-63]    := xmm[64-127];
```

or

```
xmm[0-63]    remains unchanged;
xmm[64-127]  := mem[0-63].
```

A.5.165 **MOVHPS: Move High Packed Single-Precision FP**

```
MOVHPS xmm, m64                 ; 0F 16 /r          [KATMAI, SSE]
MOVHPS m64, xmm                 ; 0F 17 /r          [KATMAI, SSE]
```

MOVHPS moves two packed single-precision FP values between the source and destination operands. One of the operands is a 64-bit memory location, the other is the high quadword of an XMM register.

The operation of this instruction is:

```
mem[0-63] := xmm[64-127];
```

or

```
xmm[0-63] remains unchanged;  
xmm[64-127] := mem[0-63].
```

A.5.166 MOVHLPS: Move Packed Single-Precision FP Low to High

```
MOVHLPS xmm1, xmm2 ; OF 16 /r [KATMAI, SSE]
```

MOVHLPS moves the two packed single-precision FP values from the low quadword of the source register `xmm2` to the high quadword of the destination register, `xmm2`. The low quadword of `xmm1` is left unchanged.

The operation of this instruction is:

```
dst[0-63] remains unchanged;  
dst[64-127] := src[0-63].
```

A.5.167 MOVLPD: Move Low Packed Double-Precision FP

```
MOVLPD xmm, m64 ; 66 OF 12 /r [WILLAMETTE, SSE2]  
MOVLPD m64, xmm ; 66 OF 13 /r [WILLAMETTE, SSE2]
```

MOVLPD moves a double-precision FP value between the source and destination operands. One of the operands is a 64-bit memory location, the other is the low quadword of an XMM register.

The operation of this instruction is:

```
mem(0-63) := xmm(0-63);
```

or

```
xmm(0-63) := mem(0-63);  
xmm(64-127) remains unchanged.
```

A.5.168 MOVLPD: Move Low Packed Single-Precision FP

```
MOVLPD xmm, m64 ; OF 12 /r [KATMAI, SSE]  
MOVLPD m64, xmm ; OF 13 /r [KATMAI, SSE]
```

MOVLPD moves two packed single-precision FP values between the source and destination operands. One of the operands is a 64-bit memory location, the other is the low quadword of an XMM register.

The operation of this instruction is:

```
mem(0-63) := xmm(0-63);
```

or

xmm(0-63) := mem(0-63);
xmm(64-127) remains unchanged.

A.5.169 MOVMSKPD: Extract Packed Double-Precision FP Sign Mask

MOVMSKPD reg32,xmm ; 66 0F 50 /r [WILLAMETTE,SSE2]

MOVMSKPD inserts a 2-bit mask in r32, formed of the most significant bits of each double-precision FP number of the source operand.

A.5.170 MOVMSKPS: Extract Packed Single-Precision FP Sign Mask

MOVMSKPS reg32,xmm ; 0F 50 /r [KATMAI,SSE]

MOVMSKPS inserts a 4-bit mask in r32, formed of the most significant bits of each single-precision FP number of the source operand.

A.5.171 MOVNTDQ: Move Double Quadword Non Temporal

MOVNTDQ m128,xmm ; 66 0F E7 /r [WILLAMETTE,SSE2]

MOVNTDQ moves the double quadword from the XMM source register to the destination memory location, using a non-temporal hint. This store instruction minimizes cache pollution.

A.5.172 MOVNTI: Move Doubleword Non Temporal

MOVNTI m32,reg32 ; 0F C3 /r [WILLAMETTE,SSE2]

MOVNTI moves the doubleword in the source register to the destination memory location, using a non-temporal hint. This store instruction minimizes cache pollution.

A.5.173 MOVNTPD: Move Aligned Four Packed Single-Precision FP Values Non Temporal

MOVNTPD m128,xmm ; 66 0F 2B /r [WILLAMETTE,SSE2]

MOVNTPD moves the double quadword from the XMM source register to the destination memory location, using a non-temporal hint. This store instruction minimizes cache pollution. The memory location must be aligned to a 16-byte boundary.

A.5.174 MOVNTPS: Move Aligned Four Packed Single-Precision FP Values Non Temporal

MOVNTPS m128,xmm ; 0F 2B /r [KATMAI,SSE]

MOVNTPS moves the double quadword from the XMM source register to the destination memory location, using a non-temporal hint. This store instruction minimizes cache pollution. The memory location must be aligned to a 16-byte boundary.

A.5.175 MOVNTQ: Move Quadword Non Temporal

MOVNTQ m64,mm ; 0F E7 /r [KATMAI,MMX]

MOVNTQ moves the quadword in the MMX source register to the destination memory location, using a non-temporal hint. This store instruction minimizes cache pollution.

A.5.176 MOVQ: Move Quadword to/from MMX Register

```
MOVQ mm1, mm2/m64 ; 0F 6F /r [PENT, MMX]
MOVQ mm1/m64, mm2 ; 0F 7F /r [PENT, MMX]

MOVQ xmm1, xmm2/m64 ; F3 0F 7E /r [WILLAMETTE, SSE2]
MOVQ xmm1/m64, xmm2 ; 66 0F D6 /r [WILLAMETTE, SSE2]
```

MOVQ copies 64 bits from its source (second) operand into its destination (first) operand. When the source is an XMM register, the low quadword is moved. When the destination is an XMM register, the destination is the low quadword, and the high quadword is cleared.

A.5.177 MOVQ2DQ: Move Quadword from MMX to XMM register.

```
MOVQ2DQ xmm, mm ; F3 0F D6 /r [WILLAMETTE, SSE2]
```

MOVQ2DQ moves the quadword from the source operand to the low quadword of the destination operand, and clears the high quadword.

A.5.178 MOVSB, MOVSW, MOVSD: Move String

```
MOVSB ; A4 [8086]
MOVSW ; 016 A5 [8086]
MOVSD ; 032 A5 [386]
```

MOVSB copies the byte at [DS:SI] or [DS:ESI] to [ES:DI] or [ES:EDI]. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) SI and DI (or ESI and EDI).

The registers used are SI and DI if the address size is 16 bits, and ESI and EDI if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit a16 or a32 prefix.

The segment register used to load from [SI] or [ESI] can be overridden by using a segment register name as a prefix (for example, ES MOVSB). The use of ES for the store to [DI] or [EDI] cannot be overridden.

MOVSW and MOVSD work in the same way, but they copy a word or a doubleword instead of a byte, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The REP prefix may be used to repeat the instruction CX (or ECX - again, the address size chooses which) times. The REP alias REPE, as well as the differently-encoded REPNE, are both allowed as well. They behave in the same way as REP.

A.5.178.1 Pseudo-code examples

a16 MOVSB without segment override and with Direction Flag clear (UP) is equal to

```
MOV BYTE [ES:DI], BYTE [SI]
LEA SI, [SI + 1]
LEA DI, [DI + 1]
```

a16 REP MOVSW without segment override and with Direction Flag clear (UP) is equal to

```
JCXZ @FF
```



```

@@:
MOV WORD [ES:DI], WORD [SI]
LEA SI, [SI + 2]
LEA DI, [DI + 2]
a16 LOOP @B
@@:

```

a32 ES MOVSD with Direction Flag set (DN) is equal to

```

MOV DWORD [ES:EDI], DWORD [ES:ESI]
LEA ESI, [ESI - 4]
LEA EDI, [EDI - 4]

```

A.5.179 MOVSD: Move Scalar Double-Precision FP Value

```

MOVSD xmm1, xmm2/m64          ; F2 0F 10 /r      [WILLAMETTE, SSE2]
MOVSD xmm1/m64, xmm2         ; F2 0F 11 /r      [WILLAMETTE, SSE2]

```

MOVSD moves a double-precision FP value from the source operand to the destination operand. When the source or destination is a register, the low-order FP value is read or written.

A.5.180 MOVSS: Move Scalar Single-Precision FP Value

```

MOVSS xmm1, xmm2/m32         ; F3 0F 10 /r      [KATMAI, SSE]
MOVSS xmm1/m32, xmm2        ; F3 0F 11 /r      [KATMAI, SSE]

```

MOVSS moves a single-precision FP value from the source operand to the destination operand. When the source or destination is a register, the low-order FP value is read or written.

A.5.181 MOVSX, MOVZX: Move Data with Sign or Zero Extend

```

MOVSX reg16, r/m8           ; 016 0F BE /r      [386]
MOVSX reg32, r/m8          ; 032 0F BE /r      [386]
MOVSX reg32, r/m16         ; 032 0F BF /r      [386]

MOVZX reg16, r/m8          ; 016 0F B6 /r      [386]
MOVZX reg32, r/m8          ; 032 0F B6 /r      [386]
MOVZX reg32, r/m16         ; 032 0F B7 /r      [386]

```

MOVSX sign-extends its source (second) operand to the length of its destination (first) operand, and copies the result into the destination operand. MOVZX does the same, but zero-extends rather than sign-extending.

A.5.182 MOVUPD: Move Unaligned Packed Double-Precision FP Values

```

MOVUPD xmm1, xmm2/mem128    ; 66 0F 10 /r      [WILLAMETTE, SSE2]
MOVUPD xmm1/mem128, xmm2    ; 66 0F 11 /r      [WILLAMETTE, SSE2]

```

MOVUPD moves a double quadword containing 2 packed double-precision FP values from the source operand to the destination. This instruction makes no assumptions about alignment of memory operands.

To move data in and out of memory locations that are known to be on 16-byte boundaries, use the MOVAPD instruction (section A.5.157).

A.5.183 MOVUPS: Move Unaligned Packed Single-Precision FP Values

```
MOVUPS xmm1, xmm2/mem128      ; 0F 10 /r      [KATMAI, SSE]
MOVUPS xmm1/mem128, xmm2      ; 0F 11 /r      [KATMAI, SSE]
```

MOVUPS moves a double quadword containing 4 packed single-precision FP values from the source operand to the destination. This instruction makes no assumptions about alignment of memory operands.

To move data in and out of memory locations that are known to be on 16-byte boundaries, use the MOVAPS instruction (section A.5.158).

A.5.184 MUL: Unsigned Integer Multiply

```
MUL r/m8                       ; F6 /4      [8086]
MUL r/m16                      ; 016 F7 /4  [8086]
MUL r/m32                      ; 032 F7 /4  [386]
```

MUL performs unsigned integer multiplication. The other operand to the multiplication, and the destination operand, are implicit, in the following way:

- For MUL r/m8, AL is multiplied by the given operand; the product is stored in AX.
- For MUL r/m16, AX is multiplied by the given operand; the product is stored in DX:AX.
- For MUL r/m32, EAX is multiplied by the given operand; the product is stored in EDX:EAX.

Signed integer multiplication is performed by the IMUL instruction: see section A.5.118.

A.5.185 MULPD: Packed Single-FP Multiply

```
MULPD xmm1, xmm2/mem128      ; 66 0F 59 /r      [WILLAMETTE, SSE2]
```

MULPD performs a SIMD multiply of the packed double-precision FP values in both operands, and stores the results in the destination register.

A.5.186 MULPS: Packed Single-FP Multiply

```
MULPS xmm1, xmm2/mem128      ; 0F 59 /r      [KATMAI, SSE]
```

MULPS performs a SIMD multiply of the packed single-precision FP values in both operands, and stores the results in the destination register.

A.5.187 MULSD: Scalar Single-FP Multiply

```
MULSD xmm1, xmm2/mem32       ; F2 0F 59 /r      [WILLAMETTE, SSE2]
```

MULSD multiplies the lowest double-precision FP values of both operands, and stores the result in the low quadword of xmm1.

A.5.188 MULSS: Scalar Single-FP Multiply

```
MULSS xmm1, xmm2/mem32       ; F3 0F 59 /r      [KATMAI, SSE]
```

MULSS multiplies the lowest single-precision FP values of both operands, and stores the result in the low doubleword of xmm1.

A.5.189 NEG, NOT: Two's and Ones' Complement

NEG r/m8	; F6 /3	[8086]
NEG r/m16	; 016 F7 /3	[8086]
NEG r/m32	; 032 F7 /3	[386]
NOT r/m8	; F6 /2	[8086]
NOT r/m16	; 016 F7 /2	[8086]
NOT r/m32	; 032 F7 /2	[386]

NEG replaces the contents of its operand by the two's complement negation (invert all the bits and then add one) of the original value. NOT, similarly, performs ones' complement (inverts all the bits).

The Carry Flag is cleared by NOT. The Zero Flag is set according to whether the result is zero.

A.5.190 NOP: No Operation

NOP	; 90	[8086]
-----	------	--------

NOP performs no operation. Its opcode is the same as that generated by XCHG AX,AX or XCHG EAX,EAX (depending on the processor mode; see section A.5.333).

A.5.191 OR: Bitwise OR

OR r/m8,reg8	; 08 /r	[8086]
OR r/m16,reg16	; 016 09 /r	[8086]
OR r/m32,reg32	; 032 09 /r	[386]
OR reg8,r/m8	; 0A /r	[8086]
OR reg16,r/m16	; 016 0B /r	[8086]
OR reg32,r/m32	; 032 0B /r	[386]
OR r/m8,imm8	; 80 /1 ib	[8086]
OR r/m16,imm16	; 016 81 /1 iw	[8086]
OR r/m32,imm32	; 032 81 /1 id	[386]
OR r/m16,imm8	; 016 83 /1 ib	[8086]
OR r/m32,imm8	; 032 83 /1 ib	[386]
OR AL,imm8	; 0C ib	[8086]
OR AX,imm16	; 016 0D iw	[8086]
OR EAX,imm32	; 032 0D id	[386]

OR performs a bitwise OR operation between its two operands (i.e. each bit of the result is 1 if and only if at least one of the corresponding bits of the two inputs was 1), and stores the result in the destination (first) operand.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent

versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the `STRICT WORD` or `STRICT DWORD` qualifier.

The Carry Flag is cleared by `OR`. The Zero Flag is set according to whether the result is zero.

The MMX instruction `POR` (see section A.5.247) performs the same operation on the 64-bit MMX registers.

A.5.192 **ORPD: Bit-wise Logical OR of Double-Precision FP Data**

```
ORPD xmm1, xmm2/m128          ; 66 0F 56 /r          [WILLAMETTE, SSE2]
```

`ORPD` return a bit-wise logical OR between `xmm1` and `xmm2/mem`, and stores the result in `xmm1`. If the source operand is a memory location, it must be aligned to a 16-byte boundary.

A.5.193 **ORPS: Bit-wise Logical OR of Single-Precision FP Data**

