

## 4. Instruction tables

**Lists of instruction latencies, throughputs and micro-operation breakdowns for Intel, AMD and VIA CPUs**

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### Introduction

This is the fourth in a series of five manuals:

1. Optimizing software in C++: An optimization guide for Windows, Linux and Mac platforms.
2. Optimizing subroutines in assembly language: An optimization guide for x86 platforms.
3. The microarchitecture of Intel, AMD and VIA CPUs: An optimization guide for assembly programmers and compiler makers.
4. Instruction tables: Lists of instruction latencies, throughputs and micro-operation breakdowns for Intel, AMD and VIA CPUs.
5. Calling conventions for different C++ compilers and operating systems.

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The present manual contains tables of instruction latencies, throughputs and micro-operation breakdown and other tables for x86 family microprocessors from Intel, AMD and VIA.

The figures in the instruction tables represent the results of my measurements rather than the official values published by microprocessor vendors. Some values in my tables are higher or lower than the values published elsewhere. The discrepancies can be explained by the following factors:

- My figures are experimental values while figures published by microprocessor vendors may be based on theory or simulations.
- My figures are obtained with a particular test method under particular conditions. It is possible that different values can be obtained under other conditions.
- Some latencies are difficult or impossible to measure accurately, especially for memory access and type conversions that cannot be chained.
- Latencies for moving data from one execution unit to another are listed explicitly in some of my tables while they are included in the general latencies in some tables published by Intel.

Most values are the same in all microprocessor modes (real, virtual, protected, 16-bit, 32-bit, 64-bit). Values for far calls and interrupts may be different in different modes. Call gates have not been tested.

Instructions with a LOCK prefix have a long latency that depends on cache organization and possibly RAM speed. If there are multiple processors or cores or direct memory access (DMA) devices then all locked instructions will lock a cache line for exclusive access, which may involve RAM access. A LOCK prefix typically costs more than a hundred clock cycles, even on single-processor systems. This also applies to the XCHG instruction with a memory operand.

If any text in the pdf version of this manual is unreadable, then please refer to the spreadsheet version.

### Copyright notice

## Introduction

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## Definition of terms

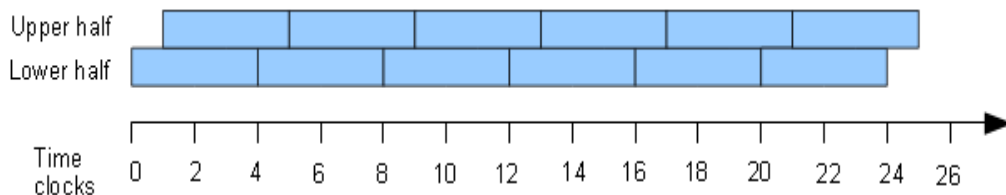
### Definition of terms

**Instruction** The instruction name is the assembly code for the instruction. Multiple instructions or multiple variants of the same instruction may be joined into the same line. Instructions with and without a 'v' prefix to the name have the same values unless otherwise noted.

**Operands** Operands can be different types of registers, memory, or immediate constants. Abbreviations used in the tables are: i = immediate constant, r = any general purpose register, r32 = 32-bit register, etc., mm = 64 bit mmx register, x or xmm = 128 bit xmm register, y = 256 bit ymm register, z = 512 bit zmm register, v = any vector register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.

**Latency** The latency of an instruction is the delay that the instruction generates in a dependency chain. The measurement unit is clock cycles. Where the clock frequency is varied dynamically, the figures refer to the core clock frequency. The numbers listed are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity may increase the latencies by possibly more than 100 clock cycles on many processors, except in move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results may give a similar delay. A missing value in the table means that the value has not been measured or that it cannot be measured in a meaningful way.

Some processors have a pipelined execution unit that is smaller than the largest register size so that different parts of the operand are calculated at different times. Assume, for example, that we have a long dependency chain of 128-bit vector instructions running in a fully pipelined 64-bit execution unit with a latency of 4. The lower 64 bits of each operation will be calculated at times 0, 4, 8, 12, 16, etc. And the upper 64 bits of each operation will be calculated at times 1, 5, 9, 13, 17, etc. as shown in the figure below. If we look at one 128-bit instruction in isolation, the latency will be 5. But if we look at a long chain of 128-bit instructions, the total latency will be 4 clock cycles per instruction plus one extra clock cycle in the end. The latency in this case is listed as 4 in the tables because this is the value it adds to a dependency chain.



### Reciprocal throughput

The throughput is the maximum number of instructions of the same kind that can be executed per clock cycle when the operands of each instruction are independent of the preceding instructions. The values listed are the reciprocals of the throughputs, i.e. the average number of clock cycles per instruction when the instructions are not part of a limiting dependency chain. For example, a reciprocal throughput of 2 for FMUL means that a new FMUL instruction can start executing 2 clock cycles after a previous FMUL. A reciprocal throughput of 0.33 for ADD means that the execution units can handle 3 integer additions per clock cycle.

The reason for listing the reciprocal values is that this makes comparisons between latency and throughput easier. The reciprocal throughput is also called issue latency.

## Definition of terms

The values listed are for a single thread or a single core. A missing value in the table means that the value has not been measured.

**μops** Uop or μop is an abbreviation for micro-operation. Processors with out-of-order cores are capable of splitting complex instructions into μops. For example, a read-modify instruction may be split into a read-μop and a modify-μop. The number of μops that an instruction generates is important when certain bottlenecks in the pipeline limit the number of μops per clock cycle.

**Execution unit** The execution core of a microprocessor has several execution units. Each execution unit can handle a particular category of μops, for example floating point additions. The information about which execution unit a particular μop goes to can be useful for two purposes. Firstly, two μops cannot execute simultaneously if they need the same execution unit. And secondly, some processors have a latency of an extra clock cycle when the result of a μop executing in one execution unit is needed as input for a μop in another execution unit.

**Execution port** The execution units are clustered around a few execution ports on most Intel processors. Each μop passes through an execution port to get to the right execution unit. An execution port can be a bottleneck because it can handle only one μop at a time. Two μops cannot execute simultaneously if they need the same execution port, even if they are going to different execution units.

**Instruction set** This indicates which instruction set an instruction belongs to. The instruction is only available in processors that support this instruction set. The different instruction sets are listed at the end of this manual. Availability in processors prior to 80386 does not apply for 32-bit and 64-bit operands. Availability in the MMX instruction set does not apply to 128-bit packed integer instructions, which require SSE2. Availability in the SSE instruction set does not apply to double precision floating point instructions, which require SSE2.

32-bit instructions are available in 80386 and later. 64-bit instructions in general purpose registers are available only under 64-bit operating systems. Instructions that use XMM registers (SSE and later) are only available under operating systems that support this register set. Instructions that use YMM registers (AVX and later) are only available under operating systems that support this register set.

## How the values were measured

The values in the tables are measured with the use of my own test programs, which are available from [www.agner.org/optimize/testp.zip](http://www.agner.org/optimize/testp.zip)

The time unit for all measurements is CPU clock cycles. It is attempted to obtain the highest clock frequency if the clock frequency is varying with the workload. Many Intel processors have a performance counter named "core clock cycles". This counter gives measurements that are independent of the varying clock frequency. Where no "core clock cycles" counter is available, the "time stamp counter" is used (RDTSC instruction). In cases where this gives inconsistent results (e.g. in AMD Bobcat) it is necessary to make the processor boost the clock frequency by executing a large number of instructions (> 1 million) or turn off the power-saving feature in the BIOS setup.

Instruction throughputs are measured with a long sequence of instructions of the same kind, where subsequent instructions use different registers in order to avoid dependence of each instruction on the previous one. The input registers are cleared in the cases where it is impossible to use different registers. The test code is carefully constructed in each case to make sure that no other bottleneck is limiting the throughput than the one that is being measured.

Instruction latencies are measured in a long dependency chain of identical instructions where the output of each instruction is needed as input for the next instruction.

## Definition of terms

The sequence of instructions should be long, but not so long that it doesn't fit into the level-1 code cache. A typical length is 100 instructions of the same type. This sequence is repeated in a loop if a larger number of instructions is desired.

It is not possible to measure the latency of a memory read or write instruction with software methods. It is only possible to measure the combined latency of a memory write followed by a memory read from the same address. What is measured here is not actually the cache access time, because in most cases the microprocessor is smart enough to make a "store forwarding" directly from the write unit to the read unit rather than waiting for the data to go to the cache and back again. The latency of this store forwarding process is arbitrarily divided into a write latency and a read latency in the tables. But in fact, the only value that makes sense to performance optimization is the sum of the write time and the read time.

A similar problem occurs where the input and the output of an instruction use different types of registers. For example, the MOVD instruction can transfer data between general purpose registers and XMM vector registers. The value that can be measured is the combined latency of data transfer from one type of registers to another type and back again ( $A \rightarrow B \rightarrow A$ ). The division of this latency between the  $A \rightarrow B$  latency and the  $B \rightarrow A$  latency is sometimes obvious, sometimes based on guesswork,  $\mu\text{op}$  counts, indirect evidence, or triangular sequences such as  $A \rightarrow B \rightarrow \text{Memory} \rightarrow A$ . In many cases, however, the division of the total latency between  $A \rightarrow B$  latency and  $B \rightarrow A$  latency is arbitrary. However, what cannot be measured cannot matter for performance optimization. What counts is the sum of the  $A \rightarrow B$  latency and the  $B \rightarrow A$  latency, not the individual terms.

The  $\mu\text{op}$  counts are usually measured with the use of the performance monitor counters (PMCs) that are built into modern microprocessors. The PMCs for VIA processors are undocumented, and the interpretation of these PMCs is based on experimentation.

The execution ports and execution units that are used by each instruction or  $\mu\text{op}$  are detected in different ways depending on the particular microprocessor. Some microprocessors have PMCs that can give this information directly. In other cases it is necessary to obtain this information indirectly by testing whether a particular instruction or  $\mu\text{op}$  can execute simultaneously with another instruction/ $\mu\text{op}$  that is known to go to a particular execution port or execution unit. On some processors, there is a delay for transmitting data from one execution unit (or cluster of execution units) to another. This delay can be used for detecting whether two different instructions/ $\mu\text{ops}$  are using the same or different execution units.