```
ORPS xmm1, xmm2/m128          ; 0F 56 /r          [KATMAI, SSE]
```

`ORPS` return a bit-wise logical OR between `xmm1` and `xmm2/mem`, and stores the result in `xmm1`. If the source operand is a memory location, it must be aligned to a 16-byte boundary.

A.5.194 **OUT: Output Data to I/O Port**

```
OUT imm8, AL                   ; E6 ib          [8086]
OUT imm8, AX                    ; 016 E7 ib      [8086]
OUT imm8, EAX                   ; 032 E7 ib      [386]
OUT DX, AL                      ; EE             [8086]
OUT DX, AX                      ; 016 EF         [8086]
OUT DX, EAX                     ; 032 EF         [386]
```

`OUT` writes the contents of the given source register to the specified I/O port. The port number may be specified as an immediate value if it is between 0 and 255, and otherwise must be stored in `DX`. See also `IN` (section A.5.119).

A.5.195 **OUTSB, OUTSW, OUTSD: Output String to I/O Port**

```
OUTSB                          ; 6E             [186]
OUTSW                          ; 016 6F         [186]
OUTSD                          ; 032 6F         [386]
```

`OUTSB` loads a byte from `[DS:SI]` or `[DS:ESI]` and writes it to the I/O port specified in `DX`. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) `SI` or `ESI`.

The register used is `SI` if the address size is 16 bits, and `ESI` if it is 32 bits. If you need to use an address size not equal to the current `BITS` setting, you can use an explicit `a16` or `a32` prefix.

The segment register used to load from `[SI]` or `[ESI]` can be overridden by using a segment register name as a prefix (for example, `ES OUTSB`).

`OUTSW` and `OUTSD` work in the same way, but they output a word or a doubleword instead of a byte, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The REP prefix may be used to repeat the instruction CX (or ECX - again, the address size chooses which) times. The REP alias REPE, as well as the differently-encoded REPNE, are both allowed as well. They behave in the same way as REP.

A.5.195.1 Pseudo-code examples

a16 OUTSB without segment override and with Direction Flag clear (UP) is equal to

```
OUT DX, BYTE [SI]
LEA SI, [SI + 1]
```

a16 REP OUTSW without segment override and with Direction Flag clear (UP) is equal to

```
JCXZ @FF
@@:
OUT DX, WORD [SI]
LEA SI, [SI + 2]
a16 LOOP @B
@@:
```

a32 ES OUTSD with Direction Flag set (DN) is equal to

```
OUT DX, DWORD [ES:ESI]
LEA ESI, [ESI - 4]
```

A.5.196 PACKSSDW, PACKSSWB, PACKUSWB: Pack Data

PACKSSDW	mm1, mm2/m64	; 0F 6B /r	[PENT, MMX]
PACKSSWB	mm1, mm2/m64	; 0F 63 /r	[PENT, MMX]
PACKUSWB	mm1, mm2/m64	; 0F 67 /r	[PENT, MMX]
PACKSSDW	xmm1, xmm2/m128	; 66 0F 6B /r	[WILLAMETTE, SSE2]
PACKSSWB	xmm1, xmm2/m128	; 66 0F 63 /r	[WILLAMETTE, SSE2]
PACKUSWB	xmm1, xmm2/m128	; 66 0F 67 /r	[WILLAMETTE, SSE2]

All these instructions start by combining the source and destination operands, and then splitting the result in smaller sections which it then packs into the destination register. The MMX versions pack two 64-bit operands into one 64-bit register, while the SSE versions pack two 128-bit operands into one 128-bit register.

- PACKSSWB splits the combined value into words, and then reduces the words to bytes, using signed saturation. It then packs the bytes into the destination register in the same order the words were in.
- PACKSSDW performs the same operation as PACKSSWB, except that it reduces doublewords to words, then packs them into the destination register.
- PACKUSWB performs the same operation as PACKSSWB, except that it uses unsigned saturation when reducing the size of the elements.

To perform signed saturation on a number, it is replaced by the largest signed number (7FFFh or 7Fh) that *will* fit, and if it is too small it is replaced by the smallest signed number (8000h or 80h) that will fit. To perform unsigned saturation, the input is treated as unsigned, and the input is replaced by the largest unsigned number that will fit.

A.5.197 PADDB, PADDW, PADDD: Add Packed Integers

PADDB	mm1, mm2/m64	; 0F FC /r	[PENT, MMX]
PADDW	mm1, mm2/m64	; 0F FD /r	[PENT, MMX]
PADDD	mm1, mm2/m64	; 0F FE /r	[PENT, MMX]
PADDB	xmm1, xmm2/m128	; 66 0F FC /r	[WILLAMETTE, SSE2]
PADDW	xmm1, xmm2/m128	; 66 0F FD /r	[WILLAMETTE, SSE2]
PADDD	xmm1, xmm2/m128	; 66 0F FE /r	[WILLAMETTE, SSE2]

PADDx performs packed addition of the two operands, storing the result in the destination (first) operand.

- PADDB treats the operands as packed bytes, and adds each byte individually;
- PADDW treats the operands as packed words;
- PADDD treats its operands as packed doublewords.

When an individual result is too large to fit in its destination, it is wrapped around and the low bits are stored, with the carry bit discarded.

A.5.198 PADDQ: Add Packed Quadword Integers

PADDQ	mm1, mm2/m64	; 0F D4 /r	[PENT, MMX]
PADDQ	xmm1, xmm2/m128	; 66 0F D4 /r	[WILLAMETTE, SSE2]

PADDQ adds the quadwords in the source and destination operands, and stores the result in the destination register.

When an individual result is too large to fit in its destination, it is wrapped around and the low bits are stored, with the carry bit discarded.

A.5.199 PADDSB, PADDW: Add Packed Signed Integers With Saturation

PADDSB	mm1, mm2/m64	; 0F EC /r	[PENT, MMX]
PADDW	mm1, mm2/m64	; 0F ED /r	[PENT, MMX]
PADDSB	xmm1, xmm2/m128	; 66 0F EC /r	[WILLAMETTE, SSE2]
PADDW	xmm1, xmm2/m128	; 66 0F ED /r	[WILLAMETTE, SSE2]

PADDsx performs packed addition of the two operands, storing the result in the destination (first) operand. PADDSB treats the operands as packed bytes, and adds each byte individually; and PADDW treats the operands as packed words.

When an individual result is too large to fit in its destination, a saturated value is stored. The resulting value is the value with the largest magnitude of the same sign as the result which will fit in the available space.

A.5.200 PADDSIW: MMX Packed Addition to Implicit Destination

PADDSIW	mmxreg, r/m64	; 0F 51 /r	[CYRIX, MMX]
---------	---------------	------------	----------------

PADDSIW, specific to the Cyrix extensions to the MMX instruction set, performs the same

function as PADDQ, except that the result is placed in an implied register.

To work out the implied register, invert the lowest bit in the register number. So PADDQ MM0, MM2 would put the result in MM1, but PADDQ MM1, MM2 would put the result in MM0.

A.5.201 PADDUSB, PADDUSW: Add Packed Unsigned Integers With Saturation

```
PADDUSB mm1, mm2/m64 ; 0F DC /r [PENT, MMX]
PADDUSW mm1, mm2/m64 ; 0F DD /r [PENT, MMX]

PADDUSB xmm1, xmm2/m128 ; 66 0F DC /r [WILLAMETTE, SSE2]
PADDUSW xmm1, xmm2/m128 ; 66 0F DD /r [WILLAMETTE, SSE2]
```

PADDUSx performs packed addition of the two operands, storing the result in the destination (first) operand. PADDUSB treats the operands as packed bytes, and adds each byte individually; and PADDUSW treats the operands as packed words.

When an individual result is too large to fit in its destination, a saturated value is stored. The resulting value is the maximum value that will fit in the available space.

A.5.202 PAND, PANDN: MMX Bitwise AND and AND-NOT

```
PAND mm1, mm2/m64 ; 0F DB /r [PENT, MMX]
PANDN mm1, mm2/m64 ; 0F DF /r [PENT, MMX]

PAND xmm1, xmm2/m128 ; 66 0F DB /r [WILLAMETTE, SSE2]
PANDN xmm1, xmm2/m128 ; 66 0F DF /r [WILLAMETTE, SSE2]
```

PAND performs a bitwise AND operation between its two operands (i.e. each bit of the result is 1 if and only if the corresponding bits of the two inputs were both 1), and stores the result in the destination (first) operand.

PANDN performs the same operation, but performs a ones' complement operation on the destination (first) operand first.

A.5.203 PAUSE: Spin Loop Hint

```
PAUSE ; F3 90 [WILLAMETTE, SSE2]
```

PAUSE provides a hint to the processor that the following code is a spin loop. This improves processor performance by bypassing possible memory order violations. On older processors, this instruction operates as a NOP.

A.5.204 PAVEB: MMX Packed Average

```
PAVEB mmxreg, r/m64 ; 0F 50 /r [CYRIX, MMX]
```

PAVEB, specific to the Cyrix MMX extensions, treats its two operands as vectors of eight unsigned bytes, and calculates the average of the corresponding bytes in the operands. The resulting vector of eight averages is stored in the first operand.

This opcode maps to MOVMSKPS r32, xmm on processors that support the SSE instruction set.

A.5.205 PAVGB PAVGW: Average Packed Integers

PAVGB	mm1, mm2/m64	; 0F E0 /r	[KATMAI, MMX]
PAVGW	mm1, mm2/m64	; 0F E3 /r	[KATMAI, MMX, SM]
PAVGB	xmm1, xmm2/m128	; 66 0F E0 /r	[WILLAMETTE, SSE2]
PAVGW	xmm1, xmm2/m128	; 66 0F E3 /r	[WILLAMETTE, SSE2]

PAVGB and PAVGW add the unsigned data elements of the source operand to the unsigned data elements of the destination register, then adds 1 to the temporary results. The results of the add are then each independently right-shifted by one bit position. The high order bits of each element are filled with the carry bits of the corresponding sum.

- PAVGB operates on packed unsigned bytes, and
- PAVGW operates on packed unsigned words.

A.5.206 PAVGUSB: Average of unsigned packed 8-bit values

PAVGUSB	mm1, mm2/m64	; 0F 0F /r BF	[PENT, 3DNOW]
---------	--------------	---------------	---------------

PAVGUSB adds the unsigned data elements of the source operand to the unsigned data elements of the destination register, then adds 1 to the temporary results. The results of the add are then each independently right-shifted by one bit position. The high order bits of each element are filled with the carry bits of the corresponding sum.

This instruction performs exactly the same operations as the PAVGB MMX instruction (section A.5.205).

A.5.207 PCMPxx: Compare Packed Integers.

PCMPEQB	mm1, mm2/m64	; 0F 74 /r	[PENT, MMX]
PCMPEQW	mm1, mm2/m64	; 0F 75 /r	[PENT, MMX]
PCMPEQD	mm1, mm2/m64	; 0F 76 /r	[PENT, MMX]
PCMPGTB	mm1, mm2/m64	; 0F 64 /r	[PENT, MMX]
PCMPGTW	mm1, mm2/m64	; 0F 65 /r	[PENT, MMX]
PCMPGTD	mm1, mm2/m64	; 0F 66 /r	[PENT, MMX]
PCMPEQB	xmm1, xmm2/m128	; 66 0F 74 /r	[WILLAMETTE, SSE2]
PCMPEQW	xmm1, xmm2/m128	; 66 0F 75 /r	[WILLAMETTE, SSE2]
PCMPEQD	xmm1, xmm2/m128	; 66 0F 76 /r	[WILLAMETTE, SSE2]
PCMPGTB	xmm1, xmm2/m128	; 66 0F 64 /r	[WILLAMETTE, SSE2]
PCMPGTW	xmm1, xmm2/m128	; 66 0F 65 /r	[WILLAMETTE, SSE2]
PCMPGTD	xmm1, xmm2/m128	; 66 0F 66 /r	[WILLAMETTE, SSE2]

The PCMPxx instructions all treat their operands as vectors of bytes, words, or doublewords; corresponding elements of the source and destination are compared, and the corresponding element of the destination (first) operand is set to all zeros or all ones depending on the result of the comparison.

- PCMPxxB treats the operands as vectors of bytes;
- PCMPxxW treats the operands as vectors of words;

- PCMPxxD treats the operands as vectors of doublewords;
- PCMPSEQx sets the corresponding element of the destination operand to all ones if the two elements compared are equal;
- PCMPGTx sets the destination element to all ones if the element of the first (destination) operand is greater (treated as a signed integer) than that of the second (source) operand.

A.5.208 PDISTIB: MMX Packed Distance and Accumulate with Implied Register

PDISTIB mm,m64 ; 0F 54 /r [CYRIX,MMX]

PDISTIB, specific to the Cyrix MMX extensions, treats its two input operands as vectors of eight unsigned bytes. For each byte position, it finds the absolute difference between the bytes in that position in the two input operands, and adds that value to the byte in the same position in the implied output register. The addition is saturated to an unsigned byte in the same way as PADDUSB.

To work out the implied register, invert the lowest bit in the register number. So PDISTIB MM0,M64 would put the result in MM1, but PDISTIB MM1,M64 would put the result in MM0.

Note that PDISTIB cannot take a register as its second source operand.

Operation:

```
dstI[0-7]      := dstI[0-7] + ABS(src0[0-7] - src1[0-7]),
dstI[8-15]     := dstI[8-15] + ABS(src0[8-15] - src1[8-15]),
.....
.....
dstI[56-63]    := dstI[56-63] + ABS(src0[56-63] - src1[56-63]).
```

A.5.209 PEXTRW: Extract Word

PEXTRW reg32,mm,imm8 ; 0F C5 /r ib [KATMAI,MMX]
PEXTRW reg32,xmm,imm8 ; 66 0F C5 /r ib [WILLAMETTE,SSE2]

PEXTRW moves the word in the source register (second operand) that is pointed to by the count operand (third operand), into the lower half of a 32-bit general purpose register. The upper half of the register is cleared to all 0s.

When the source operand is an MMX register, the two least significant bits of the count specify the source word. When it is an SSE register, the three least significant bits specify the word location.

A.5.210 PF2ID: Packed Single-Precision FP to Integer Convert

PF2ID mm1,mm2/m64 ; 0F 0F /r 1D [PENT,3DNOW]

PF2ID converts two single-precision FP values in the source operand to signed 32-bit integers, using truncation, and stores them in the destination operand. Source values that are outside the range supported by the destination are saturated to the largest absolute value of the same sign.

A.5.211 **PF2IW: Packed Single-Precision FP to Integer Word Convert**

PF2IW mm1,mm2/m64 ; 0F 0F /r 1C [PENT,3DNOW]

PF2IW converts two single-precision FP values in the source operand to signed 16-bit integers, using truncation, and stores them in the destination operand. Source values that are outside the range supported by the destination are saturated to the largest absolute value of the same sign.

- In the K6-2 and K6-III, the 16-bit value is zero-extended to 32-bits before storing.
- In the K6-2+, K6-III+ and Athlon processors, the value is sign-extended to 32-bits before storing.

A.5.212 **PFACC: Packed Single-Precision FP Accumulate**

PFACC mm1,mm2/m64 ; 0F 0F /r AE [PENT,3DNOW]

PFACC adds the two single-precision FP values from the destination operand together, then adds the two single-precision FP values from the source operand, and places the results in the low and high doublewords of the destination operand.

The operation is:

```
dst[0-31] := dst[0-31] + dst[32-63],
dst[32-63] := src[0-31] + src[32-63].
```

A.5.213 **PFADD: Packed Single-Precision FP Addition**

PFADD mm1,mm2/m64 ; 0F 0F /r 9E [PENT,3DNOW]

PFADD performs addition on each of two packed single-precision FP value pairs.

```
dst[0-31] := dst[0-31] + src[0-31],
dst[32-63] := dst[32-63] + src[32-63].
```

A.5.214 **PFCMPxx: Packed Single-Precision FP Compare**

PFCMPEQ mm1,mm2/m64 ; 0F 0F /r B0 [PENT,3DNOW]
PFCMPGE mm1,mm2/m64 ; 0F 0F /r 90 [PENT,3DNOW]
PFCMPGT mm1,mm2/m64 ; 0F 0F /r A0 [PENT,3DNOW]

The PFCMPxx instructions compare the packed single-point FP values in the source and destination operands, and set the destination according to the result. If the condition is true, the destination is set to all 1s, otherwise it's set to all 0s.

- PFCMPEQ tests whether $dst == src$;
- PFCMPGE tests whether $dst \geq src$;
- PFCMPGT tests whether $dst > src$.

A.5.215 **PFMAX: Packed Single-Precision FP Maximum**

PFMAX mm1,mm2/m64 ; 0F 0F /r A4 [PENT,3DNOW]

PFMAX returns the higher of each pair of single-precision FP values. If the higher value is zero, it is returned as positive zero.

A.5.216 **PFMIN: Packed Single-Precision FP Minimum**

PFMIN mm1,mm2/m64 ; 0F 0F /r 94 [PENT,3DNOW]

PFMIN returns the lower of each pair of single-precision FP values. If the lower value is zero, it is returned as positive zero.

A.5.217 **PFMUL: Packed Single-Precision FP Multiply**

PFMUL mm1,mm2/m64 ; 0F 0F /r B4 [PENT,3DNOW]

PFMUL returns the product of each pair of single-precision FP values.

$$\begin{aligned} \text{dst}[0-31] &:= \text{dst}[0-31] * \text{src}[0-31], \\ \text{dst}[32-63] &:= \text{dst}[32-63] * \text{src}[32-63]. \end{aligned}$$

A.5.218 **PFNACC: Packed Single-Precision FP Negative Accumulate**

PFNACC mm1,mm2/m64 ; 0F 0F /r 8A [PENT,3DNOW]

PFNACC performs a negative accumulate of the two single-precision FP values in the source and destination registers. The result of the accumulate from the destination register is stored in the low doubleword of the destination, and the result of the source accumulate is stored in the high doubleword of the destination register.

The operation is:

$$\begin{aligned} \text{dst}[0-31] &:= \text{dst}[0-31] - \text{dst}[32-63], \\ \text{dst}[32-63] &:= \text{src}[0-31] - \text{src}[32-63]. \end{aligned}$$

A.5.219 **PFPNACC: Packed Single-Precision FP Mixed Accumulate**

PFPNACC mm1,mm2/m64 ; 0F 0F /r 8E [PENT,3DNOW]

PFPNACC performs a positive accumulate of the two single-precision FP values in the source register and a negative accumulate of the destination register. The result of the accumulate from the destination register is stored in the low doubleword of the destination, and the result of the source accumulate is stored in the high doubleword of the destination register.

The operation is:

$$\begin{aligned} \text{dst}[0-31] &:= \text{dst}[0-31] - \text{dst}[32-63], \\ \text{dst}[32-63] &:= \text{src}[0-31] + \text{src}[32-63]. \end{aligned}$$

A.5.220 **PFRCPP: Packed Single-Precision FP Reciprocal Approximation**

PFRCPP mm1,mm2/m64 ; 0F 0F /r 96 [PENT,3DNOW]

PFRCPP performs a low precision estimate of the reciprocal of the low-order single-precision FP value in the source operand, storing the result in both halves of the destination register. The result is accurate to 14 bits.

For higher precision reciprocals, this instruction should be followed by two more instructions: PFRCPIT1 (section A.5.221) and PFRCPIT2 (section A.5.221). This will result in a 24-bit accuracy. For more details, see the AMD 3DNow! technology manual.

A.5.221 **PFRCPIT1: Packed Single-Precision FP Reciprocal, First Iteration Step**

`PFRCPIT1 mm1,mm2/m64 ; 0F 0F /r A6 [PENT, 3DNow]`

PFRCPIT1 performs the first intermediate step in the calculation of the reciprocal of a single-precision FP value. The first source value (mm1) is the original value, and the second source value (mm2/m64) is the result of a PFRCP instruction.

For the final step in a reciprocal, returning the full 24-bit accuracy of a single-precision FP value, see PFRCPIT2 (section A.5.222). For more details, see the AMD 3DNow! technology manual.

A.5.222 **PFRCPIT2: Packed Single-Precision FP Reciprocal/ Reciprocal Square Root, Second Iteration Step**

`PFRCPIT2 mm1,mm2/m64 ; 0F 0F /r B6 [PENT, 3DNow]`

PFRCPIT2 performs the second and final intermediate step in the calculation of a reciprocal or reciprocal square root, refining the values returned by the PFRCP and PFRSQRT instructions, respectively.

The first source value (mm1) is the output of either a PFRCPIT1 or a PFRSQIT1 instruction, and the second source is the output of either the PFRCP or the PFRSQRT instruction. For more details, see the AMD 3DNow! technology manual.

A.5.223 **PFRSQIT1: Packed Single-Precision FP Reciprocal Square Root, First Iteration Step**

`PFRSQIT1 mm1,mm2/m64 ; 0F 0F /r A7 [PENT, 3DNow]`

PFRSQIT1 performs the first intermediate step in the calculation of the reciprocal square root of a single-precision FP value. The first source value (mm1) is the square of the result of a PFRSQRT instruction, and the second source value (mm2/m64) is the original value.

For the final step in a calculation, returning the full 24-bit accuracy of a single-precision FP value, see PFRCPIT2 (section A.5.222). For more details, see the AMD 3DNow! technology manual.

A.5.224 **PFRSQRT: Packed Single-Precision FP Reciprocal Square Root Approximation**

`PFRSQRT mm1,mm2/m64 ; 0F 0F /r 97 [PENT, 3DNow]`

PFRSQRT performs a low precision estimate of the reciprocal square root of the low-order single-precision FP value in the source operand, storing the result in both halves of the destination register. The result is accurate to 15 bits.

For higher precision reciprocals, this instruction should be followed by two more instructions: PFRSQIT1 (section A.5.223) and PFRCPIT2 (section A.5.221). This will result in a 24-bit accuracy. For more details, see the AMD 3DNow! technology manual.

A.5.225 PFSUB: Packed Single-Precision FP Subtract

PFSUB mm1,mm2/m64 ; 0F 0F /r 9A [PENT,3DNOW]

PFSUB subtracts the single-precision FP values in the source from those in the destination, and stores the result in the destination operand.

```
dst[0-31] := dst[0-31] - src[0-31],
dst[32-63] := dst[32-63] - src[32-63].
```

A.5.226 PFSUBR: Packed Single-Precision FP Reverse Subtract

PFSUBR mm1,mm2/m64 ; 0F 0F /r AA [PENT,3DNOW]

PFSUBR subtracts the single-precision FP values in the destination from those in the source, and stores the result in the destination operand.

```
dst[0-31] := src[0-31] - dst[0-31],
dst[32-63] := src[32-63] - dst[32-63].
```

A.5.227 PI2FD: Packed Doubleword Integer to Single-Precision FP Convert

PI2FD mm1,mm2/m64 ; 0F 0F /r 0D [PENT,3DNOW]

PI2FD converts two signed 32-bit integers in the source operand to single-precision FP values, using truncation of significant digits, and stores them in the destination operand.

A.5.228 PI2FW: Packed Word Integer to Single-Precision FP Convert

PI2FW mm1,mm2/m64 ; 0F 0F /r 0C [PENT,3DNOW]

PI2FW converts two signed 16-bit integers in the source operand to single-precision FP values, and stores them in the destination operand. The input values are in the low word of each doubleword.

A.5.229 PINSRW: Insert Word

```
PINSRW mm,r16/r32/m16,imm8 ;0F C4 /r ib [KATMAI,MMX]
PINSRW xmm,r16/r32/m16,imm8 ;66 0F C4 /r ib [WILLAMETTE,SSE2]
```

PINSRW loads a word from a 16-bit register (or the low half of a 32-bit register), or from memory, and loads it to the word position in the destination register, pointed at by the count operand (third operand). If the destination is an MMX register, the low two bits of the count byte are used, if it is an XMM register the low 3 bits are used. The insertion is done in such a way that the other words from the destination register are left untouched.

A.5.230 PMACHRIW: Packed Multiply and Accumulate with Rounding

PMACHRIW mm,m64 ; 0F 5E /r [CYRIX,MMX]

PMACHRIW takes two packed 16-bit integer inputs, multiplies the values in the inputs, rounds on bit 15 of each result, then adds bits 15-30 of each result to the corresponding position of the *implied* destination register.

The operation of this instruction is:

$$\begin{aligned} \text{dstI}[0-15] &:= \text{dstI}[0-15] + (\text{mm}[0-15] * \text{m64}[0-15] \\ &\quad + 0x00004000)[15-30], \\ \text{dstI}[16-31] &:= \text{dstI}[16-31] + (\text{mm}[16-31] * \text{m64}[16-31] \\ &\quad + 0x00004000)[15-30], \\ \text{dstI}[32-47] &:= \text{dstI}[32-47] + (\text{mm}[32-47] * \text{m64}[32-47] \\ &\quad + 0x00004000)[15-30], \\ \text{dstI}[48-63] &:= \text{dstI}[48-63] + (\text{mm}[48-63] * \text{m64}[48-63] \\ &\quad + 0x00004000)[15-30]. \end{aligned}$$

Note that PMACHRIW cannot take a register as its second source operand.

A.5.231 PMADDWD: MMX Packed Multiply and Add

```
PMADDWD mm1, mm2/m64 ; 0F F5 /r [PENT, MMX]
PMADDWD xmm1, xmm2/m128 ; 66 0F F5 /r [WILLAMETTE, SSE2]
```

PMADDWD treats its two inputs as vectors of signed words. It multiplies corresponding elements of the two operands, giving doubleword results. These are then added together in pairs and stored in the destination operand.

The operation of this instruction is:

$$\begin{aligned} \text{dst}[0-31] &:= (\text{dst}[0-15] * \text{src}[0-15]) \\ &\quad + (\text{dst}[16-31] * \text{src}[16-31]); \\ \text{dst}[32-63] &:= (\text{dst}[32-47] * \text{src}[32-47]) \\ &\quad + (\text{dst}[48-63] * \text{src}[48-63]); \end{aligned}$$

The following apply to the SSE version of the instruction:

$$\begin{aligned} \text{dst}[64-95] &:= (\text{dst}[64-79] * \text{src}[64-79]) \\ &\quad + (\text{dst}[80-95] * \text{src}[80-95]); \\ \text{dst}[96-127] &:= (\text{dst}[96-111] * \text{src}[96-111]) \\ &\quad + (\text{dst}[112-127] * \text{src}[112-127]). \end{aligned}$$

A.5.232 PMAGW: MMX Packed Magnitude

```
PMAGW mm1, mm2/m64 ; 0F 52 /r [CYRIX, MMX]
```

PMAGW, specific to the Cyrix MMX extensions, treats both its operands as vectors of four signed words. It compares the absolute values of the words in corresponding positions, and sets each word of the destination (first) operand to whichever of the two words in that position had the larger absolute value.

A.5.233 PMAWSW: Packed Signed Integer Word Maximum

```
PMAWSW mm1, mm2/m64 ; 0F EE /r [KATMAI, MMX]
PMAWSW xmm1, xmm2/m128 ; 66 0F EE /r [WILLAMETTE, SSE2]
```

PMAWSW compares each pair of words in the two source operands, and for each pair it stores the maximum value in the destination register.

A.5.234 PMAXUB: Packed Unsigned Integer Byte Maximum

```
PMAXUB mm1,mm2/m64 ; 0F DE /r [KATMAI,MMX]
PMAXUB xmm1,xmm2/m128 ; 66 0F DE /r [WILLAMETTE,SSE2]
```

PMAXUB compares each pair of bytes in the two source operands, and for each pair it stores the maximum value in the destination register.

A.5.235 PMINSW: Packed Signed Integer Word Minimum

```
PMINSW mm1,mm2/m64 ; 0F EA /r [KATMAI,MMX]
PMINSW xmm1,xmm2/m128 ; 66 0F EA /r [WILLAMETTE,SSE2]
```

PMINSW compares each pair of words in the two source operands, and for each pair it stores the minimum value in the destination register.

A.5.236 PMINUB: Packed Unsigned Integer Byte Minimum

```
PMINUB mm1,mm2/m64 ; 0F DA /r [KATMAI,MMX]
PMINUB xmm1,xmm2/m128 ; 66 0F DA /r [WILLAMETTE,SSE2]
```

PMINUB compares each pair of bytes in the two source operands, and for each pair it stores the minimum value in the destination register.

A.5.237 PMOVMSKB: Move Byte Mask To Integer

```
PMOVMSKB reg32,mm ; 0F D7 /r [KATMAI,MMX]
PMOVMSKB reg32,xmm ; 66 0F D7 /r [WILLAMETTE,SSE2]
```

PMOVMSKB returns an 8-bit or 16-bit mask formed of the most significant bits of each byte of source operand (8-bits for an MMX register, 16-bits for an XMM register).

A.5.238 PMULHRWC, PMULHRIW: Multiply Packed 16-bit Integers With Rounding, and Store High Word