## Instruction sets

### Explanation of instruction sets for x86 processors

x86	This is the name of the common instruction set, supported by all processors in this lineage.
80186	This is the first extension to the x86 instruction set. New integer instructions: PUSH i, PUSHA, POPA, IMUL r,r,i, BOUND, ENTER, LEAVE, shifts and rotates by immediate ≠ 1.
80286	System instructions for 16-bit protected mode.
80386	The eight general purpose registers are extended from 16 to 32 bits. 32-bit addressing. 32-bit protected mode. Scaled index addressing. MOVZX, MOVSX, IMUL r,r, SHLD, SHRD, BT, BTR, BTS, BTC, BSF, BSR, SETcc.
80486	BSWAP. Later versions have CPUID.
x87	This is the floating point instruction set. Supported when a 8087 or later coprocessor is present. Some 486 processors and all processors since Pentium/K5 have built-in support for floating point instructions without the need for a coprocessor.
80287	FSTSW AX
80387	FPREM1, FSIN, FCOS, FSINCOS.
Pentium	RDTSC, RDPMSR.
PPro	Conditional move (CMOV, FCMOV) and fast floating point compare (FCOMI) instructions introduced in Pentium Pro. These instructions are not supported in Pentium MMX, but are supported in all processors with SSE and later.
MMX	Integer vector instructions with packed 8, 16 and 32-bit integers in the 64-bit MMX registers MM0 - MM7, which are aliased upon the floating point stack registers ST(0) - ST(7).
SSE	Single precision floating point scalar and vector instructions in the new 128-bit XMM registers XMM0 - XMM7. PREFETCH, SFENCE, FXSAVE, FXRSTOR, MOVNTQ, MOVNTPS. The use of XMM registers requires operating system support.
SSE2	Double precision floating point scalar and vector instructions in the 128-bit XMM registers XMM0 - XMM7. 64-bit integer arithmetics in the MMX registers. Integer vector instructions with packed 8, 16, 32 and 64-bit integers in the XMM registers. MOVNTPD, MOVNTPS, PAUSE, LFENCE, MFENCE.
SSE3	FISTTP, LDDQU, MOVDDUP, MOVSHDUP, MOVSLDUP, ADDSUBPS, ADDSUSPPD, HADDPS, HADDPD, HSUBPS, HSUBPD.
SSSE3	(Supplementary SSE3): PSHUFB, PHADDW, PHADDSW, PHADDD, PMADDUBSW, PHSUBW, PHSUBSW, PHSUBD, PSIGNB, PSIGNW, PSIGND, PMULHRWSW, PABSB, PABSW, PABSD, PALIGNR.
64 bit	This instruction set is called x86-64, x64, AMD64 or EM64T. It defines a new 64-bit mode with 64-bit addressing and the following extensions: The general purpose registers are extended to 64 bits, and the number of general purpose registers is extended from eight to sixteen. The number of XMM registers is also extended from eight to sixteen, but the number of MMX and ST registers is still eight. Data can be addressed relative to the instruction pointer. There is no way to get access to these extensions in 32-bit mode  Most instructions that involve segmentation are not available in 64 bit mode. Direct far jumps and calls are not allowed, but indirect far jumps, indirect far calls and far returns are allowed. These are used in system code for switching mode. Segment registers DS, ES, and SS cannot be used. The FS and GS segments and segment prefixes are available in 64 bit mode and are used for addressing thread environment blocks and processor environment blocks

## Instruction sets

Instructions not available in 64 bit mode	<p>The following instructions are not available in 64-bit mode: PUSHA, POPA, BOUND, INTO, BCD instructions: AAA, AAS, DAA, DAS, AAD, AAM, undocumented instructions (SALC, ICEBP, 82H alias for 80H opcode), SYSENTER, SYSEXIT, ARPL. On some early Intel processors, LAHF and SAHF are not available in 64 bit mode. Increment and decrement register instructions cannot be coded in the short one-byte opcode form because these codes have been reassigned as REX prefixes.</p> <p>Most instructions that involve segmentation are not available in 64 bit mode. Direct far jumps and calls are not allowed, but indirect far jumps, indirect far calls and far returns are allowed. These are used in system code for switching mode. <a href="#">PUSH CS</a>, <a href="#">PUSH DS</a>, <a href="#">PUSH ES</a>, <a href="#">PUSH SS</a>, <a href="#">POP DS</a>, <a href="#">POP ES</a>, <a href="#">POP SS</a>, <a href="#">LDS</a> and <a href="#">LES</a> instructions are not allowed. <a href="#">CS</a>, <a href="#">DS</a>, <a href="#">ES</a> and <a href="#">SS</a> prefixes are allowed but ignored. The <a href="#">FS</a> and <a href="#">GS</a> segments and segment prefixes are available in 64 bit mode and are used for addressing thread environment blocks and processor environment blocks.</p>
Monitor	The instructions MONITOR and MWAIT are available in some Intel and AMD multiprocessor CPUs with SSE3
SSE4.1	MPSADBW, PHMINPOSUW, PMULDQ, PMULLD, DPPS, DPPD, BLEND..., PMIN..., PMAX..., ROUND..., INSERT..., EXTRACT..., PMOVX..., PMOVZX..., PTEST, PCMPEQQ, PACKUSDW, MOVNTDQA
SSE4.2	CRC32, PCMPESTRI, PCMPESTRM, PCMPISTRI, PCMPISTRM, PCMPGTQ, POPCNT.
AES	AESDEC, AESDECLAST, AESENC, AESENCLAST, AESIMC, AESKEYGENASSIST.
CLMUL	PCLMULQDQ.
AVX	The 128-bit XMM registers are extended to 256-bit YMM registers with room for further extension in the future. The use of YMM registers requires operating system support. Floating point vector instructions are available in 256-bit versions. Almost all previous XMM instructions now have two versions: with and without zero-extension into the full YMM register. The zero-extension versions have three operands in most cases. Furthermore, the following instructions are added in AVX: VBROADCASTSS, VBROADCASTSD, VEXTRACTF128, VINSERTF128, VLDMXCSR, VMASKMOVPS, VMASKMOVPD, VPERMILPD, VPERMIL2PD, VPERMILPS, VPERMIL2PS, VPERM2F128, VSTMXCSR, VZEROALL, VZERoupper.
AVX2	Integer vector instructions are available in 256-bit versions. Furthermore, the following instructions are added in AVX2: ANDN, BEXTR, BLSI, BLSMSK, BLSR, BZHI, INVPCID, LZCNT, MULX, PEXT, PDEP, RORX, SARX, SHLX, SHRX, TZCNT, VBROADCASTI128, VBROADCASTSS, VBROADCASTSD, VEXTRACTI128, VGATHERDPD, VGATHERQPD, VGATHERDPS, VGATHERQPS, VPGATHERDD, VPGATHERQD, VPGATHERDQ, VPGATHERQQ, VINSERTI128, VPERM2I128, VPERMD, VPERMPD, VPERMPS, VPERMQ, VPMASKMOVD, VPMASKMOVQ, VPSLLVD, VPSLLVQ, VPSRAVD, VPSRLVD, VPSRLVQ.
FMA3	(FMA): Fused multiply and add instructions: VFMADDxxxPD, VFMADDxxxPS, VFMADDxxxSD, VFMADDxxxSS, VFMA DDSUBxxxPD, VFMA DDSUBxxxPS, VFMSUBADDxxxPD, VFMSUBADDxxxPS, VFMSUBxxxPD, VFMSUBxxxPS, VFMSUBxxxSD, VFMSUBxxxSS, VFNMADDxxxPD, VFNMADDxxxPS, VFNMADDxxxSD, VFNMADDxxxSS, VFNMSUBxxxPD, VFNMSUBxxxPS, VFNMSUBxxxSD, VFNMSUBxxxSS.
FMA4	Same as Intel FMA, but with 4 different operands according to a preliminary Intel specification which is now supported only by AMD. Intel's FMA specification has later been changed to FMA3, which is now also supported by AMD.
MOVBE	MOVBE

## Instruction sets

POPCNT	POPCNT
PCLMUL	PCLMULQDQ
XSAVE	
XSAVEOPT	
RDRAND	RDRAND
RDSEED	RDSEED
BMI1	ANDN, BEXTR, BLSI, BLSMSK, BLSR, LZCNT, TXCNT
BMI2	BZHI, MULX, PDEP, PEXT, RORX, SARX, SHRX, SHLX
ADX	ADCX, ADOX, CLAC
AVX512F	The 256-bit YMM registers are extended to 512-bit ZMM registers. The number of vector registers is extended to 32 in 64-bit mode, while there are still only 8 vector registers in 32-bit mode. 8 new vector mask registers k0 – k7. Masked vector instructions. Many new instructions. Single- and double precision floating point vectors are always supported. Other instructions are supported if the various optional AVX512 variants, listed below, are supported as well.
AVX512BW	Vectors of 8-bit and 16-bit integers in ZMM registers.
AVX512DQ	Vectors of 32-bit and 64-bit integers in ZMM registers.
AVX512VL	The vector operations defined for 512-bit vectors in the various AVX512 subsets, including masked operations, can be applied to 128-bit and 256-bit vectors as well.
AVX512CD	Conflict detection instructions
AVX512ER	Approximate exponential function, reciprocal and reciprocal square root
AVX512PF	Gather and scatter prefetch
SHA	Secure hash algorithm
MPX	Memory protection extensions
SMAP	CLAC, STAC
CVT16	VCVTPH2PS, VCVTPS2PH.
3DNow	(AMD only. Obsolete). Single precision floating point vector instructions in the 64-bit MMX registers. Only available on AMD processors. The 3DNow instructions are: FEMMS, PAVGUSB, PF2ID, PFACC, PFADD, PFCMPEQ/GT/GE, PFMAX, PFMIN, PFRCP/IT1/IT2, PFRSQRT/IT1, PFSUB, PFSUBR, PI2FD, PMULHRW, PREFETCH/W.
3DNowE	(AMD only. Obsolete). PF2IW, PFNACC, PFPNACC, PI2FW, PSWAPD.
PREFETCHW	This instruction has survived from 3DNow and now has its own feature name
PREFETCHWT1	PREFETCHWT1
SSE4A	(AMD only). EXTRQ, INSERTQ, LZCNT, MOVNTSD, MOVNTSS, POPCNT. (POPCNT shared with Intel SSE4.2).
XOP	(AMD only). VFRCZPD, VFRCZPS, VFRCZSD, VFRCZSS, VPCMOV, VPCOMB, VPCOMD, VPCOMQ, PCOMW, VPCOMUB, VPCOMUD, VPCOMUQ, VPCOMUW, VPHADDBD, VPHADDBQ, VPHADDBW, VPHADDDQ, VPHADDUBD, VPHADDUBQ, VPHADDUBW, VPHADDUDQ, VPHADDUWD, VPHADDUWQ, VPHADDWD, VPHADDWQ, VPHSUBBW, VPHSUBDQ, VPHSUBWD, VPMACSDQ, VPMACSDQH, VPMACSDQL, VPMACSSDD, VPMACSSDQH, VPMACSSDQL, VPMACSSWD, VPMACSSWW, VPMACSWD, VPMACSWW, VPMADCSWD, VPMADCSWW, VPPER, VPROTB, VPROTD, VPROTQ, VPROTW, VPSHAB, VPSHAD, VPSHAQ, VPSHAW, VPSHLB, VPSHLD, VPSHLQ, VPSHLW.