```
PMULHRWC mm1,mm2/m64 ; 0F 59 /r [CYRIX,MMX]
PMULHRIW mm1,mm2/m64 ; 0F 5D /r [CYRIX,MMX]
```

These instructions take two packed 16-bit integer inputs, multiply the values in the inputs, round on bit 15 of each result, then store bits 15-30 of each result to the corresponding position of the destination register.

- For PMULHRWC, the destination is the first source operand.
- For PMULHRIW, the destination is an implied register (worked out as described for PADDSIW (section A.5.200)).

The operation of this instruction is:

```
dst[0-15] := (src1[0-15] * src2[0-15] + 0x00004000)[15-30]
dst[16-31] := (src1[16-31] * src2[16-31] + 0x00004000)[15-30]
dst[32-47] := (src1[32-47] * src2[32-47] + 0x00004000)[15-30]
dst[48-63] := (src1[48-63] * src2[48-63] + 0x00004000)[15-30]
```

See also PMULHRWA (section A.5.239) for a 3DNow! version of this instruction.

A.5.239 **PMULHRWA: Multiply Packed 16-bit Integers With Rounding, and Store High Word**

PMULHRWA mm1,mm2/m64 ; 0F 0F /r B7 [PENT,3DNOW]

PMULHRWA takes two packed 16-bit integer inputs, multiplies the values in the inputs, rounds on bit 16 of each result, then stores bits 16-31 of each result to the corresponding position of the destination register.

The operation of this instruction is:

```
dst[0-15] := (src1[0-15] * src2[0-15] + 0x00008000)[16-31];
dst[16-31] := (src1[16-31] * src2[16-31] + 0x00008000)[16-31];
dst[32-47] := (src1[32-47] * src2[32-47] + 0x00008000)[16-31];
dst[48-63] := (src1[48-63] * src2[48-63] + 0x00008000)[16-31].
```

See also PMULHRWC (section A.5.238) for a Cyrix version of this instruction.

A.5.240 **PMULHUW: Multiply Packed 16-bit Integers, and Store High Word**

PMULHUW mm1,mm2/m64 ; 0F E4 /r [KATMAI,MMX]
PMULHUW xmm1,xmm2/m128 ; 66 0F E4 /r [WILLAMETTE,SSE2]

PMULHUW takes two packed unsigned 16-bit integer inputs, multiplies the values in the inputs, then stores bits 16-31 of each result to the corresponding position of the destination register.

A.5.241 **PMULHW, PMULLW: Multiply Packed 16-bit Integers, and Store**

PMULHW mm1,mm2/m64 ; 0F E5 /r [PENT,MMX]
PMULLW mm1,mm2/m64 ; 0F D5 /r [PENT,MMX]
PMULHW xmm1,xmm2/m128 ; 66 0F E5 /r [WILLAMETTE,SSE2]
PMULLW xmm1,xmm2/m128 ; 66 0F D5 /r [WILLAMETTE,SSE2]

PMULxW takes two packed unsigned 16-bit integer inputs, and multiplies the values in the inputs, forming doubleword results.

- PMULHW then stores the top 16 bits of each doubleword in the destination (first) operand;
- PMULLW stores the bottom 16 bits of each doubleword in the destination operand.

A.5.242 **PMULUDQ: Multiply Packed Unsigned 32-bit Integers, and Store.**

PMULUDQ mm1,mm2/m64 ; 0F F4 /r [WILLAMETTE,SSE2]
PMULUDQ xmm1,xmm2/m128 ; 66 0F F4 /r [WILLAMETTE,SSE2]

PMULUDQ takes two packed unsigned 32-bit integer inputs, and multiplies the values in the inputs, forming quadword results. The source is either an unsigned doubleword in the low doubleword of a 64-bit operand, or it's two unsigned doublewords in the first and third doublewords of a 128-bit operand. This produces either one or two 64-bit results, which are stored in the respective quadword locations of the destination register.

The operation is:

```
dst[0-63] := dst[0-31] * src[0-31];
dst[64-127] := dst[64-95] * src[64-95].
```


A.5.243 **PMVccZB: MMX Packed Conditional Move**

PMVZB mmxreg,mem64	; 0F 58 /r	[CYRIX,MMX]
PMVNZB mmxreg,mem64	; 0F 5A /r	[CYRIX,MMX]
PMVLZB mmxreg,mem64	; 0F 5B /r	[CYRIX,MMX]
PMVGEZB mmxreg,mem64	; 0F 5C /r	[CYRIX,MMX]

These instructions, specific to the Cyrix MMX extensions, perform parallel conditional moves. The two input operands are treated as vectors of eight bytes. Each byte of the destination (first) operand is either written from the corresponding byte of the source (second) operand, or left alone, depending on the value of the byte in the *implied* operand (specified in the same way as PADDISIW, in section A.5.200).

- PMVZB performs each move if the corresponding byte in the implied operand is zero;
- PMVNZB moves if the byte is non-zero;
- PMVLZB moves if the byte is less than zero;
- PMVGEZB moves if the byte is greater than or equal to zero.

Note that these instructions cannot take a register as their second source operand.

A.5.244 **POP: Pop Data from Stack**

POP reg16	; 016 58+r	[8086]
POP reg32	; 032 58+r	[386]
POP r/m16	; 016 8F /0	[8086]
POP r/m32	; 032 8F /0	[386]
POP CS	; 0F	[8086,UNDOC]
POP DS	; 1F	[8086]
POP ES	; 07	[8086]
POP SS	; 17	[8086]
POP FS	; 0F A1	[386]
POP GS	; 0F A9	[386]

POP loads a value from the stack (from [SS : SP] or [SS : ESP]) and then increments the stack pointer.

The address-size attribute of the instruction determines whether SP or ESP is used as the stack pointer: to deliberately override the default given by the BITS setting, you can use an a16 or a32 prefix.

The operand-size attribute of the instruction determines whether the stack pointer is incremented by 2 or 4: this means that segment register pops in BITS 32 mode will pop 4 bytes off the stack and discard the upper two of them. If you need to override that, you can use an 016 or 032 prefix.

The above opcode listings give two forms for general-purpose register pop instructions: for example, POP BX has the two forms 5B and 8F C3. NASM will always generate the shorter form when given POP BX. NDISASM will disassemble both.

POP CS is not a documented instruction, and is not supported on any processor above the 8086

(since they use 0Fh as an opcode prefix for instruction set extensions). However, at least some 8086 processors do support it, and so NASM generates it for completeness. Current versions of NASM silently accept this instruction.

A.5.245 **POPAX: Pop All General-Purpose Registers**

```

POPA                ; 61                [186]
POPAW               ; 016 61           [186]
POPAD               ; 032 61           [386]

```

- POPAW pops a word from the stack into each of, successively, DI, SI, BP, nothing (it discards a word from the stack which was a placeholder for SP), BX, DX, CX and AX. It is intended to reverse the operation of PUSHAW (see section A.5.264), but it ignores the value for SP that was pushed on the stack by PUSHAW.
- POPAD pops twice as much data, and places the results in EDI, ESI, EBP, nothing (placeholder for ESP), EBX, EDX, ECX and EAX. It reverses the operation of PUSHAD.

POPA is an alias mnemonic for either POPAW or POPAD, depending on the current BITS setting.

Note that the registers are popped in reverse order of their numeric values in opcodes (see section A.2.1).

A.5.246 **POPFx: Pop Flags Register**

```

POPF                ; 9D                [8086]
POPFW               ; 016 9D           [8086]
POPFD               ; 032 9D           [386]

```

- POPFW pops a word from the stack and stores it in the bottom 16 bits of the flags register (or the whole flags register, on processors below a 386).
- POPFD pops a doubleword and stores it in the entire flags register.

POPF is an alias mnemonic for either POPFW or POPFD, depending on the current BITS setting.

See also PUSHF (section A.5.265).

A.5.247 **POR: MMX Bitwise OR**

```

POR mm1 , mm2 / m64      ; 0F EB /r                [PENT, MMX]
POR xmm1 , xmm2 / m128   ; 66 0F EB /r            [WILLAMETTE, SSE2]

```

POR performs a bitwise OR operation between its two operands (i.e. each bit of the result is 1 if and only if at least one of the corresponding bits of the two inputs was 1), and stores the result in the destination (first) operand.

A.5.248 **PREFETCH: Prefetch Data Into Caches**

```

PREFETCH mem8           ; 0F 0D /0                [PENT, 3DNOW]
PREFETCHW mem8         ; 0F 0D /1                [PENT, 3DNOW]

```

PREFETCH and PREFETCHW fetch the line of data from memory that contains the specified byte. PREFETCHW performs differently on the Athlon to earlier processors.

For more details, see the 3DNow! Technology Manual.

A.5.249 PREFETCHh: Prefetch Data Into Caches

PREFETCHNTA	m8	; 0F 18 /0	[KATMAI]
PREFETCHT0	m8	; 0F 18 /1	[KATMAI]
PREFETCHT1	m8	; 0F 18 /2	[KATMAI]
PREFETCHT2	m8	; 0F 18 /3	[KATMAI]

The PREFETCHh instructions fetch the line of data from memory that contains the specified byte. It is placed in the cache according to rules specified by locality hints h:

The hints are:

- T0 (temporal data) - prefetch data into all levels of the cache hierarchy.
- T1 (temporal data with respect to first level cache) - prefetch data into level 2 cache and higher.
- T2 (temporal data with respect to second level cache) - prefetch data into level 2 cache and higher.
- NTA (non-temporal data with respect to all cache levels) - prefetch data into non-temporal cache structure and into a location close to the processor, minimizing cache pollution.

Note that this group of instructions doesn't provide a guarantee that the data will be in the cache when it is needed. For more details, see the Intel IA32 Software Developer Manual, Volume 2.

A.5.250 PSADBW: Packed Sum of Absolute Differences

PSADBW	mm1, mm2/m64	; 0F F6 /r	[KATMAI, MMX]
PSADBW	xmm1, xmm2/m128	; 66 0F F6 /r	[WILLAMETTE, SSE2]

PSADBW The PSADBW instruction computes the absolute value of the difference of the packed unsigned bytes in the two source operands. These differences are then summed to produce a word result in the lower 16-bit field of the destination register; the rest of the register is cleared. The destination operand is an MMX or an XMM register. The source operand can either be a register or a memory operand.

A.5.251 PSHUFD: Shuffle Packed Doublewords

PSHUFD	xmm1, xmm2/m128, imm8	; 66 0F 70 /r ib	[WILLAMETTE, SSE2]
--------	-----------------------	------------------	----------------------

PSHUFD shuffles the doublewords in the source (second) operand according to the encoding specified by imm8, and stores the result in the destination (first) operand.

Bits 0 and 1 of imm8 encode the source position of the doubleword to be copied to position 0 in the destination operand. Bits 2 and 3 encode for position 1, bits 4 and 5 encode for position 2, and bits 6 and 7 encode for position 3. For example, an encoding of 10 in bits 0 and 1 of imm8 indicates that the doubleword at bits 64-95 of the source operand will be copied to bits 0-31 of the destination.

A.5.252 PSHUFW: Shuffle Packed High Words

PSHUFW	xmm1, xmm2/m128, imm8	; F3 0F 70 /r ib	[WILLAMETTE, SSE2]
--------	-----------------------	------------------	----------------------

PSHUFW shuffles the words in the high quadword of the source (second) operand according to

the encoding specified by imm8, and stores the result in the high quadword of the destination (first) operand.

The operation of this instruction is similar to the PSHUFW instruction, except that the source and destination are the top quadword of a 128-bit operand, instead of being 64-bit operands. The low quadword is copied from the source to the destination without any changes.

A.5.253 PSHUFLW: Shuffle Packed Low Words

```
PSHUFLW xmm1, xmm2/m128, imm8 ; F2 0F 70 /r ib [WILLAMETTE, SSE2]
```

PSHUFLW shuffles the words in the low quadword of the source (second) operand according to the encoding specified by imm8, and stores the result in the low quadword of the destination (first) operand.

The operation of this instruction is similar to the PSHUFW instruction, except that the source and destination are the low quadword of a 128-bit operand, instead of being 64-bit operands. The high quadword is copied from the source to the destination without any changes.

A.5.254 PSHUFW: Shuffle Packed Words

```
PSHUFW mm1, mm2/m64, imm8 ; 0F 70 /r ib [KATMAI, MMX]
```

PSHUFW shuffles the words in the source (second) operand according to the encoding specified by imm8, and stores the result in the destination (first) operand.

Bits 0 and 1 of imm8 encode the source position of the word to be copied to position 0 in the destination operand. Bits 2 and 3 encode for position 1, bits 4 and 5 encode for position 2, and bits 6 and 7 encode for position 3. For example, an encoding of 10 in bits 0 and 1 of imm8 indicates that the word at bits 32-47 of the source operand will be copied to bits 0-15 of the destination.

A.5.255 PSSLx: Packed Data Bit Shift Left Logical

```
PSLLW mm1, mm2/m64 ; 0F F1 /r [PENT, MMX]
PSLLW mm, imm8 ; 0F 71 /6 ib [PENT, MMX]
```

```
PSLLW xmm1, xmm2/m128 ; 66 0F F1 /r [WILLAMETTE, SSE2]
PSLLW xmm, imm8 ; 66 0F 71 /6 ib [WILLAMETTE, SSE2]
```

```
PSLLD mm1, mm2/m64 ; 0F F2 /r [PENT, MMX]
PSLLD mm, imm8 ; 0F 72 /6 ib [PENT, MMX]
```

```
PSLLD xmm1, xmm2/m128 ; 66 0F F2 /r [WILLAMETTE, SSE2]
PSLLD xmm, imm8 ; 66 0F 72 /6 ib [WILLAMETTE, SSE2]
```

```
PSLLQ mm1, mm2/m64 ; 0F F3 /r [PENT, MMX]
PSLLQ mm, imm8 ; 0F 73 /6 ib [PENT, MMX]
```

```
PSLLQ xmm1, xmm2/m128 ; 66 0F F3 /r [WILLAMETTE, SSE2]
PSLLQ xmm, imm8 ; 66 0F 73 /6 ib [WILLAMETTE, SSE2]
```