## Microprocessor versions tested

The tables in this manual are based on testing of the following microprocessors

Processor name	Microarchitecture Code name	Family number (hex)	Model number (hex)	Comment
AMD K7 Athlon		6	6	Step. 2, rev. A5
AMD K8 Opteron		F	5	Stepping A
AMD K10 Opteron		10	2	2350, step. 1
AMD Bulldozer	Bulldozer, Zambezi	15	1	FX-6100, step 2
AMD Piledriver	Piledriver	15	2	FX-8350, step 0. And others
AMD Steamroller	Steamroller, Kaveri	15	30	A10-7850K, step 1
AMD Ryzen	Zen	17	1	Ryzen 7 1800X, step 1
AMD Bobcat	Bobcat	14	1	E350, step. 0
AMD Kabini	Jaguar	16	0	A4-5000, step 1
Intel Pentium	P5	5	2	
Intel Pentium MMX	P5	5	4	Stepping 4
Intel Pentium II	P6	6	6	
Intel Pentium III	P6	6	7	
Intel Pentium 4	Netburst	F	2	Stepping 4, rev. B0
Intel Pentium 4 EM64T	Netburst, Prescott	F	4	Xeon. Stepping 1
Intel Pentium M	Dothan	6	D	Stepping 6, rev. B1
Intel Core Duo	Yonah	6	E	Not fully tested
Intel Core 2 (65 nm)	Merom	6	F	T5500, Step. 6, rev. B2
Intel Core 2 (45 nm)	Wolfdale	6	17	E8400, Step. 6
Intel Core i7	Nehalem	6	1A	i7-920, Step. 5, rev. D0
Intel 2nd gen. Core	Sandy Bridge	6	2A	i5-2500, Step 7
Intel 3rd gen. Core	Ivy Bridge	6	3A	i7-3770K, Step 9
Intel 4th gen. Core	Haswell	6	3C	i7-4770K, step. 3
Intel 5th gen. Core	Broadwell	6	56	D1540, step 2
Intel 6th gen. Core	Skylake	6	5E	Step. 3
Intel Atom 330	Diamondville	6	1C	Step. 2
Intel Bay Trail	Silvermont	6	37	Step. 3
Intel Apollo Lake	Goldmont	6	5C	Step. 9
Intel Xeon Phi	Knights Landing	6	57	Step. 1
VIA Nano L2200		6	F	Step. 2
VIA Nano L3050	Isaiah	6	F	Step. 8 (prerelease sample)

**AMD K7****List of instruction timings and macro-operation breakdown***Explanation of column headings:*

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency listed does not include the memory operand where the operand is listed as register or memory (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution unit:</b>	Indicates which execution unit is used for the macro-operations. ALU means any of the three integer ALU's. ALU0_1 means that ALU0 and ALU1 are both used. AGU means any of the three integer address generation units. FADD means floating point adder unit. FMUL means floating point multiplier unit. FMISC means floating point store and miscellaneous unit. FA/M means FADD or FMUL is used. FANY means any of the three floating point units can be used. Two macro-operations can execute simultaneously if they go to different execution units.

**Integer instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	1/3	ALU	
MOV	r,i	1	1	1/3	ALU	
MOV	r8,m8	1	4	1/2	ALU, AGU	Any addr. mode. Add 1 clk if code segment base ≠ 0
MOV	r16,m16	1	4	1/2	ALU, AGU	do.
MOV	r32,m32	1	3	1/2	AGU	do.
MOV	m8,r8H	1	8	1/2	AGU	AH, BH, CH, DH
MOV	m8,r8L	1	2	1/2	AGU	Any other 8-bit register
MOV	m16/32,r	1	2	1/2	AGU	Any addressing mode
MOV	m,i	1	2	1/2	AGU	
MOV	r,sr	1	2	1		

AMD K7

MOV	sr,r/m	6	9-13	8		
MOVZX, MOVSX	r,r	1	1	1/3	ALU	
MOVZX, MOVSX	r,m	1	4	1/2	ALU, AGU	
CMOVcc	r,r	1	1	1/3	ALU	
CMOVcc	r,m	1		1/2	ALU, AGU	
XCHG	r,r	3	2	1	ALU	
XCHG	r,m	3	16	16	ALU, AGU	Timing depends on hw
XLAT		2	5		ALU, AGU	
PUSH	r	1		1	ALU, AGU	
PUSH	i	1		1	ALU, AGU	
PUSH	m	2		1	ALU, AGU	
PUSH	sr	2		1	ALU, AGU	
PUSHF(D)		1		1	ALU, AGU	
PUSHA(D)		9		4	ALU, AGU	
POP	r	2		1	ALU, AGU	
POP	m	3		1	ALU, AGU	
POP	DS/ES/FS/GS	6		10	ALU, AGU	
POP	SS	9		18	ALU, AGU	
POPF(D)		2		1	ALU, AGU	
POPA(D)		9		4	ALU, AGU	
LEA	r16,[m]	2	3	1	AGU	Any addr. size
LEA	r32,[m]	1	2	1/3	AGU	Any addr. size
LAHF		4	3	2	ALU	
SAHF		2	2	2	ALU	
SALC		1	1	1	ALU	
LDS, LES, ...	r,m	10		9		
BSWAP	r	1	1	1/3	ALU	
<b>Arithmetic instructions</b>						
ADD, SUB	r,r/i	1	1	1/3	ALU	
ADD, SUB	r,m	1	1	1/2	ALU, AGU	
ADD, SUB	m,r	1	7	2,5	ALU, AGU	
ADC, SBB	r,r/i	1	1	1/3	ALU	
ADC, SBB	r,m	1	1	1/2	ALU, AGU	
ADC, SBB	m,r/i	1	7	2,5	ALU, AGU	
CMP	r,r/i	1	1	1/3	ALU	
CMP	r,m	1		1/2	ALU, AGU	
INC, DEC, NEG	r	1	1	1/3	ALU	
INC, DEC, NEG	m	1	7	3	ALU, AGU	
AAA, AAS		9	5	5	ALU	
DAA		12	6	6	ALU	
DAS		16	7	7	ALU	
AAD		4	5		ALU0	
AAM		31	13		ALU	
MUL, IMUL	r8/m8	3	3	2	ALU0	
MUL, IMUL	r16/m16	3	3	2	ALU0_1	latency ax=3, dx=4
MUL, IMUL	r32/m32	3	4	3	ALU0_1	
IMUL	r16,r16/m16	2	3	2	ALU0	

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IMUL	r32,r32/m32	2	4	2,5	ALU0
IMUL	r16,(r16),i	2	4	1	ALU0
IMUL	r32,(r32),i	2	5	2	ALU0
IMUL	r16,m16,i	3		2	ALU0
IMUL	r32,m32,i	3		2	ALU0
DIV	r8/m8	32	24	23	ALU
DIV	r16/m16	47	24	23	ALU
DIV	r32/m32	79	40	40	ALU
IDIV	r8	41	17	17	ALU
IDIV	r16	56	25	25	ALU
IDIV	r32	88	41	41	ALU
IDIV	m8	42	17	17	ALU
IDIV	m16	57	25	25	ALU
IDIV	m32	89	41	41	ALU
CBW, CWDE		1	1	1/3	ALU
CWD, CDQ		1	1	1/3	ALU
<b>Logic instructions</b>					
AND, OR, XOR	r,r	1	1	1/3	ALU
AND, OR, XOR	r,m	1	1	1/2	ALU, AGU
AND, OR, XOR	m,r	1	7	2,5	ALU, AGU
TEST	r,r	1	1	1/3	ALU
TEST	r,m	1	1	1/2	ALU, AGU
NOT	r	1	1	1/3	ALU
NOT	m	1	7	2,5	ALU, AGU
SHL, SHR, SAR	r,i/CL	1	1	1/3	ALU
ROL, ROR	r,i/CL	1	1	1/3	ALU
RCL, RCR	r,1	1	1	1/3	ALU
RCL	r,i	9	4	4	ALU
RCR	r,i	7	3	3	ALU
RCL	r,CL	9	3	3	ALU
RCR	r,CL	7	3	3	ALU
SHL,SHR,SAR,ROL,ROR	m,i /CL	1	7	3	ALU, AGU
RCL, RCR	m,1	1	7	4	ALU, AGU
RCL	m,i	10	5	4	ALU, AGU
RCR	m,i	9	8	4	ALU, AGU
RCL	m,CL	9	6	4	ALU, AGU
RCR	m,CL	8	7	3	ALU, AGU
SHLD, SHRD	r,r,i	6	4	2	ALU
SHLD, SHRD	r,r,cl	7	4	3	ALU
SHLD, SHRD	m,r,i/CL	8	7	3	ALU, AGU
BT	r,r/i	1	1	1/3	ALU
BT	m,i	1		1/2	ALU, AGU
BT	m,r	5		2	ALU, AGU
BTC, BTR, BTS	r,r/i	2	2	1	ALU
BTC	m,i	5	7	2	ALU, AGU
BTR, BTS	m,i	4	7	2	ALU, AGU
BTC, BTR, BTS	m,r	8	6	3	ALU, AGU
BSF	r,r	19	7	7	ALU
BSR	r,r	23	9	9	ALU

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BSF	r,m	20	8	8	ALU, AGU	
BSR	r,m	23	10	10	ALU, AGU	
SETcc	r	1	1	1/3	ALU	
SETcc	m	1		1/2	ALU, AGU	
CLC, STC		1		1/3	ALU	
CMC		1	1	1/3	ALU	
CLD		2		1	ALU	
STD		3		2	ALU	
<b>Control transfer instructions</b>						
JMP	short/near	1		2	ALU	
JMP	far	16-20	23-32			low values = real mode
JMP	r	1		2	ALU	
JMP	m(near)	1		2	ALU, AGU	
JMP	m(far)	17-21	25-33			low values = real mode
Jcc	short/near	1		1/3 - 2	ALU	rcp. t.= 2 if jump
J(E)CXZ	short	2		1/3 - 2	ALU	rcp. t.= 2 if jump
LOOP	short	7	3-4	3-4	ALU	
CALL	near	3	2	2	ALU	
CALL	far	16-22	23-32			low values = real mode
CALL	r	4	3	3	ALU	
CALL	m(near)	5	3	3	ALU, AGU	
CALL	m(far)	16-22	24-33			low values = real mode
RETN		2	3	3	ALU	
RETN	i	2	3	3	ALU	
RETF		15-23	24-35			low values = real mode
RETF	i	15-24	24-35			low values = real mode
IRET		32	81			real mode
INT	i	33	42			real mode
BOUND	m	6		2		values are for no jump
INTO		2		2		values are for no jump
<b>String instructions</b>						
LODS		4	2	2		
REP LODS		5	2	2		values per count
STOS		4	2	2		
REP STOS		3	1	1		values per count
MOVS		7	3	3		
REP MOVS		4	1-4	1-4		values per count
SCAS		5	2	2		
REP SCAS		5	2	2		values per count
CMPS		7	6	6		
REP CMPS		6	3-4	3-4		values per count