```
PSLLDQ xmm1, imm8 ; 66 0F 73 /7 ib [WILLAMETTE, SSE2]
```

PSSLx performs logical left shifts of the data elements in the destination (first) operand, moving

each bit in the separate elements left by the number of bits specified in the source (second) operand, clearing the low-order bits as they are vacated. PSLLDQ shifts bytes, not bits.

- PSLW shifts word sized elements.
- PSLD shifts doubleword sized elements.
- PSLQ shifts quadword sized elements.
- PSLDQ shifts double quadword sized elements.

A.5.256 PSRAx: Packed Data Bit Shift Right Arithmetic

PSRAW mm1, mm2/m64	; 0F E1 /r	[PENT, MMX]
PSRAW mm, imm8	; 0F 71 /4 ib	[PENT, MMX]
PSRAW xmm1, xmm2/m128	; 66 0F E1 /r	[WILLAMETTE, SSE2]
PSRAW xmm, imm8	; 66 0F 71 /4 ib	[WILLAMETTE, SSE2]
PSRAD mm1, mm2/m64	; 0F E2 /r	[PENT, MMX]
PSRAD mm, imm8	; 0F 72 /4 ib	[PENT, MMX]
PSRAD xmm1, xmm2/m128	; 66 0F E2 /r	[WILLAMETTE, SSE2]
PSRAD xmm, imm8	; 66 0F 72 /4 ib	[WILLAMETTE, SSE2]

PSRAx performs arithmetic right shifts of the data elements in the destination (first) operand, moving each bit in the separate elements right by the number of bits specified in the source (second) operand, setting the high-order bits to the value of the original sign bit.

- PSRAW shifts word sized elements.
- PSRAD shifts doubleword sized elements.

A.5.257 PSRLx: Packed Data Bit Shift Right Logical

PSRLW mm1, mm2/m64	; 0F D1 /r	[PENT, MMX]
PSRLW mm, imm8	; 0F 71 /2 ib	[PENT, MMX]
PSRLW xmm1, xmm2/m128	; 66 0F D1 /r	[WILLAMETTE, SSE2]
PSRLW xmm, imm8	; 66 0F 71 /2 ib	[WILLAMETTE, SSE2]
PSRLD mm1, mm2/m64	; 0F D2 /r	[PENT, MMX]
PSRLD mm, imm8	; 0F 72 /2 ib	[PENT, MMX]
PSRLD xmm1, xmm2/m128	; 66 0F D2 /r	[WILLAMETTE, SSE2]
PSRLD xmm, imm8	; 66 0F 72 /2 ib	[WILLAMETTE, SSE2]
PSRLQ mm1, mm2/m64	; 0F D3 /r	[PENT, MMX]
PSRLQ mm, imm8	; 0F 73 /2 ib	[PENT, MMX]
PSRLQ xmm1, xmm2/m128	; 66 0F D3 /r	[WILLAMETTE, SSE2]
PSRLQ xmm, imm8	; 66 0F 73 /2 ib	[WILLAMETTE, SSE2]
PSRLDQ xmm1, imm8	; 66 0F 73 /3 ib	[WILLAMETTE, SSE2]

PSRLx performs logical right shifts of the data elements in the destination (first) operand, moving each bit in the separate elements right by the number of bits specified in the source

(second) operand, clearing the high-order bits as they are vacated. PSRLDQ shifts bytes, not bits.

- PSRLW shifts word sized elements.
- PSRLD shifts doubleword sized elements.
- PSRLQ shifts quadword sized elements.
- PSRLDQ shifts double quadword sized elements.

A.5.258 PSUBx: Subtract Packed Integers

PSUBB mm1, mm2/m64	; 0F F8 /r	[PENT, MMX]
PSUBW mm1, mm2/m64	; 0F F9 /r	[PENT, MMX]
PSUBD mm1, mm2/m64	; 0F FA /r	[PENT, MMX]
PSUBQ mm1, mm2/m64	; 0F FB /r	[WILLAMETTE, SSE2]
PSUBB xmm1, xmm2/m128	; 66 0F F8 /r	[WILLAMETTE, SSE2]
PSUBW xmm1, xmm2/m128	; 66 0F F9 /r	[WILLAMETTE, SSE2]
PSUBD xmm1, xmm2/m128	; 66 0F FA /r	[WILLAMETTE, SSE2]
PSUBQ xmm1, xmm2/m128	; 66 0F FB /r	[WILLAMETTE, SSE2]

PSUBx subtracts packed integers in the source operand from those in the destination operand. It doesn't differentiate between signed and unsigned integers, and doesn't set any of the flags.

- PSUBB operates on byte sized elements.
- PSUBW operates on word sized elements.
- PSUBD operates on doubleword sized elements.
- PSUBQ operates on quadword sized elements.

A.5.259 PSUBSxx, PSUBUSx: Subtract Packed Integers With Saturation

PSUBSB mm1, mm2/m64	; 0F E8 /r	[PENT, MMX]
PSUBSW mm1, mm2/m64	; 0F E9 /r	[PENT, MMX]
PSUBSB xmm1, xmm2/m128	; 66 0F E8 /r	[WILLAMETTE, SSE2]
PSUBSW xmm1, xmm2/m128	; 66 0F E9 /r	[WILLAMETTE, SSE2]
PSUBUSB mm1, mm2/m64	; 0F D8 /r	[PENT, MMX]
PSUBUSW mm1, mm2/m64	; 0F D9 /r	[PENT, MMX]
PSUBUSB xmm1, xmm2/m128	; 66 0F D8 /r	[WILLAMETTE, SSE2]
PSUBUSW xmm1, xmm2/m128	; 66 0F D9 /r	[WILLAMETTE, SSE2]

PSUBSx and PSUBUSx subtracts packed integers in the source operand from those in the destination operand, and use saturation for results that are outside the range supported by the destination operand.

- PSUBSB operates on signed bytes, and uses signed saturation on the results.
- PSUBSW operates on signed words, and uses signed saturation on the results.

- PSUBUSB operates on unsigned bytes, and uses signed saturation on the results.
- PSUBUSW operates on unsigned words, and uses signed saturation on the results.

A.5.260 PSUBSIW: MMX Packed Subtract with Saturation to Implied Destination

PSUBSIW mm1,mm2/m64 ; 0F 55 /r [CYRIX,MMX]

PSUBSIW, specific to the Cyrix extensions to the MMX instruction set, performs the same function as PSUBSW, except that the result is not placed in the register specified by the first operand, but instead in the implied destination register, specified as for PADDSIW (section A.5.200).

A.5.261 PSWAPD: Swap Packed Data

PSWAPD mm1,mm2/m64 ; 0F 0F /r BB [PENT,3DNOW]

PSWAPD swaps the packed doublewords in the source operand, and stores the result in the destination operand.

In the K6-2 and K6-III processors, this opcode uses the mnemonic PSWAPW, and it swaps the order of words when copying from the source to the destination.

The operation in the K6-2 and K6-III processors is

```
dst[0-15] = src[48-63];
dst[16-31] = src[32-47];
dst[32-47] = src[16-31];
dst[48-63] = src[0-15].
```

The operation in the K6-x+, ATHLON and later processors is:

```
dst[0-31] = src[32-63];
dst[32-63] = src[0-31].
```

A.5.262 PUNPCKxxx: Unpack and Interleave Data

PUNPCKHBW mm1,mm2/m64 ; 0F 68 /r [PENT,MMX]
PUNPCKHWD mm1,mm2/m64 ; 0F 69 /r [PENT,MMX]
PUNPCKHDQ mm1,mm2/m64 ; 0F 6A /r [PENT,MMX]

PUNPCKHBW xmm1,xmm2/m128 ; 66 0F 68 /r [WILLAMETTE,SSE2]
PUNPCKHWD xmm1,xmm2/m128 ; 66 0F 69 /r [WILLAMETTE,SSE2]
PUNPCKHDQ xmm1,xmm2/m128 ; 66 0F 6A /r [WILLAMETTE,SSE2]
PUNPCKHQDQ xmm1,xmm2/m128 ; 66 0F 6D /r [WILLAMETTE,SSE2]

PUNPCKLBW mm1,mm2/m32 ; 0F 60 /r [PENT,MMX]
PUNPCKLWD mm1,mm2/m32 ; 0F 61 /r [PENT,MMX]
PUNPCKLDQ mm1,mm2/m32 ; 0F 62 /r [PENT,MMX]

PUNPCKLBW xmm1,xmm2/m128 ; 66 0F 60 /r [WILLAMETTE,SSE2]
PUNPCKLWD xmm1,xmm2/m128 ; 66 0F 61 /r [WILLAMETTE,SSE2]

```
PUNPCKLDQ xmm1, xmm2/m128      ; 66 0F 62 /r      [WILLAMETTE, SSE2]
PUNPCKLQDQ xmm1, xmm2/m128     ; 66 0F 6C /r      [WILLAMETTE, SSE2]
```

PUNPCK xx all treat their operands as vectors, and produce a new vector generated by interleaving elements from the two inputs. The PUNPCKH xx instructions start by throwing away the bottom half of each input operand, and the PUNPCKL xx instructions throw away the top half.

The remaining elements, are then interleaved into the destination, alternating elements from the second (source) operand and the first (destination) operand: so the leftmost part of each element in the result always comes from the second operand, and the rightmost from the destination.

- PUNPCK x BW works a byte at a time, producing word sized output elements.
- PUNPCK x WD works a word at a time, producing doubleword sized output elements.
- PUNPCK x DQ works a doubleword at a time, producing quadword sized output elements.
- PUNPCK x QDQ works a quadword at a time, producing double quadword sized output elements.

So, for example, for MMX operands, if the first operand held 0x7A6A5A4A3A2A1A0A and the second held 0x7B6B5B4B3B2B1B0B, then:

- PUNPCKHBW would return 0x7B7A6B6A5B5A4B4A.
- PUNPCKHWD would return 0x7B6B7A6A5B4B5A4A.
- PUNPCKHDQ would return 0x7B6B5B4B7A6A5A4A.
- PUNPCKLBW would return 0x3B3A2B2A1B1A0B0A.
- PUNPCKLWD would return 0x3B2B3A2A1B0B1A0A.
- PUNPCKLDQ would return 0x3B2B1B0B3A2A1A0A.

A.5.263 PUSH: Push Data on Stack

```
PUSH reg16      ; 016 50+r      [8086]
PUSH reg32      ; 032 50+r      [386]

PUSH r/m16      ; 016 FF /6      [8086]
PUSH r/m32      ; 032 FF /6      [386]

PUSH CS         ; 0E          [8086]
PUSH DS         ; 1E          [8086]
PUSH ES         ; 06          [8086]
PUSH SS         ; 16          [8086]
PUSH FS         ; 0F A0       [386]
PUSH GS         ; 0F A8       [386]

PUSH imm8       ; 6A ib        [186]
PUSH imm16      ; 016 68 iw       [186]
PUSH imm32      ; 032 68 id       [386]
```


PUSH decrements the stack pointer (SP or ESP) by 2 or 4, and then stores the given value at [SS:SP] or [SS:ESP].

The address-size attribute of the instruction determines whether SP or ESP is used as the stack pointer: to deliberately override the default given by the BITS setting, you can use an a16 or a32 prefix.

The operand-size attribute of the instruction determines whether the stack pointer is decremented by 2 or 4: this means that segment register pushes in BITS 32 mode will push 4 bytes on the stack, of which the upper two are undefined. If you need to override that, you can use an o16 or o32 prefix.

The above opcode listings give two forms for general-purpose register push instructions: for example, PUSH BX has the two forms 53 and FF F3. NASM will always generate the shorter form when given PUSH BX. NDISASM will disassemble both.

Unlike the undocumented and barely supported POP CS, PUSH CS is a perfectly valid and sensible instruction, supported on all processors.

The instruction PUSH SP may be used to distinguish an 8086 from later processors: on an 8086, the value of SP stored is the value it has *after* the push instruction, whereas on later processors it is the value *before* the push instruction.

A.5.264 PUSHAX: Push All General-Purpose Registers

PUSHA	; 60	[186]
PUSHAD	; o32 60	[386]
PUSHAW	; o16 60	[186]

PUSHAW pushes, in succession, AX, CX, DX, BX, SP, BP, SI and DI on the stack, decrementing the stack pointer by a total of 16.

PUSHAD pushes, in succession, EAX, ECX, EDX, EBX, ESP, EBP, ESI and EDI on the stack, decrementing the stack pointer by a total of 32.

In both cases, the value of SP or ESP pushed is its *original* value, as it had before the instruction was executed.

PUSHA is an alias mnemonic for either PUSHAW or PUSHAD, depending on the current BITS setting.

Note that the registers are pushed in order of their numeric values in opcodes (see section A.2.1).

See also POPA (section A.5.245).

A.5.265 PUSHFx: Push Flags Register

PUSHF	; 9C	[8086]
PUSHFD	; o32 9C	[386]
PUSHFW	; o16 9C	[8086]

- PUSHFW pushes the bottom 16 bits of the flags register (or the whole flags register, on processors below a 386) onto the stack.
- PUSHFD pushes the entire flags register onto the stack.

PUSHF is an alias mnemonic for either PUSHFW or PUSHFD, depending on the current BITS setting.

See also POPF (section A.5.246).

A.5.266 PXOR: MMX Bitwise XOR

```
PXOR mm1,mm2/m64 ; 0F EF /r [PENT,MMX]
PXOR xmm1,xmm2/m128 ; 66 0F EF /r [WILLAMETTE,SSE2]
```

PXOR performs a bitwise XOR operation between its two operands (i.e. each bit of the result is 1 if and only if exactly one of the corresponding bits of the two inputs was 1), and stores the result in the destination (first) operand.

A.5.267 RCL, RCR: Bitwise Rotate through Carry Bit

```
RCL r/m8,1 ; D0 /2 [8086]
RCL r/m8,CL ; D2 /2 [8086]
RCL r/m8,imm8 ; C0 /2 ib [186]
RCL r/m16,1 ; 016 D1 /2 [8086]
RCL r/m16,CL ; 016 D3 /2 [8086]
RCL r/m16,imm8 ; 016 C1 /2 ib [186]
RCL r/m32,1 ; 032 D1 /2 [386]
RCL r/m32,CL ; 032 D3 /2 [386]
RCL r/m32,imm8 ; 032 C1 /2 ib [386]

RCR r/m8,1 ; D0 /3 [8086]
RCR r/m8,CL ; D2 /3 [8086]
RCR r/m8,imm8 ; C0 /3 ib [186]
RCR r/m16,1 ; 016 D1 /3 [8086]
RCR r/m16,CL ; 016 D3 /3 [8086]
RCR r/m16,imm8 ; 016 C1 /3 ib [186]
RCR r/m32,1 ; 032 D1 /3 [386]
RCR r/m32,CL ; 032 D3 /3 [386]
RCR r/m32,imm8 ; 032 C1 /3 ib [386]
```

RCL and RCR perform a 9-bit, 17-bit or 33-bit bitwise rotation operation, involving the given source/destination (first) operand and the carry bit. Thus, for example, in the operation RCL AL, 1, a 9-bit rotation is performed in which AL is shifted left by 1, the top bit of AL moves into the carry flag, and the original value of the carry flag is placed in the low bit of AL.

The number of bits to rotate by is given by the second operand. Only the bottom five bits of the rotation count are considered by processors above the 8086.

You can force the longer (186 and upwards, beginning with a C1 or C0 byte) form of RCL foo, 1 by using a BYTE prefix: RCL foo, BYTE 1. Similarly with RCR.

A.5.268 RCPPS: Packed Single-Precision FP Reciprocal

```
RCPPS xmm1,xmm2/m128 ; 0F 53 /r [KATMAI,SSE]
```

RCPPS returns an approximation of the reciprocal of the packed single-precision FP values from xmm2/m128. The maximum error for this approximation is: |Error| <= 1.5 x 2⁻¹²

A.5.269 RCPSS: Scalar Single-Precision FP Reciprocal

RCPSS `xmm1, xmm2/m128` ; F3 0F 53 /r [KATMAI, SSE]

RCPSS returns an approximation of the reciprocal of the lower single-precision FP value from `xmm2/m32`; the upper three fields are passed through from `xmm1`. The maximum error for this approximation is: $|\text{Error}| \leq 1.5 \times 2^{-12}$

A.5.270 RDMSR: Read Model-Specific Registers

RDMSR ; 0F 32 [PENT, PRIV]

RDMSR reads the processor Model-Specific Register (MSR) whose index is stored in `ECX`, and stores the result in `EDX:EAX`. See also `WRMSR` (section A.5.329).

A.5.271 RDPMC: Read Performance-Monitoring Counters

RDPMC ; 0F 33 [P6]

RDPMC reads the processor performance-monitoring counter whose index is stored in `ECX`, and stores the result in `EDX:EAX`.

This instruction is available on P6 and later processors and on MMX class processors.

A.5.272 RDSHR: Read SMM Header Pointer Register

RDSHR `r/m32` ; 0F 36 /0 [386, CYRIX, SMM]

RDSHR reads the contents of the SMM header pointer register and saves it to the destination operand, which can be either a 32 bit memory location or a 32 bit register.

See also `WRSHR` (section A.5.330).

A.5.273 RDTSC: Read Time-Stamp Counter

RDTSC ; 0F 31 [PENT]

RDTSC reads the processor's time-stamp counter into `EDX:EAX`.

A.5.274 RET, RETF, RETN: Return from Procedure Call

RET ; C3 [8086]

RET `imm16` ; C2 `iw` [8086]

RETF ; CB [8086]

RETF `imm16` ; CA `iw` [8086]

RETN ; C3 [8086]

RETN `imm16` ; C2 `iw` [8086]

- `RET`, and its exact synonym `RETN`, pop `IP` or `EIP` from the stack and transfer control to the new address. Optionally, if a numeric second operand is provided, they increment the stack pointer by a further `imm16` bytes after popping the return address.
- `RETF` executes a far return: after popping `IP/EIP`, it then pops `CS`, and *then* increments the stack pointer by the optional argument if present.

A.5.275 ROL, ROR: Bitwise Rotate

ROL <i>r/m8</i> , 1	; D0 /0	[8086]
ROL <i>r/m8</i> , CL	; D2 /0	[8086]
ROL <i>r/m8</i> , imm8	; C0 /0 ib	[186]
ROL <i>r/m16</i> , 1	; o16 D1 /0	[8086]
ROL <i>r/m16</i> , CL	; o16 D3 /0	[8086]
ROL <i>r/m16</i> , imm8	; o16 C1 /0 ib	[186]
ROL <i>r/m32</i> , 1	; o32 D1 /0	[386]
ROL <i>r/m32</i> , CL	; o32 D3 /0	[386]
ROL <i>r/m32</i> , imm8	; o32 C1 /0 ib	[386]
ROR <i>r/m8</i> , 1	; D0 /1	[8086]
ROR <i>r/m8</i> , CL	; D2 /1	[8086]
ROR <i>r/m8</i> , imm8	; C0 /1 ib	[186]
ROR <i>r/m16</i> , 1	; o16 D1 /1	[8086]
ROR <i>r/m16</i> , CL	; o16 D3 /1	[8086]
ROR <i>r/m16</i> , imm8	; o16 C1 /1 ib	[186]
ROR <i>r/m32</i> , 1	; o32 D1 /1	[386]
ROR <i>r/m32</i> , CL	; o32 D3 /1	[386]
ROR <i>r/m32</i> , imm8	; o32 C1 /1 ib	[386]

ROL and ROR perform a bitwise rotation operation on the given source/destination (first) operand. Thus, for example, in the operation `ROL AL, 1`, an 8-bit rotation is performed in which AL is shifted left by 1 and the original top bit of AL moves round into the low bit.

The number of bits to rotate by is given by the second operand. Only the bottom five bits of the rotation count are considered by processors above the 8086.

You can force the longer (186 and upwards, beginning with a C1 or C0 byte) form of `ROL foo, 1` by using a BYTE prefix: `ROL foo, BYTE 1`. Similarly with ROR.

A.5.276 RSDC: Restore Segment Register and Descriptor

`RSDC segreg, mem80` ; 0F 79 /r [486, CYRIX, SMM]

RSDC restores a segment register (DS, ES, FS, GS, or SS) from mem80, and sets up its descriptor.

A.5.277 RSLDT: Restore Segment Register and Descriptor

`RSLDT mem80` ; 0F 7B /0 [486, CYRIX, SMM]

RSLDT restores the Local Descriptor Table (LDTR) from mem80.

A.5.278 RSM: Resume from System-Management Mode

`RSM` ; 0F AA [PENT]

RSM returns the processor to its normal operating mode when it was in System-Management Mode.

A.5.279 RSQRTPS: Packed Single-Precision FP Square Root Reciprocal

`RSQRTPS xmm1, xmm2/m128` ; 0F 52 /r [KATMAI, SSE]

RSQRTPS computes the approximate reciprocals of the square roots of the packed single-precision floating-point values in the source and stores the results in xmm1. The maximum error for this approximation is: $|\text{Error}| \leq 1.5 \times 2^{-12}$

A.5.280 RSQRTSS: Scalar Single-Precision FP Square Root Reciprocal

RSQRTSS xmm1, xmm2/m128 ; F3 0F 52 /r [KATMAI, SSE]

RSQRTSS returns an approximation of the reciprocal of the square root of the lowest order single-precision FP value from the source, and stores it in the low doubleword of the destination register. The upper three fields of xmm1 are preserved. The maximum error for this approximation is: $|\text{Error}| \leq 1.5 \times 2^{-12}$

A.5.281 RSTS: Restore TSR and Descriptor

RSTS mem80 ; 0F 7D /0 [486, CYRIX, SMM]

RSTS restores Task State Register (TSR) from mem80.

A.5.282 SAHF: Store AH to Flags

SAHF ; 9E [8086]

SAHF sets the low byte of the flags word according to the contents of the AH register.

The operation of SAHF is:

AH --> SF:ZF:0:AF:0:PF:1:CF

See also LAHF (section A.5.131).

A.5.283 SAL, SAR: Bitwise Arithmetic Shifts

SAL r/m8, 1	; D0 /4	[8086]
SAL r/m8, CL	; D2 /4	[8086]
SAL r/m8, imm8	; C0 /4 ib	[186]
SAL r/m16, 1	; o16 D1 /4	[8086]
SAL r/m16, CL	; o16 D3 /4	[8086]
SAL r/m16, imm8	; o16 C1 /4 ib	[186]
SAL r/m32, 1	; o32 D1 /4	[386]
SAL r/m32, CL	; o32 D3 /4	[386]
SAL r/m32, imm8	; o32 C1 /4 ib	[386]
SAR r/m8, 1	; D0 /7	[8086]
SAR r/m8, CL	; D2 /7	[8086]
SAR r/m8, imm8	; C0 /7 ib	[186]
SAR r/m16, 1	; o16 D1 /7	[8086]
SAR r/m16, CL	; o16 D3 /7	[8086]
SAR r/m16, imm8	; o16 C1 /7 ib	[186]
SAR r/m32, 1	; o32 D1 /7	[386]
SAR r/m32, CL	; o32 D3 /7	[386]
SAR r/m32, imm8	; o32 C1 /7 ib	[386]

SAL and SAR perform an arithmetic shift operation on the given source/destination (first)

operand. The vacated bits are filled with zero for SAL, and with copies of the original high bit of the source operand for SAR.

SAL is a synonym for SHL (see section A.5.290). NASM will assemble either one to the same code, but NDISASM will always disassemble that code as SHL.

The number of bits to shift by is given by the second operand. Only the bottom five bits of the shift count are considered by processors above the 8086.

You can force the longer (186 and upwards, beginning with a C1 or C0 byte) form of SAL `foo,1` by using a BYTE prefix: SAL `foo,BYTE 1`. Similarly with SAR.

A.5.284 SALC: Set AL from Carry Flag

SALC ; D6 [8086,UNDOC]

SALC is an early undocumented instruction similar in concept to SETCC (section A.5.287). Its function is to set AL to zero if the carry flag is clear, or to 0xFF if it is set.

A.5.285 SBB: Subtract with Borrow

SBB <code>r/m8,reg8</code>	; 18 /r	[8086]
SBB <code>r/m16,reg16</code>	; 016 19 /r	[8086]
SBB <code>r/m32,reg32</code>	; 032 19 /r	[386]
SBB <code>reg8,r/m8</code>	; 1A /r	[8086]
SBB <code>reg16,r/m16</code>	; 016 1B /r	[8086]
SBB <code>reg32,r/m32</code>	; 032 1B /r	[386]
SBB <code>r/m8,imm8</code>	; 80 /3 ib	[8086]
SBB <code>r/m16,imm16</code>	; 016 81 /3 iw	[8086]
SBB <code>r/m32,imm32</code>	; 032 81 /3 id	[386]
SBB <code>r/m16,imm8</code>	; 016 83 /3 ib	[8086]
SBB <code>r/m32,imm8</code>	; 032 83 /3 ib	[386]
SBB <code>AL,imm8</code>	; 1C ib	[8086]
SBB <code>AX,imm16</code>	; 016 1D iw	[8086]
SBB <code>EAX,imm32</code>	; 032 1D id	[386]

SBB performs integer subtraction: it subtracts its second operand, plus the value of the carry flag, from its first, and leaves the result in its destination (first) operand. The flags are set according to the result of the operation: in particular, the carry flag is affected and can be used by a subsequent SBB instruction.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the STRICT WORD or STRICT DWORD qualifier.

To subtract one number from another without also subtracting the contents of the carry flag, use SUB (section A.5.305).

A.5.286 SCASB, SCASW, SCASD: Scan String

SCASB	; AE	[8086]
SCASW	; 016 AF	[8086]
SCASD	; 032 AF	[386]

SCASB compares the byte in AL with the byte at [ES:DI] or [ES:EDI], and sets the flags accordingly. It then increments or decrements (depending on the direction flag: increments if the flag is clear, decrements if it is set) DI (or EDI).

The register used is DI if the address size is 16 bits, and EDI if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit a16 or a32 prefix.

Segment override prefixes have no effect for this instruction: the use of ES for the load from [DI] or [EDI] cannot be overridden.

SCASW and SCASD work in the same way, but they compare a word to AX or a doubleword to EAX instead of a byte to AL, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The REPE and REPNE prefixes (equivalently, REPZ and REPNZ) may be used to repeat the instruction up to CX (or ECX - again, the address size chooses which) times until the first unequal or equal element is found. To NASM, REP is an alias for REPE.

A.5.286.1 Pseudo-code examples

a16 SCASB and with Direction Flag clear (UP) is equal to

```
CMP AL, BYTE [ES:DI]
LEA DI, [DI + 1]
```

a16 REPE SCASW and with Direction Flag clear (UP) is equal to

```
JCXZ @FF
@@:
CMP AX, WORD [ES:DI]
LEA DI, [DI + 2]
a16 LOOPE @B
@@:
```

a32 SCASD with Direction Flag set (DN) is equal to

```
CMP EAX, DWORD [ES:EDI]
LEA EDI, [EDI - 4]
```

A.5.287 SETcc: Set Register from Condition

SETcc r/m8	; 0F 90+cc /2	[386]
------------	---------------	---------

SETcc sets the given 8-bit operand to zero if its condition is not satisfied, and to 1 if it is.

A.5.288 SFENCE: Store Fence

SFENCE	; 0F AE /7	[KATMAI]
--------	------------	------------

SFENCE performs a serialising operation on all writes to memory that were issued before the

SFENCE instruction. This guarantees that all memory writes before the SFENCE instruction are visible before any writes after the SFENCE instruction.

SFENCE is ordered relative to other SFENCE instruction, MFENCE, any memory write and any other serialising instruction (such as CPUID).

Weakly ordered memory types can be used to achieve higher processor performance through such techniques as out-of-order issue, write-combining, and write-collapsing. The degree to which a consumer of data recognizes or knows that the data is weakly ordered varies among applications and may be unknown to the producer of this data. The SFENCE instruction provides a performance-efficient way of insuring store ordering between routines that produce weakly-ordered results and routines that consume this data.

SFENCE uses the following ModR/M encoding:

```

Mod (7:6)           = 11B
Reg/Opcode (5:3)   = 111B
R/M (2:0)          = 000B

```

All other ModR/M encodings are defined to be reserved, and use of these encodings risks incompatibility with future processors.

See also LFENCE (section A.5.137) and MFENCE (section A.5.151).

A.5.289 SGDT, SIDT, SLDT: Store Descriptor Table Pointers

```

SGDT mem           ; 0F 01 /0           [286,PRIV]
SIDT mem           ; 0F 01 /1           [286,PRIV]
SLDT r/m16         ; 0F 00 /0           [286,PRIV]

```

SGDT and SIDT both take a 6-byte memory area as an operand: they store the contents of the GDTR (global descriptor table register) or IDTR (interrupt descriptor table register) as a 16-bit size limit and a 32-bit linear address into that area (limit word first, then linear address dword). The GDT and IDT instructions are the only instructions which directly use *linear* addresses, rather than segment/offset pairs.

SLDT stores the segment selector corresponding to the LDT (local descriptor table) into the given operand.

See also LGDT, LIDT and LLDT (section A.5.138).

A.5.290 SHL, SHR: Bitwise Logical Shifts

```

SHL r/m8,1         ; D0 /4           [8086]
SHL r/m8,CL        ; D2 /4           [8086]
SHL r/m8,imm8      ; C0 /4 ib        [186]
SHL r/m16,1        ; 016 D1 /4       [8086]
SHL r/m16,CL       ; 016 D3 /4       [8086]
SHL r/m16,imm8     ; 016 C1 /4 ib     [186]
SHL r/m32,1        ; 032 D1 /4       [386]
SHL r/m32,CL       ; 032 D3 /4       [386]
SHL r/m32,imm8     ; 032 C1 /4 ib     [386]