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<b>Other</b>						
NOP (90)		1	0	1/3	ALU	3 ops, 5 clk if 16 bit
Long NOP (0F 1F)		1	0	1/3	ALU	
ENTER		i,0	12	12	12	
LEAVE		3		3		
CLI		8-9		5		
STI		16-17		27		
CPUID		19-28	44-74			
RDTSC		5		11		
RDPMC		9		11		

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
FLD	r	1	2	1/2	FA/M	
FLD	m32/64	1	4	1/2	FANY	
FLD	m80	7	16	4		
FBLD	m80	30	41	39		
FST(P)	r	1	2	1/2	FA/M	
FST(P)	m32/64	1	3	1	FMISC	
FSTP	m80	10	7	5		
FBSTP	m80	260		188		
FXCH	r	1	0	0,4		
FILD	m	1	9	1	FMISC	
FIST(P)	m	1	7	1	FMISC, FA/M	
FLDZ, FLD1		1		1	FMISC	
FCMOVcc	st0,r	9	6	5	FMISC, FA/M	Low latency immediately after FCOMI
FFREE	r	1		1/3	FANY	
FINCSTP, FDECSTP		1	0	1/3	FANY	Low latency immediately after FCOM FTST
FNSTSW	AX	2	6-12	12	FMISC, ALU	do.
FSTSW	AX	3	6-12	12	FMISC, ALU	do.
FNSTSW	m16	2		8	FMISC, ALU	do.
FNSTCW	m16	3		1	FMISC, ALU	faster if unchanged
FLDCW	m16	14		42	FMISC, ALU	
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	4	1	FADD	
FIADD,FISUB(R)	m	2	4	1-2	FADD,FMISC	
FMUL(P)	r/m	1	4	1	FMUL	
FIMUL	m	2	4	2	FMUL,FMISC	
FDIV(R)(P)	r/m	1	11-25	8-22	FMUL	Low values are for round divisors

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FIDIV(R)	m	2	12-26	9-23	FMUL,FMISC	do.
FABS, FCHS		1	2	1	FMUL	
FCOM(P), FUCOM(P)	r/m	1	2	1	FADD	
FCOMPP, FUCOMPP		1	2	1	FADD	
FCOMI(P)	r	1	3	1	FADD	
FICOM(P)	m	2		1	FADD, FMISC	
FTST		1	2	1	FADD	
FXAM		2		2	FMISC, ALU	
FRNDINT		5	10	3		
FPREM		1	7-10	8	FMUL	
FPREM1		1	8-11	8	FMUL	
<b>Math</b>						
FSQRT		1	35	12	FMUL	
FSIN		44	90-100			
FCOS		51	90-100			
FSINCOS		76	100-150			
FPTAN		46	100-200			
FPATAN		72	160-170			
FSCALE		5	8			
EXTRACT		7	11			
F2XM1		8	27			
FYL2X		49	126			
FYL2XP1		63	147			
<b>Other</b>						
FNOP		1	0	1/3	FANY	
(F)WAIT		1	0	1/3	ALU	
FNCLEX		7		24	FMISC	
FNINIT		25		92	FMISC	
FNSAVE		76		147		
FRSTOR		65		120		
FXSAVE		44		59		
FXRSTOR		85		87		

**Integer MMX instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVD	r32, mm	2	7	2	FMISC, ALU	
MOVD	mm, r32	2	9	2	FANY, ALU	
MOVD	mm,m32	1		1/2	FANY	
MOVD	m32, r	1		1	FMISC	
MOVQ	mm,mm	1	2	1/2	FA/M	
MOVQ	mm,m64	1		1/2	FANY	
MOVQ	m64,mm	1		1	FMISC	
MOVNTQ	m,mm	1		2	FMISC	
PACKSSWB/DW						
PACKUSWB	mm,r/m	1	2	2	FA/M	

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PUNPCKH/LBW/WD	mm,r/m	1	2	2	FA/M
PSHUFW	mm,mm,i	1	2	1/2	FA/M
MASKMOVQ	mm,mm	32		24	
PMOVMSKB	r32,mm	3		3	FADD
PEXTRW	r32,mm,i	2	5	2	FMISC, ALU
PINSRW	mm,r32,i	2	12	2	FA/M
<b>Arithmetic instructions</b>					
PADDB/W/D PADDWB/W					
PADDUSB/W					
PSUBB/W/D PSUBSB/W					
PSUBUSB/W					
	mm,r/m	1	2	1/2	FA/M
PCMPEQ/GT B/W/D	mm,r/m	1	2	1/2	FA/M
PMULLW PMULHW					
PMULHUW	mm,r/m	1	3	1	FMUL
PMADDWD	mm,r/m	1	3	1	FMUL
PAVGB/W	mm,r/m	1	2	1/2	FA/M
PMIN/MAX SW/UB	mm,r/m	1	2	1/2	FA/M
PSADBW	mm,r/m	1	3	1	FADD
<b>Logic</b>					
PAND PANDN POR					
PXOR	mm,r/m	1	2	1/2	FA/M
PSLL/RLW/D/Q PSRAW/D					
	mm,i/mm/m	1	2	1/2	FA/M
<b>Other</b>					
EMMS		1		1/3	FANY

**Floating point XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVAPS	r,r	2	2	1	FA/M	
MOVAPS	r,m	2		2	FMISC	
MOVAPS	m,r	2		2	FMISC	
MOVUPS	r,r	2	2	1	FA/M	
MOVUPS	r,m	5		2		
MOVUPS	m,r	5		2		
MOVSS	r,r	1	2	1	FA/M	
MOVSS	r,m	2	4	1	FANY FMISC	
MOVSS	m,r	1	3	1	FMISC	
MOVHPS, MOVLHPS	r,r	1	2	1/2	FA/M	
MOVHPS, MOVLPS	r,m	1		1/2	FMISC	
MOVHPS, MOVLPS	m,r	1		1	FMISC	
MOVNTPS	m,r	2		4	FMISC	
MOVMSKPS	r32,r	3		2	FADD	
SHUFPS	r,r/m,i	3	3	3	FMUL	



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UNPCK H/L PS	r,r/m	2	3	3	FMUL	
<b>Conversion</b>						
CVTPI2PS	xmm,mm	1	4		FMISC	
CVT(T)PS2PI	mm,xmm	1	6		FMISC	
CVTSS2SI	xmm,r32	4		10	FMISC	
CVT(T)SS2SI	r32,xmm	2		3	FMISC	
<b>Arithmetic</b>						
ADDSS SUBSS	r,r/m	1	4	1	FADD	
ADDPS SUBPS	r,r/m	2	4	2	FADD	
MULSS	r,r/m	1	4	1	FMUL	
MULPS	r,r/m	2	4	2	FMUL	
DIVSS	r,r/m	1	11-16	8-13	FMUL	Low values are for round divisors, e.g. powers of 2.
DIVPS	r,r/m	2	18-30	18-30	FMUL	do.
RCPSS	r,r/m	1	3	1	FMUL	
RCPPS	r,r/m	2	3	2	FMUL	
MAXSS MINSS	r,r/m	1	2	1	FADD	
MAXPS MINPS	r,r/m	2	2	2	FADD	
CMP <sub>cc</sub> SS	r,r/m	1	2	1	FADD	
CMP <sub>cc</sub> PS	r,r/m	2	2	2	FADD	
COMISS UCOMISS	r,r/m	1	2	1	FADD	
<b>Logic</b>						
ANDPS/D ANDNPS/D ORPS/D XORPS/D	r,r/m	2	2	2	FMUL	
<b>Math</b>						
SQRTSS	r,r/m	1	19	16	FMUL	
SQRTPS	r,r/m	2	36	36	FMUL	
RSQRTSS	r,r/m	1	3	1	FMUL	
RSQRTPS	r,r/m	2	3	2	FMUL	
<b>Other</b>						
LDMXCSR	m	8		9		
STMXCSR	m	3		10		

**3DNow instructions (obsolete)**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move and convert instructions</b>						
PREFETCH(W)	m	1		1/2	AGU	
PF2ID	mm,mm	1	5	1	FMISC	
PI2FD	mm,mm	1	5	1	FMISC	
PF2IW	mm,mm	1	5	1	FMISC	3DNow E
PI2FW	mm,mm	1	5	1	FMISC	3DNow E
PSWAPD	mm,mm	1	2	1/2	FA/M	3DNow E

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<b>Integer instructions</b>						
PAVGUSB	mm,mm	1	2	1/2	FA/M	
PMULHRW	mm,mm	1	3	1	FMUL	
<b>Floating point instructions</b>						
PFADD/SUB/SUBR	mm,mm	1	4	1	FADD	
PFCMPEQ/GE/GT	mm,mm	1	2	1	FADD	
PFCMPLE/GE/GT	mm,mm	1	2	1	FADD	
PFCMPLE/GE/GT	mm,mm	1	2	1	FADD	
PFCMPLE/GE/GT	mm,mm	1	2	1	FADD	
PFMUL	mm,mm	1	4	1	FMUL	
PFACC	mm,mm	1	4	1	FADD	
PFNACC, PFPNACC	mm,mm	1	4	1	FADD	3DNow E
PFRCP	mm,mm	1	3	1	FMUL	
PFRCPIT1/2	mm,mm	1	4	1	FMUL	
PFRSQRT	mm,mm	1	3	1	FMUL	
PFRSQIT1	mm,mm	1	4	1	FMUL	
<b>Other</b>						
FEMMS	mm,mm	1		1/3	FANY	

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### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency listed does not include the memory operand where the operand is listed as register or memory (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution unit:</b>	Indicates which execution unit is used for the macro-operations. ALU means any of the three integer ALU's. ALU0_1 means that ALU0 and ALU1 are both used. AGU means any of the three integer address generation units. FADD means floating point adder unit. FMUL means floating point multiplier unit. FMISC means floating point store and miscellaneous unit. FA/M means FADD or FMUL is used. FANY means any of the three floating point units can be used. Two macro-operations can execute simultaneously if they go to different execution units.

### Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	1/3	ALU	
MOV	r,i	1	1	1/3	ALU	
MOV	r8,m8	1	4	1/2	ALU, AGU	Any addressing mode.
MOV	r16,m16	1	4	1/2	ALU, AGU	Add 1 clock if code segment base ≠ 0
MOV	r32,m32	1	3	1/2	AGU	
MOV	r64,m64	1	3	1/2	AGU	
MOV	m8,r8H	1	8	1/2	AGU	AH, BH, CH, DH
MOV	m8,r8L	1	3	1/2	AGU	Any other 8-bit register
MOV	m16/32/64,r	1	3	1/2	AGU	Any addressing mode
MOV	m,i	1	3	1/2	AGU	
MOV	m64,i32	1	3	1/2	AGU	
MOV	r,sr	1	2	1/2-1		
MOV	sr,r/m	6	9-13	8		
MOVNTI	m,r	1		2-3	AGU	

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MOVZX, MOVSX	r,r	1	1	1/3	ALU	
MOVZX, MOVSX	r,m	1	4	1/2	ALU, AGU	
MOVSXD	r64,r32	1	1	1/3	ALU	
MOVSXD	r64,m32	1		1/2	ALU, AGU	
CMOVcc	r,r	1	1	1/3	ALU	
CMOVcc	r,m	1		1/2	ALU, AGU	
XCHG	r,r	3	2	1	ALU	
XCHG	r,m	3	16	16	ALU, AGU	Timing depends on hw
XLAT		2	5		ALU, AGU	
PUSH	r	1	1	1	ALU, AGU	
PUSH	i	1	1	1	ALU, AGU	
PUSH	m	2	1	1	ALU, AGU	
PUSH	sr	2	1	1	ALU, AGU	
PUSHF(D/Q)		5	2	2	ALU, AGU	
PUSHA(D)		9	4	4	ALU, AGU	
POP	r	2	1	1	ALU, AGU	
POP	m	3	1	1	ALU, AGU	
POP	DS/ES/FS/GS	4-6	8	8	ALU, AGU	
POP	SS	7-9	28	28	ALU, AGU	
POPF(D/Q)		25	10	10	ALU, AGU	
POPA(D)		9	4	4	ALU, AGU	
LEA	r16,[m]	2	3	1	AGU	Any address size
LEA	r32,[m]	1	2	1/3	AGU	Any address size
LEA	r64,[m]	1	2	1/3	AGU	Any address size
LAHF		4	3	2	ALU	
SAHF		1	1	1/3	ALU	
SALC		1	1	1/3	ALU	
LDS, LES, ...	r,m	10		9		
BSWAP	r	1	1	1/3	ALU	
PREFETCHNTA	m	1		1/2	AGU	
PREFETCHT0/1/2	m	1		1/2	AGU	
SFENCE		6		8		
LFENCE		1		5		
MFENCE		7		16		
IN	r,i/DX	270				
OUT	i/DX,r	300				
<b>Arithmetic instructions</b>						
ADD, SUB	r,r/i	1	1	1/3	ALU	
ADD, SUB	r,m	1	1	1/2	ALU, AGU	
ADD, SUB	m,r	1	7	2,5	ALU, AGU	
ADC, SBB	r,r/i	1	1	1/3	ALU	
ADC, SBB	r,m	1	1	1/2	ALU, AGU	
ADC, SBB	m,r/i	1	7	2,5	ALU, AGU	
CMP	r,r/i	1	1	1/3	ALU	
CMP	r,m	1		1/2	ALU, AGU	
INC, DEC, NEG	r	1	1	1/3	ALU	
INC, DEC, NEG	m	1	7	3	ALU, AGU	
AAA, AAS		9	5	5	ALU	
DAA		12	6	6	ALU	
DAS		16	7	7	ALU	
AAD		4	5		ALU0	

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AAM		31	13		ALU	
MUL, IMUL	r8/m8	1	3	1	ALU0	
MUL, IMUL	r16/m16	3	3-4	2	ALU0_1	latency ax=3, dx=4
MUL, IMUL	r32/m32	2	3	1	ALU0_1	
MUL, IMUL	r64/m64	2	4-5	2	ALU0_1	latency rax=4, rdx=5
IMUL	r16,r16/m16	1	3	1	ALU0	
IMUL	r32,r32/m32	1	3	1	ALU0	
IMUL	r64,r64/m64	1	4	2	ALU0_1	
IMUL	r16,(r16),i	2	4	1	ALU0	
IMUL	r32,(r32),i	1	3	1	ALU0	
IMUL	r64,(r64),i	1	4	2	ALU0	
IMUL	r16,m16,i	3		2	ALU0	
IMUL	r32,m32,i	3		2	ALU0	
IMUL	r64,m64,i	3		2	ALU0_1	
DIV	r8/m8	31	15	15	ALU	
DIV	r16/m16	46	23	23	ALU	
DIV	r32/m32	78	39	39	ALU	
DIV	r64/m64	143	71	71	ALU	
IDIV	r8	40	17	17	ALU	
IDIV	r16	55	25	25	ALU	
IDIV	r32	87	41	41	ALU	
IDIV	r64	152	73	73	ALU	
IDIV	m8	41	17	17	ALU	
IDIV	m16	56	25	25	ALU	
IDIV	m32	88	41	41	ALU	
IDIV	m64	153	73	73	ALU	
CBW, CWDE, CDQE		1	1	1/3	ALU	
CWD, CDQ, CQO		1	1	1/3	ALU	
<b>Logic instructions</b>						
AND, OR, XOR	r,r	1	1	1/3	ALU	
AND, OR, XOR	r,m	1	1	1/2	ALU, AGU	
AND, OR, XOR	m,r	1	7	2,5	ALU, AGU	
TEST	r,r	1	1	1/3	ALU	
TEST	r,m	1	1	1/2	ALU, AGU	
NOT	r	1	1	1/3	ALU	
NOT	m	1	7	2,5	ALU, AGU	
SHL, SHR, SAR	r,i/CL	1	1	1/3	ALU	
ROL, ROR	r,i/CL	1	1	1/3	ALU	
RCL, RCR	r,1	1	1	1/3	ALU	
RCL	r,i	9	3	3	ALU	
RCR	r,i	7	3	3	ALU	
RCL	r,CL	9	4	4	ALU	
RCR	r,CL	7	3	3	ALU	
SHL,SHR,SAR,ROL,ROR	m,i /CL	1	7	3	ALU, AGU	
RCL, RCR	m,1	1	7	4	ALU, AGU	
RCL	m,i	10	9	4	ALU, AGU	
RCR	m,i	9	8	4	ALU, AGU	
RCL	m,CL	9	7	4	ALU, AGU	
RCR	m,CL	8	8	3	ALU, AGU	
SHLD, SHRD	r,r,i	6	3	3	ALU	
SHLD, SHRD	r,r,cl	7	3	3	ALU	

## K8

SHLD, SHRD	m,r,i/CL	8	6	3	ALU, AGU	
BT	r,r/i	1	1	1/3	ALU	
BT	m,i	1		1/2	ALU, AGU	
BT	m,r	5		2	ALU, AGU	
BTC, BTR, BTS	r,r/i	2	2	1	ALU	
BTC	m,i	5	7	2	ALU, AGU	
BTR, BTS	m,i	4	7	2	ALU, AGU	
BTC	m,r	8	5	5	ALU, AGU	
BTR, BTS	m,r	8	8	3	ALU, AGU	
BSF	r16/32,r	21	8	8	ALU	
BSF	r64,r	22	9	9	ALU	
BSR	r,r	28	10	10	ALU	
BSF	r16,m	20	8	8	ALU, AGU	
BSF	r32,m	22	9	9	ALU, AGU	
BSF	r64,m	25	10	10	ALU, AGU	
BSR	r,m	28	10	10	ALU, AGU	
SETcc	r	1	1	1/3	ALU	
SETcc	m	1		1/2	ALU, AGU	
CLC, STC		1		1/3	ALU	
CMC		1	1	1/3	ALU	
CLD		1		1/3	ALU	
STD		2		1/3	ALU	
<b>Control transfer instructions</b>						
JMP	short/near	1		2	ALU	
JMP	far	16-20	23-32			low values = real mode
JMP	r	1		2	ALU	
JMP	m(near)	1		2	ALU, AGU	
JMP	m(far)	17-21	25-33			low values = real mode
Jcc	short/near	1		1/3 - 2	ALU	recip. thrp.= 2 if jump
J(E/R)CXZ	short	2		1/3 - 2	ALU	recip. thrp.= 2 if jump
LOOP	short	7	3-4	3-4	ALU	
CALL	near	3	2	2	ALU	
CALL	far	16-22	23-32			low values = real mode
CALL	r	4	3	3	ALU	
CALL	m(near)	5	3	3	ALU, AGU	
CALL	m(far)	16-22	24-33			low values = real mode
RETN		2	3	3	ALU	
RETN	i	2	3	3	ALU	
RETF		15-23	24-35			low values = real mode
RETF	i	15-24	24-35			low values = real mode
IRET		32	81			real mode
INT	i	33	42			real mode
BOUND	m	6		2		values are for no jump
INTO		2		2		values are for no jump
<b>String instructions</b>						

## K8

LODS	4	2	2		
REP LODS	5	2	2		values are per count
STOS	4	2	2		
REP STOS	1.5 - 2	0.5 - 1	0.5 - 1		values are per count
MOVS	7	3	3		
REP MOVS	3	1-2	1-2		values are per count
SCAS	5	2	2		
REP SCAS	5	2	2		values are per count
CMPS	2	3	3		
REP CMPS	6	2	2		values are per count
<b>Other</b>					
NOP (90)	1	0	1/3	ALU	
Long NOP (0F 1F)	1	0	1/3	ALU	
ENTER	i,0	12	12	12	
LEAVE	2		3		3 ops, 5 clk if 16 bit
CLI	8-9		5		
STI	16-17		27		
CPUID	22-50	47-164			
RDTSC	6	10	7		
RDPMSR	9	12	7		

## Floating point x87 instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
FLD	r	1	2	1/2	FA/M	
FLD	m32/64	1	4	1/2	FANY	
FLD	m80	7	16	4		
FBLD	m80	30	41	39		
FST(P)	r	1	2	1/2	FA/M	
FST(P)	m32/64	1	3	1	FMISC	
FSTP	m80	10	7	5		
FBSTP	m80	260	173	160		
FXCH	r	1	0	0,4		
FILD	m	1	9	1	FMISC	
FIST(P)	m	1	7	1	FMISC, FA/M	
FLDZ, FLD1		1		1	FMISC	
FCMOVcc	st0,r	9	4-15	4	FMISC, FA/M	Low latency immediately after FCOMI
FFREE	r	1		2	FANY	
FINCSTP, FDECSTP		1	0	1/3	FANY	
FNSTSW	AX	2	6-12	12	FMISC, ALU	FTST
FSTSW	AX	3	6-12	12	FMISC, ALU	do.
FNSTSW	m16	2		8	FMISC, ALU	do.
FNSTCW	m16	3		1	FMISC, ALU	
FLDCW	m16	18		50	FMISC, ALU	faster if unchanged
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	4	1	FADD	