SHR r/m8,1         ; D0 /5           [8086]
SHR r/m8,CL        ; D2 /5           [8086]

```


SHR r/m8,imm8	; C0 /5 ib	[186]
SHR r/m16,1	; 016 D1 /5	[8086]
SHR r/m16,CL	; 016 D3 /5	[8086]
SHR r/m16,imm8	; 016 C1 /5 ib	[186]
SHR r/m32,1	; 032 D1 /5	[386]
SHR r/m32,CL	; 032 D3 /5	[386]
SHR r/m32,imm8	; 032 C1 /5 ib	[386]

SHL and SHR perform a logical shift operation on the given source/destination (first) operand. The vacated bits are filled with zero.

A synonym for SHL is SAL (see section A.5.283). NASM will assemble either one to the same code, but NDISASM will always disassemble that code as SHL.

The number of bits to shift by is given by the second operand. Only the bottom five bits of the shift count are considered by processors above the 8086.

You can force the longer (186 and upwards, beginning with a C1 or C0 byte) form of SHL foo,1 by using a BYTE prefix: SHL foo,BYTE 1. Similarly with SHR.

A.5.291 SHLD, SHRD: Bitwise Double-Precision Shifts

SHLD r/m16,reg16,imm8	; 016 0F A4 /r ib	[386]
SHLD r/m16,reg32,imm8	; 032 0F A4 /r ib	[386]
SHLD r/m16,reg16,CL	; 016 0F A5 /r	[386]
SHLD r/m16,reg32,CL	; 032 0F A5 /r	[386]
SHRD r/m16,reg16,imm8	; 016 0F AC /r ib	[386]
SHRD r/m32,reg32,imm8	; 032 0F AC /r ib	[386]
SHRD r/m16,reg16,CL	; 016 0F AD /r	[386]
SHRD r/m32,reg32,CL	; 032 0F AD /r	[386]

- SHLD performs a double-precision left shift. It notionally places its second operand to the right of its first, then shifts the entire bit string thus generated to the left by a number of bits specified in the third operand. It then updates only the *first* operand according to the result of this. The second operand is not modified.
- SHRD performs the corresponding right shift: it notionally places the second operand to the *left* of the first, shifts the whole bit string right, and updates only the first operand.

For example, if EAX holds 0x01234567 and EBX holds 0x89ABCDEF, then the instruction SHLD EAX,EBX,4 would update EAX to hold 0x12345678. Under the same conditions, SHRD EAX,EBX,4 would update EAX to hold 0xF0123456.

The number of bits to shift by is given by the third operand. Only the bottom five bits of the shift count are considered.

A.5.292 SHUFPS: Shuffle Packed Single-Precision FP Values

SHUFPS xmm1,xmm2/m128,imm8	; 66 0F C6 /r ib	[WILLAMETTE,SSE2]
----------------------------	------------------	-------------------

SHUFPS moves one of the packed single-precision FP values from the destination operand into the low quadword of the destination operand; the upper quadword is generated by moving one of the single-precision FP values from the source operand into the destination. The select (third) operand selects which of the values are moved to the destination register.

The select operand is an 8-bit immediate: bit 0 selects which value is moved from the destination operand to the result (where 0 selects the low quadword and 1 selects the high quadword) and bit 1 selects which value is moved from the source operand to the result. Bits 2 through 7 of the shuffle operand are reserved.

A.5.293 SHUFPS: Shuffle Packed Single-Precision FP Values

SHUFPS `xmm1, xmm2/m128, imm8 ; 0F C6 /r ib [KATMAI, SSE]`

SHUFPS moves two of the packed single-precision FP values from the destination operand into the low quadword of the destination operand; the upper quadword is generated by moving two of the single-precision FP values from the source operand into the destination. The select (third) operand selects which of the values are moved to the destination register.

The select operand is an 8-bit immediate: bits 0 and 1 select the value to be moved from the destination operand the low doubleword of the result, bits 2 and 3 select the value to be moved from the destination operand the second doubleword of the result, bits 4 and 5 select the value to be moved from the source operand the third doubleword of the result, and bits 6 and 7 select the value to be moved from the source operand to the high doubleword of the result.

A.5.294 SMI: System Management Interrupt

SMI ; F1 [386, UNDOC]

SMI puts some AMD processors into SMM mode. It is available on some 386 and 486 processors, and is only available when DR7 bit 12 is set, otherwise it generates an Int 1.

A.5.295 SMINT, SMINTOLD: Software SMM Entry (CYRIX)

SMINT ; 0F 38 [PENT, CYRIX]
SMINTOLD ; 0F 7E [486, CYRIX]

SMINT puts the processor into SMM mode. The CPU state information is saved in the SMM memory header, and then execution begins at the SMM base address.

SMINTOLD is the same as SMINT, but was the opcode used on the 486.

This pair of opcodes is specific to the Cyrix and compatible range of processors (Cyrix, IBM, Via).

A.5.296 SMSW: Store Machine Status Word

SMSW `r/m16 ; 0F 01 /4 [286, PRIV]`

SMSW stores the bottom half of the CR0 control register (or the Machine Status Word, on 286 processors) into the destination operand. See also LMSW (section A.5.139).

For 32-bit code, this would store all of CR0 in the specified register (or the bottom 16 bits if the destination is a memory location), without needing an operand size override byte.

A.5.297 SQRTPD: Packed Double-Precision FP Square Root

SQRTPD `xmm1, xmm2/m128 ; 66 0F 51 /r [WILLAMETTE, SSE2]`

SQRTPD calculates the square root of the packed double-precision FP value from the source operand, and stores the double-precision results in the destination register.

A.5.298 **SQRTPS: Packed Single-Precision FP Square Root**

SQRTPS *xmm1, xmm2/m128* ; 0F 51 /r [KATMAI, SSE]

SQRTPS calculates the square root of the packed single-precision FP value from the source operand, and stores the single-precision results in the destination register.

A.5.299 **SQRTSD: Scalar Double-Precision FP Square Root**

SQRTSD *xmm1, xmm2/m128* ; F2 0F 51 /r [WILLAMETTE, SSE2]

SQRTSD calculates the square root of the low-order double-precision FP value from the source operand, and stores the double-precision result in the destination register. The high-quadword remains unchanged.

A.5.300 **SQRTSS: Scalar Single-Precision FP Square Root**

SQRTSS *xmm1, xmm2/m128* ; F3 0F 51 /r [KATMAI, SSE]

SQRTSS calculates the square root of the low-order single-precision FP value from the source operand, and stores the single-precision result in the destination register. The three high doublewords remain unchanged.

A.5.301 **STC, STD, STI: Set Flags**

STC	; F9	[8086]
STD	; FD	[8086]
STI	; FB	[8086]

These instructions set various flags. STC sets the carry flag; STD sets the direction flag; and STI sets the interrupt flag (thus enabling interrupts).

To clear the carry, direction, or interrupt flags, use the CLC, CLD and CLI instructions (section A.5.20). To invert the carry flag, use CMC (section A.5.22).

A.5.302 **STMXCSR: Store Streaming SIMD Extension Control/Status**

STMXCSR *m32* ; 0F AE /3 [KATMAI, SSE]

STMXCSR stores the contents of the MXCSR control/status register to the specified memory location. MXCSR is used to enable masked/unmasked exception handling, to set rounding modes, to set flush-to-zero mode, and to view exception status flags. The reserved bits in the MXCSR register are stored as 0s.

For details of the MXCSR register, see the Intel processor docs.

See also LDMXCSR (section A.5.133).

A.5.303 **STOSB, STOSW, STOSD: Store Byte to String**

STOSB	; AA	[8086]
STOSW	; 016 AB	[8086]
STOSD	; 032 AB	[386]

STOSB stores the byte in AL at [ES:DI] or [ES:EDI], and sets the flags accordingly. It then increments or decrements (depending on the direction flag: increments if the flag is clear,

decrements if it is set) DI (or EDI).

The register used is DI if the address size is 16 bits, and EDI if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit a16 or a32 prefix.

Segment override prefixes have no effect for this instruction: the use of ES for the store to [DI] or [EDI] cannot be overridden.

STOSW and STOSD work in the same way, but they store the word in AX or the doubleword in EAX instead of the byte in AL, and increment or decrement the addressing registers by 2 or 4 instead of 1.

The REP prefix may be used to repeat the instruction CX (or ECX - again, the address size chooses which) times. The REP alias REPE, as well as the differently-encoded REPNE, are both allowed as well. They behave in the same way as REP.

A.5.303.1 Pseudo-code examples

a16 STOSB and with Direction Flag clear (UP) is equal to

```
MOV BYTE [ES:DI], AL
LEA DI, [DI + 1]
```

a16 REP STOSW and with Direction Flag clear (UP) is equal to

```
JCZX @FF
@@:
MOV WORD [ES:DI], AX
LEA DI, [DI + 2]
a16 LOOP @B
@@:
```

a32 STOSD with Direction Flag set (DN) is equal to

```
MOV DWORD [ES:EDI], EAX
LEA EDI, [EDI - 4]
```

A.5.304 STR: Store Task Register

```
STR r/m16 ; 0F 00 /1 [286, PRIV]
```

STR stores the segment selector corresponding to the contents of the Task Register into its operand. When the operand size is 32 bit and the destination is a register, the upper 16-bits are cleared to 0s. When the destination operand is a memory location, 16 bits are written regardless of the operand size.

A.5.305 SUB: Subtract Integers

```
SUB r/m8, reg8 ; 28 /r [8086]
SUB r/m16, reg16 ; 016 29 /r [8086]
SUB r/m32, reg32 ; 032 29 /r [386]

SUB reg8, r/m8 ; 2A /r [8086]
SUB reg16, r/m16 ; 016 2B /r [8086]
SUB reg32, r/m32 ; 032 2B /r [386]
```

SUB r/m8,imm8	; 80 /5 ib	[8086]
SUB r/m16,imm16	; 016 81 /5 iw	[8086]
SUB r/m32,imm32	; 032 81 /5 id	[386]
SUB r/m16,imm8	; 016 83 /5 ib	[8086]
SUB r/m32,imm8	; 032 83 /5 ib	[386]
SUB AL,imm8	; 2C ib	[8086]
SUB AX,imm16	; 016 2D iw	[8086]
SUB EAX,imm32	; 032 2D id	[386]

SUB performs integer subtraction: it subtracts its second operand from its first, and leaves the result in its destination (first) operand. The flags are set according to the result of the operation: in particular, the carry flag is affected and can be used by a subsequent SBB instruction (section A.5.285).

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The BYTE qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the STRICT WORD or STRICT DWORD qualifier.

The CMP (see section A.5.24) instruction performs the same operation as SUB but without writing to the destination operand. That is, it only reads the operands and writes the status flags.

A.5.306 SUBPD: Packed Double-Precision FP Subtract

SUBPD xmm1,xmm2/m128 ; 66 0F 5C /r [WILLAMETTE,SSE2]

SUBPD subtracts the packed double-precision FP values of the source operand from those of the destination operand, and stores the result in the destination operation.

A.5.307 SUBPS: Packed Single-Precision FP Subtract

SUBPS xmm1,xmm2/m128 ; 0F 5C /r [KATMAI,SSE]

SUBPS subtracts the packed single-precision FP values of the source operand from those of the destination operand, and stores the result in the destination operation.

A.5.308 SUBSD: Scalar Single-FP Subtract

SUBSD xmm1,xmm2/m128 ; F2 0F 5C /r [WILLAMETTE,SSE2]

SUBSD subtracts the low-order double-precision FP value of the source operand from that of the destination operand, and stores the result in the destination operation. The high quadword is unchanged.

A.5.309 SUBSS: Scalar Single-FP Subtract

SUBSS xmm1,xmm2/m128 ; F3 0F 5C /r [KATMAI,SSE]

SUBSS subtracts the low-order single-precision FP value of the source operand from that of the destination operand, and stores the result in the destination operation. The three high doublewords are unchanged.

A.5.310 **SVDC: Save Segment Register and Descriptor**

SVDC m80,segreg ; 0F 78 /r [486,CYRIX,SMM]

SVDC saves a segment register (DS, ES, FS, GS, or SS) and its descriptor to mem80.

A.5.311 **SVLDT: Save LDTR and Descriptor**

SVLDT m80 ; 0F 7A /0 [486,CYRIX,SMM]

SVLDT saves the Local Descriptor Table (LDTR) to mem80.

A.5.312 **SVTS: Save TSR and Descriptor**

SVTS m80 ; 0F 7C /0 [486,CYRIX,SMM]

SVTS saves the Task State Register (TSR) to mem80.

A.5.313 **SYSCALL: Call Operating System**

SYSCALL ; 0F 05 [P6,AMD]

SYSCALL provides a fast method of transferring control to a fixed entry point in an operating system.

- The EIP register is copied into the ECX register.
- Bits [31-0] of the 64-bit SYSCALL/SYSRET Target Address Register (STAR) are copied into the EIP register.
- Bits [47-32] of the STAR register specify the selector that is copied into the CS register.
- Bits [47-32]+1000b of the STAR register specify the selector that is copied into the SS register.

The CS and SS registers should not be modified by the operating system between the execution of the SYSCALL instruction and its corresponding SYSRET instruction.

For more information, see the SYSCALL and SYSRET Instruction Specification (AMD document number 21086.pdf).

A.5.314 **SYSENTER: Fast System Call**

SYSENTER ; 0F 34 [P6]

SYSENTER executes a fast call to a level 0 system procedure or routine. Before using this instruction, various MSRs need to be set up:

- SYSENTER_CS_MSR contains the 32-bit segment selector for the privilege level 0 code segment. (This value is also used to compute the segment selector of the privilege level 0 stack segment.)
- SYSENTER_EIP_MSR contains the 32-bit offset into the privilege level 0 code segment to the first instruction of the selected operating procedure or routine.
- SYSENTER_ESP_MSR contains the 32-bit stack pointer for the privilege level 0 stack.

SYSENTER performs the following sequence of operations:

- Loads the segment selector from the SYSENTER_CS_MSR into the CS register.
- Loads the instruction pointer from the SYSENTER_EIP_MSR into the EIP register.
- Adds 8 to the value in SYSENTER_CS_MSR and loads it into the SS register.
- Loads the stack pointer from the SYSENTER_ESP_MSR into the ESP register.
- Switches to privilege level 0.
- Clears the VM flag in the EFLAGS register, if the flag is set.
- Begins executing the selected system procedure.

In particular, note that this instruction does not save the values of CS or (E)IP. If you need to return to the calling code, you need to write your code to cater for this.

For more information, see the Intel Architecture Software Developer's Manual, Volume 2.

A.5.315 SYSEXIT: Fast Return From System Call

SYSEXIT ; 0F 35 [P6, PRIV]

SYSEXIT executes a fast return to privilege level 3 user code. This instruction is a companion instruction to the SYSENTER instruction, and can only be executed by privilege level 0 code. Various registers need to be set up before calling this instruction:

- SYSENTER_CS_MSR contains the 32-bit segment selector for the privilege level 0 code segment in which the processor is currently executing. (This value is used to compute the segment selectors for the privilege level 3 code and stack segments.)
- EDX contains the 32-bit offset into the privilege level 3 code segment to the first instruction to be executed in the user code.
- ECX contains the 32-bit stack pointer for the privilege level 3 stack.

SYSEXIT performs the following sequence of operations:

- Adds 16 to the value in SYSENTER_CS_MSR and loads the sum into the CS selector register.
- Loads the instruction pointer from the EDX register into the EIP register.
- Adds 24 to the value in SYSENTER_CS_MSR and loads the sum into the SS selector register.
- Loads the stack pointer from the ECX register into the ESP register.
- Switches to privilege level 3.
- Begins executing the user code at the EIP address.

For more information on the use of the SYSENTER and SYSEXIT instructions, see the Intel Architecture Software Developer's Manual, Volume 2.

A.5.316 **SYSRET: Return From Operating System**

SYSRET ; 0F 07 [P6,AMD,PRIV]

SYSRET is the return instruction used in conjunction with the SYSCALL instruction to provide fast entry/exit to an operating system.

- The ECX register, which points to the next sequential instruction after the corresponding SYSCALL instruction, is copied into the EIP register.
- Bits [63-48] of the STAR register specify the selector that is copied into the CS register.
- Bits [63-48]+1000b of the STAR register specify the selector that is copied into the SS register.
- Bits [1-0] of the SS register are set to 11b (RPL of 3) regardless of the value of bits [49-48] of the STAR register.

The CS and SS registers should not be modified by the operating system between the execution of the SYSCALL instruction and its corresponding SYSRET instruction.

For more information, see the SYSCALL and SYSRET Instruction Specification (AMD document number 21086.pdf).

A.5.317 **TEST: Test Bits (notional bitwise AND)**

```
TEST r/m8,reg8 ; 84 /r [8086]
TEST r/m16,reg16 ; 016 85 /r [8086]
TEST r/m32,reg32 ; 032 85 /r [386]

TEST r/m8,imm8 ; F6 /0 ib [8086]
TEST r/m16,imm16 ; 016 F7 /0 iw [8086]
TEST r/m32,imm32 ; 032 F7 /0 id [386]

TEST AL,imm8 ; A8 ib [8086]
TEST AX,imm16 ; 016 A9 iw [8086]
TEST EAX,imm32 ; 032 A9 id [386]
```

TEST performs a ‘mental’ bitwise AND of its two operands, and affects the flags as if the operation had taken place, but does not store the result of the operation anywhere. (For bitwise AND that does store the result, see section A.5.8.)

The Carry Flag is cleared by TEST. The Zero Flag is set according to whether the result is zero.

A.5.318 **UCOMISD: Unordered Scalar Double-Precision FP compare and set EFLAGS**

UCOMISD xmm1,xmm2/m128 ; 66 0F 2E /r [WILLAMETTE,SSE2]

UCOMISD compares the low-order double-precision FP numbers in the two operands, and sets the ZF, PF and CF bits in the EFLAGS register. In addition, the OF, SF and AF bits in the EFLAGS register are zeroed out. The unordered predicate (ZF, PF and CF all set) is returned if either source operand is a NaN (qNaN or sNaN).

A.5.319 UCOMISS: Unordered Scalar Single-Precision FP compare and set EFLAGS

UCOMISS *xmm1*, *xmm2/m128* ; 0F 2E /r [KATMAI, SSE]

UCOMISS compares the low-order single-precision FP numbers in the two operands, and sets the ZF, PF and CF bits in the EFLAGS register. In addition, the OF, SF and AF bits in the EFLAGS register are zeroed out. The unordered predicate (ZF, PF and CF all set) is returned if either source operand is a NaN (qNaN or sNaN).

A.5.320 UD0, UD1, UD2: Undefined Instruction

UD0 ; 0F FF [186, UNDOC]
UD1 ; 0F B9 [186, UNDOC]
UD2 ; 0F 0B [186]

UDx can be used to generate an invalid opcode exception, for testing purposes.

UD0 is specifically documented by AMD as being reserved for this purpose.

UD1 is documented by Intel as being available for this purpose.

UD2 is specifically documented by Intel as being reserved for this purpose. Intel document this as the preferred method of generating an invalid opcode exception.

All these opcodes can be used to generate invalid opcode exceptions on all currently available processors.

A.5.321 UMOV: User Move Data

UMOV *r/m8*, *reg8* ; 0F 10 /r [386, UNDOC]
UMOV *r/m16*, *reg16* ; 016 0F 11 /r [386, UNDOC]
UMOV *r/m32*, *reg32* ; 032 0F 11 /r [386, UNDOC]

UMOV *reg8*, *r/m8* ; 0F 12 /r [386, UNDOC]
UMOV *reg16*, *r/m16* ; 016 0F 13 /r [386, UNDOC]
UMOV *reg32*, *r/m32* ; 032 0F 13 /r [386, UNDOC]

This undocumented instruction is used by in-circuit emulators to access user memory (as opposed to host memory). It is used just like an ordinary memory/register or register/register MOV instruction, but accesses user space.

This instruction is only available on some AMD and IBM 386 and 486 processors.

A.5.322 UNPCKHPD: Unpack and Interleave High Packed Double-Precision FP Values

UNPCKHPD *xmm1*, *xmm2/m128* ; 66 0F 15 /r [WILLAMETTE, SSE2]

UNPCKHPD performs an interleaved unpack of the high-order data elements of the source and destination operands, saving the result in *xmm1*. It ignores the lower half of the sources.

The operation of this instruction is:

```
dst[63-0] := dst[127-64];
dst[127-64] := src[127-64].
```

A.5.323 UNPCKHPS: Unpack and Interleave High Packed Single-Precision FP Values

```
UNPCKHPS xmm1,xmm2/m128 ; 0F 15 /r [KATMAI,SSE]
```

UNPCKHPS performs an interleaved unpack of the high-order data elements of the source and destination operands, saving the result in `xmm1`. It ignores the lower half of the sources.

The operation of this instruction is:

```
dst[31-0] := dst[95-64];
dst[63-32] := src[95-64];
dst[95-64] := dst[127-96];
dst[127-96] := src[127-96].
```

A.5.324 UNPCKLPD: Unpack and Interleave Low Packed Double-Precision FP Data

```
UNPCKLPD xmm1,xmm2/m128 ; 66 0F 14 /r [WILLAMETTE,SSE2]
```

UNPCKLPD performs an interleaved unpack of the low-order data elements of the source and destination operands, saving the result in `xmm1`. It ignores the lower half of the sources.

The operation of this instruction is:

```
dst[63-0] := dst[63-0];
dst[127-64] := src[63-0].
```

A.5.325 UNPCKLPS: Unpack and Interleave Low Packed Single-Precision FP Data

```
UNPCKLPS xmm1,xmm2/m128 ; 0F 14 /r [KATMAI,SSE]
```

UNPCKLPS performs an interleaved unpack of the low-order data elements of the source and destination operands, saving the result in `xmm1`. It ignores the lower half of the sources.

The operation of this instruction is:

```
dst[31-0] := dst[31-0];
dst[63-32] := src[31-0];
dst[95-64] := dst[63-32];
dst[127-96] := src[63-32].
```

A.5.326 VERR, VERW: Verify Segment Readability/Writability

```
VERR r/m16 ; 0F 00 /4 [286,PRIV]
```

```
VERW r/m16 ; 0F 00 /5 [286,PRIV]
```

- VERR sets the zero flag if the segment specified by the selector in its operand can be read from at the current privilege level. Otherwise it is cleared.
- VERW sets the zero flag if the segment can be written.

A.5.327 WAIT: Wait for Floating-Point Processor

WAIT ; 9B [8086]
FWAIT ; 9B [8086]

WAIT, on 8086 systems with a separate 8087 FPU, waits for the FPU to have finished any operation it is engaged in before continuing main processor operations, so that (for example) an FPU store to main memory can be guaranteed to have completed before the CPU tries to read the result back out.

On higher processors, WAIT is unnecessary for this purpose, and it has the alternative purpose of ensuring that any pending unmasked FPU exceptions have happened before execution continues.

A.5.328 WBINVD: Write Back and Invalidate Cache

WBINVD ; 0F 09 [486]

WBINVD invalidates and empties the processor's internal caches, and causes the processor to instruct external caches to do the same. It writes the contents of the caches back to memory first, so no data is lost. To flush the caches quickly without bothering to write the data back first, use INVD (section A.5.125).

A.5.329 WRMSR: Write Model-Specific Registers

WRMSR ; 0F 30 [PENT]

WRMSR writes the value in EDX:EAX to the processor Model-Specific Register (MSR) whose index is stored in ECX. See also RDMSR (section A.5.270).

A.5.330 WRSHR: Write SMM Header Pointer Register

WRSHR r/m32 ; 0F 37 /0 [386, CYRIX, SMM]

WRSHR loads the contents of either a 32-bit memory location or a 32-bit register into the SMM header pointer register.

See also RDSHR (section A.5.272).

A.5.331 XADD: Exchange and Add

XADD r/m8, reg8 ; 0F C0 /r [486]
XADD r/m16, reg16 ; 016 0F C1 /r [486]
XADD r/m32, reg32 ; 032 0F C1 /r [486]

XADD exchanges the values in its two operands, and then adds them together and writes the result into the destination (first) operand. This instruction can be used with a LOCK prefix for multi-processor synchronisation purposes.

A.5.332 XBTS: Extract Bit String

XBTS reg16, r/m16 ; 016 0F A6 /r [386, UNDOC]
XBTS reg32, r/m32 ; 032 0F A6 /r [386, UNDOC]

The implied operation of this instruction is:

```
XBTS r/m16,reg16,AX,CL
XBTS r/m32,reg32,EAX,CL
```

Writes a bit string from the source operand to the destination. CL indicates the number of bits to be copied, and (E)AX indicates the low order bit offset in the source. The bits are written to the low order bits of the destination register. For example, if CL is set to 4 and AX (for 16-bit code) is set to 5, bits 5-8 of src will be copied to bits 0-3 of dst. This instruction is very poorly documented, and I have been unable to find any official source of documentation on it.

XBTS is supported only on the early Intel 386s, and conflicts with the opcodes for CMPXCHG486 (on early Intel 486s). NASM supports it only for completeness. Its counterpart is IBTS (see section A.5.116).

A.5.333 XCHG: Exchange

```
XCHG reg8,r/m8           ; 86 /r           [8086]
XCHG reg16,r/m8          ; 016 87 /r          [8086]
XCHG reg32,r/m32         ; 032 87 /r          [386]

XCHG r/m8,reg8           ; 86 /r           [8086]
XCHG r/m16,reg16         ; 016 87 /r          [8086]
XCHG r/m32,reg32         ; 032 87 /r          [386]

XCHG AX,reg16            ; 016 90+r          [8086]
XCHG EAX,reg32           ; 032 90+r          [386]
XCHG reg16,AX            ; 016 90+r          [8086]
XCHG reg32,EAX           ; 032 90+r          [386]
```

XCHG exchanges the values in its two operands. It can be used with a LOCK prefix for purposes of multi-processor synchronisation.

XCHG AX,AX or XCHG EAX,EAX (depending on the BITS setting) generates the opcode 90h, and so is a synonym for NOP (section A.5.190).

A.5.334 XLATB: Translate Byte in Lookup Table

```
XLAT           ; D7           [8086]
XLATB          ; D7           [8086]
```

XLATB adds the value in AL, treated as an unsigned byte, to BX or EBX, and loads the byte from the resulting address (in the segment specified by DS) back into AL.

The base register used is BX if the address size is 16 bits, and EBX if it is 32 bits. If you need to use an address size not equal to the current BITS setting, you can use an explicit a16 or a32 prefix.

The segment register used to load from [BX+AL] or [EBX+AL] can be overridden by using a segment register name as a prefix (for example, ES XLATB).

A.5.335 XOR: Bitwise Exclusive OR

```
XOR r/m8,reg8           ; 30 /r           [8086]
XOR r/m16,reg16         ; 016 31 /r          [8086]
XOR r/m32,reg32         ; 032 31 /r          [386]
```

XOR reg8,r/m8	; 32 /r	[8086]
XOR reg16,r/m16	; o16 33 /r	[8086]
XOR reg32,r/m32	; o32 33 /r	[386]
XOR r/m8,imm8	; 80 /6 ib	[8086]
XOR r/m16,imm16	; o16 81 /6 iw	[8086]
XOR r/m32,imm32	; o32 81 /6 id	[386]
XOR r/m16,imm8	; o16 83 /6 ib	[8086]
XOR r/m32,imm8	; o32 83 /6 ib	[386]
XOR AL,imm8	; 34 ib	[8086]
XOR AX,imm16	; o16 35 iw	[8086]
XOR EAX,imm32	; o32 35 id	[386]

XOR performs a bitwise XOR operation between its two operands (i.e. each bit of the result is 1 if and only if exactly one of the corresponding bits of the two inputs was 1), and stores the result in the destination (first) operand.

In the forms with an 8-bit immediate second operand and a longer first operand, the second operand is considered to be signed, and is sign-extended to the length of the first operand. The `BYTE` qualifier can be used to force NASM to generate this form of the instruction. Recent versions of NASM automatically optimise to this form if the immediate operand's value is known during the assembling of that instruction, and fits in the range of a signed byte. The longer variant can then still be forced using the `STRICT WORD` or `STRICT DWORD` qualifier.

The Carry Flag is cleared by XOR. The Zero Flag is set according to whether the result is zero.

The MMX instruction `PXOR` (see section A.5.266) performs the same operation on the 64-bit MMX registers.

A.5.336 XORPD: Bitwise Logical XOR of Double-Precision FP Values

XORPD xmm1,xmm2/m128	; 66 0F 57 /r	[WILLAMETTE,SSE2]
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XORPD returns a bit-wise logical XOR between the source and destination operands, storing the result in the destination operand.

A.5.337 XORPS: Bitwise Logical XOR of Single-Precision FP Values

XORPS xmm1,xmm2/m128	; 0F 57 /r	[KATMAI,SSE]
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XORPS returns a bit-wise logical XOR between the source and destination operands, storing the result in the destination operand.

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