## K8

FIADD,FISUB(R)	m	2	4	1-2	FADD,FMISC	Low values are for round divisors do.
FMUL(P)	r/m	1	4	1	FMUL	
FIMUL	m	2	4	2	FMUL,FMISC	
FDIV(R)(P)	r/m	1	11-25	8-22	FMUL	
FIDIV(R)	m	2	12-26	9-23	FMUL,FMISC	
FABS, FCHS		1	2	1	FMUL	
FCOM(P), FUCOM(P)	r/m	1	2	1	FADD	
FCOMPP, FUCOMPP		1	2	1	FADD	
FCOMI(P)	r	1	3	1	FADD	
FICOM(P)	m	2		1	FADD, FMISC	
FTST		1	2	1	FADD	
FXAM		2		1	FMISC, ALU	
FRNDINT		5	10	3		
FPREM		1	7-10	8	FMUL	
FPREM1		1	8-11	8	FMUL	
<b>Math</b>						
FSQRT		1	27	12	FMUL	
FLDPI, etc.		1		1	FMISC	
FSIN		66	140-190			
FCOS		73	150-190			
FSINCOS		98	170-200			
FPTAN		67	150-180			
FPATAN		97	217			
FSCALE		5	8			
FXTRACT		7	12	7		
F2XM1		53	126			
FYL2X		72	179			
FYL2XP1		75	175			
<b>Other</b>						
FNOP		1	0	1/3	FANY	
(F)WAIT		1	0	1/3	ALU	
FNCLEX		8		27	FMISC	
FNINIT		26		100	FMISC	
FNSAVE		77		171		
FRSTOR		70		136		
FXSAVE		61		56		
FXRSTOR		101		95		

**Integer MMX and XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVD	r32, mm	2	4	2	FMISC, ALU	
MOVD	mm, r32	2	9	2	FANY, ALU	
MOVD	mm,m32	1		1/2	FANY	
MOVD	r32, xmm	3	2	2	FMISC, ALU	
MOVD	xmm, r32	3	3	2		
MOVD	xmm,m32	2		1	FANY	
MOVD	m32, r	1		1	FMISC	



## K8

MOVD (MOVQ)	r64,mm/xmm	2	4	2	FMISC, ALU	Moves 64 bits.Name of instruction differs
MOVD (MOVQ)	mm,r64	2	9	2	FANY, ALU	do.
MOVD (MOVQ)	xmm,r64	3	9	2	FANY, ALU	do.
MOVQ	mm,mm	1	2	1/2	FA/M	
MOVQ	xmm,xmm	2	2	1	FA/M, FMISC	
MOVQ	mm,m64	1		1/2	FANY	
MOVQ	xmm,m64	2		1	FANY, FMISC	
MOVQ	m64,mm/x	1		1	FMISC	
MOVDQA	xmm,xmm	2	2	1	FA/M	
MOVDQA	xmm,m	2		2	FMISC	
MOVDQA	m,xmm	2		2	FMISC	
MOVDQU	xmm,m	4		2		
MOVDQU	m,xmm	5		2		
MOVDQ2Q	mm,xmm	1	2	1/2	FA/M	
MOVQ2DQ	xmm,mm	2	2	1	FA/M, FMISC	
MOVNTQ	m,mm	1		2	FMISC	
MOVNTDQ	m,xmm	2		3	FMISC	
PACKSSWB/DW						
PACKUSWB	mm,r/m	1	2	2	FA/M	
PACKSSWB/DW						
PACKUSWB	xmm,r/m	3	3	2	FA/M	
PUNPCKH/LBW/WD/DQ	mm,r/m	1	2	2	FA/M	
PUNPCKH/LBW/WD/DQ	xmm,r/m	2	2	2	FA/M	
PUNPCKHQDQ	xmm,r/m	2	2	1	FA/M	
PUNPCKLQDQ	xmm,r/m	1	2	1/2	FA/M	
PSHUFD	xmm,xmm,i	3	3	1,5	FA/M	
PSHUFW	mm,mm,i	1	2	1/2	FA/M	
PSHUFL/HW	xmm,xmm,i	2	2	1	FA/M	
MASKMOVQ	mm,mm	32		13		
MASKMOVDQU	xmm,xmm	64		26		
PMOVMASKB	r32,mm/xmm	1	2	1	FADD	
PEXTRW	r32,mm/x,i	2	5	2	FMISC, ALU	
PINSRW	mm,r32,i	2	12	2	FA/M	
PINSRW	xmm,r32,i	3	12	3	FA/M	
<b>Arithmetic instructions</b>						
PADDB/W/D/Q						
PADDSB/W						
PADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	mm,r/m	1	2	1/2	FA/M	
PADDB/W/D/Q						
PADDSB/W						
ADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	xmm,r/m	2	2	1	FA/M	
PCMPEQ/GT B/W/D	mm,r/m	1	2	1/2	FA/M	
PCMPEQ/GT B/W/D	xmm,r/m	2	2	1	FA/M	

## K8

PMULLW PMULHW PMULHUW PMULUDQ	mm,r/m	1	3	1	FMUL
PMULLW PMULHW PMULHUW PMULUDQ	xmm,r/m	2	3	2	FMUL
PMADDWD	mm,r/m	1	3	1	FMUL
PMADDWD	xmm,r/m	2	3	2	FMUL
PAVGB/W	mm,r/m	1	2	1/2	FA/M
PAVGB/W	xmm,r/m	2	2	1	FA/M
PMIN/MAX SW/UB	mm,r/m	1	2	1/2	FA/M
PMIN/MAX SW/UB	xmm,r/m	2	2	1	FA/M
PSADBW	mm,r/m	1	3	1	FADD
PSADBW	xmm,r/m	2	3	2	FADD
<b>Logic</b>					
PAND PANDN POR PXOR	mm,r/m	1	2	1/2	FA/M
PAND PANDN POR PXOR	xmm,r/m	2	2	1	FA/M
PSLL/RL W/D/Q PSRAW/D	mm,i/mm/m	1	2	1/2	FA/M
PSLL/RL W/D/Q PSRAW/D	x,i/x/m	2	2	1	FA/M
PSLLDQ, PSRLDQ	xmm,i	2	2	1	FA/M
<b>Other</b>					
EMMS		1		1/3	FANY

**Floating point XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVAPS/D	r,r	2	2	1	FA/M	
MOVAPS/D	r,m	2		2	FMISC	
MOVAPS/D	m,r	2		2	FMISC	
MOVUPS/D	r,r	2	2	1	FA/M	
MOVUPS/D	r,m	4		2		
MOVUPS/D	m,r	5		2		
MOVSS/D	r,r	1	2	1	FA/M	
MOVSS/D	r,m	2	4	1	FANY FMISC	
MOVSS/D	m,r	1	3	1	FMISC	
MOVHLPS, MOVLHPS	r,r	1	2	1/2	FA/M	
MOVHPS/D, MOVLPS/D	r,m	1		1	FMISC	
MOVHPS/D, MOVLPS/D	m,r	1		1	FMISC	
MOVDDUP	r,r	2	2	1		SSE3
MOVSH/LDUP	r,r	2	2	2		SSE3
MOVNTPS/D	m,r	2		3	FMISC	
MOVMSKPS/D	r32,r	1	8	1	FADD	

## K8

SHUFPS/D	r,r/m,i	3	3	2	FMUL	
UNPCK H/L PS/D	r,r/m	2	3	3	FMUL	
<b>Conversion</b>						
CVTSP2PD	r,r/m	2	4	2	FMISC	
CVTPD2PS	r,r/m	4	8	3	FMISC	
CVTSD2SS	r,r/m	3	8	8	FMISC	
CVTSS2SD	r,r/m	1	2	1	FMISC	
CVTDQ2PS	r,r/m	2	5	2	FMISC	
CVTDQ2PD	r,r/m	2	5	2	FMISC	
CVT(T)PS2DQ	r,r/m	2	5	2	FMISC	
CVT(T)PD2DQ	r,r/m	4	8	3	FMISC	
CVTPI2PS	xmm,mm	1	4	1	FMISC	
CVTPI2PD	xmm,mm	2	5	2	FMISC	
CVT(T)PS2PI	mm,xmm	1	6	1	FMISC	
CVT(T)PD2PI	mm,xmm	3	8	2	FMISC	
CVTSI2SS	xmm,r32	3	14	2	FMISC	
CVTSI2SD	xmm,r32	2	12	2	FMISC	
CVT(T)SD2SI	r32,xmm	2	10	2	FMISC	
CVT(T)SS2SI	r32,xmm	2	9	2	FMISC	
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	r,r/m	1	4	1	FADD	
ADDPS/D SUBPS/D	r,r/m	2	4	2	FADD	
HADDPS/D						
HSUBPS/D	r,r/m	2	4	2	FADD	SSE3
MULSS/D	r,r/m	1	4	1	FMUL	
MULPS/D	r,r/m	2	4	2	FMUL	
						Low values are for round divisors, e.g. powers of 2.
DIVSS	r,r/m	1	11-16	8-13	FMUL	
DIVPS	r,r/m	2	18-30	18-30	FMUL	do.
DIVSD	r,r/m	1	11-20	8-17	FMUL	do.
DIVPD	r,r/m	2	16-34	16-34	FMUL	do.
RCPSS	r,r/m	1	3	1	FMUL	
RCPPS	r,r/m	2	3	2	FMUL	
MAXSS/D MINSS/D	r,r/m	1	2	1	FADD	
MAXPS/D MINPS/D	r,r/m	2	2	2	FADD	
CMPccSS/D	r,r/m	1	2	1	FADD	
CMPccPS/D	r,r/m	2	2	2	FADD	
COMISS/D						
UCOMISS/D	r,r/m	1	2	1	FADD	
<b>Logic</b>						
ANDPS/D ANDNPS/D						
ORPS/D XORPS/D	r,r/m	2	2	2	FMUL	
<b>Math</b>						
SQRTSS	r,r/m	1	19	16	FMUL	
SQRTPS	r,r/m	2	36	36	FMUL	
SQRTSD	r,r/m	1	27	24	FMUL	
SQRTPD	r,r/m	2	48	48	FMUL	
RSQRTSS	r,r/m	1	3	1	FMUL	

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RSQRTPS	r,r/m	2	3	2	FMUL	
<b>Other</b>						
LDMXCSR	m	8		9		
STMXCSR	m	3		10		

## AMD K10

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency listed does not include the memory operand where the operand is listed as register or memory (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution unit:</b>	Indicates which execution unit is used for the macro-operations. ALU means any of the three integer ALU's. ALU0_1 means that ALU0 and ALU1 are both used. AGU means any of the three integer address generation units. FADD means floating point adder unit. FMUL means floating point multiplier unit. FMISC means floating point store and miscellaneous unit. FA/M means FADD or FMUL is used. FANY means any of the three floating point units can be used. Two macro-operations can execute simultaneously if they go to different execution units.

### Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	1/3	ALU	
MOV	r,i	1	1	1/3	ALU	
MOV	r8,m8	1	4	1/2	ALU, AGU	Any addr. mode. Add 1 clock if code segment base ≠ 0
MOV	r16,m16	1	4	1/2	ALU, AGU	
MOV	r32,m32	1	3	1/2	AGU	
MOV	r64,m64	1	3	1/2	AGU	
MOV	m8,r8H	1	8	1/2	AGU	AH, BH, CH, DH
MOV	m8,r8L	1	3	1/2	AGU	Any other 8-bit reg.
MOV	m16/32/64,r	1	3	1/2	AGU	Any addressing mode
MOV	m,i	1	3	1/2	AGU	
MOV	m64,i32	1	3	1/2	AGU	
MOV	r,sr	1	3-4	1/2		
MOV	sr,r/m	6	8-26	8		from AMD manual
MOVNTI	m,r	1		1	AGU	
MOVZX, MOVSX	r,r	1	1	1/3	ALU	

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MOVZX, MOVSX	r,m	1	4	1/2	ALU, AGU	
MOVSXD	r64,r32	1	1	1/3	ALU	
MOVSXD	r64,m32	1	4	1/2	ALU, AGU	
CMOVcc	r,r	1	1	1/3	ALU	
CMOVcc	r,m	1	4	1/2	ALU, AGU	
XCHG	r,r	2	1	1	ALU	
XCHG	r,m	2	21	19	ALU, AGU	Timing depends on hw
XLAT		2	5	5	ALU, AGU	
PUSH	r	1		1/2	ALU, AGU	
PUSH	i	1		1/2	ALU, AGU	
PUSH	m	2		1	ALU, AGU	
PUSH	sr	2		1	ALU, AGU	
PUSHF(D/Q)		9		3	ALU, AGU	
PUSHA(D)		9	6	6	ALU, AGU	
POP	r	1		1/2	ALU, AGU	
POP	m	3	3	1	ALU, AGU	
POP	DS/ES/FS/GS	6	10	8	ALU, AGU	
POP	SS	10	26	16	ALU, AGU	
POPF(D/Q)		28	16	11	ALU, AGU	
POPA(D)		9	6	6	ALU, AGU	
LEA	r16,[m]	2	3	1	ALU, AGU	Any address size
LEA	r32/64,[m]	1	1	1/3	ALU	≤ 2 source operands
LEA	r32/64,[m]	1	2	1/3	AGU	W. scale or 3 opr.
LAHF		4	3	2	ALU	
SAHF		1	1	1/3	ALU	
SALC		1	1	1	ALU	
LDS, LES, ...	r,m	10		10		
BSWAP	r	1	1	1/3	ALU	
PREFETCHNTA	m	1		1/2	AGU	
PREFETCHT0/1/2	m	1		1/2	AGU	
PREFETCH(W)	m	1		1/2	AGU	3DNow
SFENCE		6		8		
LFENCE		1		1		
MFENCE		4		33		
IN	r,i/DX	~270				
OUT	i/DX,r	~300				
<b>Arithmetic instructions</b>						
ADD, SUB	r,r/i	1	1	1/3	ALU	
ADD, SUB	r,m	1		1/2	ALU, AGU	
ADD, SUB	m,r	1	4	1	ALU, AGU	
ADC, SBB	r,r/i	1	1	1/3	ALU	
ADC, SBB	r,m	1		1/2	ALU, AGU	
ADC, SBB	m,r/i	1	4	1	ALU, AGU	
CMP	r,r/i	1	1	1/3	ALU	
CMP	r,m	1		1/2	ALU, AGU	
INC, DEC, NEG	r	1	1	1/3	ALU	
INC, DEC, NEG	m	1	7	2	ALU, AGU	
AAA, AAS		9	5	5	ALU	
DAA		12	6	6	ALU	
DAS		16	7	7	ALU	
AAD		4	5	5	ALU0	
AAM		30	13	13	ALU	

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MUL, IMUL	r8/m8	1	3	1	ALU0	
MUL, IMUL	r16/m16	3	3	2	ALU0_1	latency ax=3, dx=4
MUL, IMUL	r32/m32	2	3	1	ALU0_1	
MUL, IMUL	r64/m64	2	4	2	ALU0_1	latency rax=4, rdx=5
IMUL	r16,r16/m16	1	3	1	ALU0	
IMUL	r32,r32/m32	1	3	1	ALU0	
IMUL	r64,r64/m64	1	4	2	ALU0_1	
IMUL	r16,(r16),i	2	4	1	ALU0	
IMUL	r32,(r32),i	1	3	1	ALU0	
IMUL	r64,(r64),i	1	4	2	ALU0	
IMUL	r16,m16,i	3		2	ALU0	
IMUL	r32,m32,i	3		2	ALU0	
IMUL	r64,m64,i	3		2	ALU0_1	
DIV	r8/m8		17	17	ALU	
IDIV	r8		19	19	ALU	
IDIV	m8		22	22	ALU	
DIV	r16/m16		15-30	15-30	ALU	Depends on number of significant bits in absolute value of dividend. See AMD software optimization guide.
DIV	r32/m32		15-46	15-46	ALU	
DIV	r64/m64		15-78	15-78	ALU	
IDIV	r16/m16		24-39	24-39	ALU	
IDIV	r32/m32		24-55	24-55	ALU	
IDIV	r64/m64		24-87	24-87	ALU	
CBW, CWDE, CDQE		1	1	1/3	ALU	
CWD, CDQ, CQO		1	1	1/3	ALU	
<b>Logic instructions</b>						
AND, OR, XOR	r,r	1	1	1/3	ALU	
AND, OR, XOR	r,m	1		1/2	ALU, AGU	
AND, OR, XOR	m,r	1	4	1	ALU, AGU	
TEST	r,r	1	1	1/3	ALU	
TEST	r,m	1		1/2	ALU, AGU	
NOT	r	1	1	1/3	ALU	
NOT	m	1	7	1	ALU, AGU	
SHL, SHR, SAR	r,i/CL	1	1	1/3	ALU	
ROL, ROR	r,i/CL	1	1	1/3	ALU	
RCL, RCR	r,1	1	1	1	ALU	
RCL	r,i	9	3	3	ALU	
RCR	r,i	7	3	3	ALU	
RCL	r,CL	9	4	4	ALU	
RCR	r,CL	7	3	3	ALU	
SHL,SHR,SAR,ROL,RC	m,i /CL	1	7	1	ALU, AGU	
RCL, RCR	m,1	1	7	1	ALU, AGU	
RCL	m,i	10	7	5	ALU, AGU	
RCR	m,i	9	7	6	ALU, AGU	
RCL	m,CL	9	8	6	ALU, AGU	
RCR	m,CL	8	7	5	ALU, AGU	
SHLD, SHRD	r,r,i	6	3	2	ALU	
SHLD, SHRD	r,r,cl	7	3	3	ALU	
SHLD, SHRD	m,r,i/CL	8	7,5	6	ALU, AGU	
BT	r,r/i	1	1	1/3	ALU	
BT	m,i	1		1/2	ALU, AGU	
BT	m,r	5	7	2	ALU, AGU	
BTC, BTR, BTS	r,r/i	2	2	1/3	ALU	

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BTC	m,i	5	9	1,5	ALU, AGU	
BTR, BTS	m,i	4	9	1,5	ALU, AGU	
BTC	m,r	8	8	10	ALU, AGU	
BTR, BTS	m,r	8	8	7	ALU, AGU	
BSF	r,r	6	4	3	ALU	
BSR	r,r	7	4	3	ALU	
BSF	r,m	7	7	3	ALU, AGU	
BSR	r,m	8	7	3	ALU, AGU	
POPCNT	r,r/m	1	2	1	ALU	SSE4.A / SSE4.2
LZCNT	r,r/m	1	2	1	ALU	SSE4.A, AMD only
SETcc	r	1	1	1/3	ALU	
SETcc	m	1		1/2	ALU, AGU	
CLC, STC		1		1/3	ALU	
CMC		1	1	1/3	ALU	
CLD		1		1/3	ALU	
STD		2		2/3	ALU	
<b>Control transfer instructions</b>						
JMP	short/near	1		2	ALU	
JMP	far	16-20	23-32			low values = real mode
JMP	r	1		2	ALU	
JMP	m(near)	1		2	ALU, AGU	
JMP	m(far)	17-21	25-33			low values = real mode
Jcc	short/near	1		1/3 - 2	ALU	recip. thrp.= 2 if jump
J(E/R)CXZ	short	2		2/3 - 2	ALU	recip. thrp.= 2 if jump
LOOP	short	7		3	ALU	
CALL	near	3	2	2	ALU	
CALL	far	16-22	23-32			low values = real mode
CALL	r	4	3	3	ALU	
CALL	m(near)	5	3	3	ALU, AGU	
CALL	m(far)	16-22	24-33			low values = real mode
RETN		2	3	3	ALU	
RETN	i	2	3	3	ALU	
RETF		15-23	24-35			low values = real mode
RETF	i	15-24	24-35			low values = real mode
IRET		32	81			real mode
INT	i	33	42			real mode
BOUND	m	6		2		values are for no jump
INTO		2		2		values are for no jump
<b>String instructions</b>						
LODS		4	2	2		
REP LODS		5	2	2		values are per count
STOS		4	2	2		
REP STOS		2	1	1		values are per count
MOVS		7	3	3		
REP MOVS		3	1	1		values are per count
SCAS		5	2	2		
REP SCAS		5	2	2		values are per count
CMPS		7	3	3		
REP CMPS		3	1	1		values are per count
<b>Other</b>						



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NOP (90)		1	0	1/3	ALU	
Long NOP (0F 1F)		1	0	1/3	ALU	
ENTER		i,0	12		12	
LEAVE		2		3		3 ops, 5 clk if 16 bit
CLI		8-9		5		
STI		16-17		27		
CPUID		22-50	47-164			
RDTSC		30		67		
RDPMC		13		5		

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
FLD	r	1	2	1/2	FA/M	
FLD	m32/64	1	4	1/2	FANY	
FLD	m80	7	13	4		
FBLD	m80	20	94	30		
FST(P)	r	1	2	1/2	FA/M	
FST(P)	m32/64	1	2	1	FMISC	
FSTP	m80	10	8	7		
FBSTP	m80	218	167	163		
FXCH	r	1	0	1/3		
FILD	m	1	6	1	FMISC	
FIST(P)	m	1	4	1	FMISC	
FLDZ, FLD1		1		1	FMISC	
FCMOVcc	st0,r	9			FMISC, FA/M	Low latency immediately after FCOMI
FFREE	r	1		1/3	FANY	
FINCSTP, FDECSTP		1	0	1/3	FANY	
FNSTSW	AX	2		16	FMISC, ALU	Low latency immediately after FCOM FTST
FSTSW	AX	3		14	FMISC, ALU	do.
FNSTSW	m16	2		9	FMISC, ALU	do.
FNSTCW	m16	3		2	FMISC, ALU	
FLDCW	m16	12		14	FMISC, ALU	faster if unchanged
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	4	1	FADD	
FIADD,FISUB(R)	m	2		4	FADD,FMISC	
FMUL(P)	r/m	1	4	1	FMUL	
FIMUL	m	2		4	FMUL,FMISC	
FDIV(R)(P)	r/m	1	?	24	FMUL	
FIDIV(R)	m	2	31	24	FMUL,FMISC	
FABS, FCHS		1	2	2	FMUL	
FCOM(P), FUCOM(P)	r/m	1		1	FADD	
FCOMPP, FUCOMPP		1		1	FADD	
FCOMI(P)	r	1		1	FADD	
FICOM(P)	m	2		1	FADD, FMISC	
FTST		1		1	FADD	
FXAM		2		1	FMISC, ALU	
FRNDINT		6		37		

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FPREM		1		7	FMUL
FPREM1		1		7	FMUL
<b>Math</b>					
FSQRT		1	35	35	FMUL
FLDPI, etc.		1		1	FMISC
FSIN		45	~51?		
FCOS		51	~90?		
FSINCOS		76	~125?		
FPTAN		45	~119		
FPATAN		9	151?	45?	
FSCALE		5	9	29	
FEXTRACT		11	9	41	
F2XM1		8	65	30?	
FYL2X		8	13	30?	
FYL2XP1		12	114	44?	
<b>Other</b>					
FNOP		1	0	1/3	FANY
(F)WAIT		1	0	1/3	ALU
FNCLEX		8		28	FMISC
FNINIT		26		103	FMISC
FNSAVE	m	77	162	149	
FRSTOR	m	70	133	149	
FXSAVE	m	61	63	58	
FXRSTOR	m	85	89	79	

**Integer MMX and XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVD	r32, mm	1	3	1	FADD	
MOVD	mm, r32	2	6	3		
MOVD	mm, m32	1	4	1/2	FANY	
MOVD	r32, xmm	1	3	1	FADD	
MOVD	xmm, r32	2	6	3		
MOVD	xmm, m32	1	2	1/2		
MOVD	m32, mm/x	1	2	1	FMISC	
MOVD (MOVQ)	r64, (x)mm	1	3	1	FADD	Moves 64 bits. Name of instruction differs
MOVD (MOVQ)	mm, r64	2	6	3		do.
MOVD (MOVQ)	xmm, r64	2	6	3	FMUL, ALU	do.
MOVQ	mm, mm	1	2	1/2	FA/M	
MOVQ	xmm, xmm	1	2,5	1/3	FANY	
MOVQ	mm, m64	1	4	1/2	FANY	
MOVQ	xmm, m64	1	2	1/2	?	
MOVQ	m64, (x)mm	1	2	1	FMISC	
MOVDQA	xmm, xmm	1	2,5	1/3	FANY	
MOVDQA	xmm, m	1	2	1/2	?	
MOVDQA	m, xmm	2	2	1	FMUL, FMISC	
MOVDQU	xmm, m	1	2	1/2		

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MOVDQU	m, xmm	3	3	2		
MOVDQ2Q	mm, xmm	1	2	1/3	FANY	
MOVQ2DQ	xmm, mm	1	2	1/3	FANY	
MOVNTQ	m, mm	1		1	FMISC	
MOVNTDQ	m, xmm	2		1	FMUL, FMISC	
PACKSSWB/DW						
PACKUSWB	mm, r/m	1	2	1/2	FA/M	
PACKSSWB/DW						
PACKUSWB	xmm, r/m	1	3	1/2	FA/M	
PUNPCKH/LBW/WD/D Q	mm, r/m	1	2	1/2	FA/M	
PUNPCKH/LBW/WD/D Q	xmm, r/m	1	3	1/2	FA/M	
PUNPCKHQDQ	xmm, r/m	1	3	1/2	FA/M	
PUNPCKLQDQ	xmm, r/m	1	3	1/2	FA/M	
PSHUFD	xmm, xmm, i	1	3	1/2	FA/M	
PSHUFW	mm, mm, i	1	2	1/2	FA/M	
PSHUFL/HW	xmm, xmm, i	1	2	1/2	FA/M	
MASKMOVQ	mm, mm	32		13		
MASKMOVDQU	xmm, xmm	64		24		
PMOVMSKB	r32, mm/xmm	1	3	1	FADD	
PEXTRW	r32, (x)mm, i	2	6	1		
PINSRW	(x)mm, r32, i	2	9	3	FA/M	
INSERTQ	xmm, xmm	3	6	2	FA/M	SSE4.A, AMD only
INSERTQ	xmm, xmm, i, i	3	6	2	FA/M	SSE4.A, AMD only
EXTRQ	xmm, xmm	1	2	1/2	FA/M	SSE4.A, AMD only
EXTRQ	xmm, xmm, i, i	1	2	1/2	FA/M	SSE4.A, AMD only
<b>Arithmetic instructions</b>						
PADDB/W/D/Q						
PADDSB/W						
PADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	mm/xmm, r/m	1	2	1/2	FA/M	
PCMPEQ/GT B/W/D	mm/xmm, r/m	1	2	1/2	FA/M	
PMULLW PMULHW						
PMULHUW						
PMULUDQ	mm/xmm, r/m	1	3	1	FMUL	
PMADDWD	mm/xmm, r/m	1	3	1	FMUL	
PAVGB/W	mm/xmm, r/m	1	2	1/2	FA/M	
PMIN/MAX SW/UB	mm/xmm, r/m	1	2	1/2	FA/M	
PSADBW	mm/xmm, r/m	1	3	1	FADD	
<b>Logic</b>						
PAND PANDN POR PXOR	mm/xmm, r/m	1	2	1/2	FA/M	
PSLL/RL W/D/Q						
PSRAW/D	mm, i/mm/m	1	2	1/2	FA/M	
PSLL/RL W/D/Q						
PSRAW/D	x, i/(x)mm	1	3	1/2	FA/M	
PSLLDQ, PSRLDQ	xmm, i	1	3	1/2	FA/M	

<b>Other</b>					
EMMS		1		1/3	FANY

### Floating point XMM instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move instructions</b>						
MOVAPS/D	r,r	1	2,5	1/2	FANY	
MOVAPS/D	r,m	1	2	1/2	?	
MOVAPS/D	m,r	2	2	1	FMUL,FMISC	
MOVUPS/D	r,r	1	2,5	1/2	FANY	
MOVUPS/D	r,m	1	2	1/2	?	
MOVUPS/D	m,r	3	3	2	FMISC	
MOVSS/D	r,r	1	2	1/2	FA/M	
MOVSS/D	r,m	1	2	1/2	?	
MOVSS/D	m,r	1	2	1	FMISC	
MOVHLPs, MOVLHPS	r,r	1	3	1/2	FA/M	
MOVHPS/D, MOVLPS/D	r,m	1	4	1/2	FA/M	
MOVHPS/D, MOVLPS/D	m,r	1		1	FMISC	
MOVNTPS/D	m,r	2		3	FMUL,FMISC	
MOVNTSS/D	m,r	1		1	FMISC	SSE4.A, AMD only
MOVMSKPS/D	r32,r	1	3	1	FADD	
SHUFPS/D	r,r/m,i	1	3	1/2	FA/M	
UNPCK H/L PS/D	r,r/m	1	3	1/2	FA/M	
<b>Conversion</b>						
CVTPS2PD	r,r/m	1	2	1	FMISC	
CVTPD2PS	r,r/m	2	7	1		
CVTSD2SS	r,r/m	3	8	2		
CVTSS2SD	r,r/m	3	7	2		
CVTDQ2PS	r,r/m	1	4	1	FMISC	
CVTDQ2PD	r,r/m	1	4	1	FMISC	
CVT(T)PS2DQ	r,r/m	1	4	1	FMISC	
CVT(T)PD2DQ	r,r/m	2	7	1		
CVTPI2PS	xmm,mm	2	7	1		
CVTPI2PD	xmm,mm	1	4	1	FMISC	
CVT(T)PS2PI	mm,xmm	1	4	1	FMISC	
CVT(T)PD2PI	mm,xmm	2	7	1		
CVTSI2SS	xmm,r32	3	14	3		
CVTSI2SD	xmm,r32	3	14	3		
CVT(T)SD2SI	r32,xmm	2	8	1	FADD,FMISC	
CVT(T)SS2SI	r32,xmm	2	8	1	FADD,FMISC	
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	r,r/m	1	4	1	FADD	
ADDPS/D SUBPS/D	r,r/m	1	4	1	FADD	
MULSS/D	r,r/m	1	4	1	FMUL	

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MULPS/D	r,r/m	1	4	1	FMUL
DIVSS	r,r/m	1	16	13	FMUL
DIVPS	r,r/m	1	18	15	FMUL
DIVSD	r,r/m	1	20	17	FMUL
DIVPD	r,r/m	1	20	17	FMUL
RCPSS RCPPS	r,r/m	1	3	1	FMUL
MAXSS/D MINSS/D	r,r/m	1	2	1	FADD
MAXPS/D MINPS/D	r,r/m	1	2	1	FADD
CMP <sub>cc</sub> SS/D	r,r/m	1	2	1	FADD
CMP <sub>cc</sub> PS/D	r,r/m	1	2	1	FADD
COMISS/D					
UCOMISS/D	r,r/m	1		1	FADD
<b>Logic</b>					
ANDPS/D ANDNPS/D					
ORPS/D XORPS/D	r,r/m	1	2	1/2	FA/M
<b>Math</b>					
SQRTSS	r,r/m	1	19	16	FMUL
SQRTPS	r,r/m	1	21	18	FMUL
SQRTSD	r,r/m	1	27	24	FMUL
SQRTPD	r,r/m	1	27	24	FMUL
RSQRTSS	r,r/m	1	3	1	FMUL
RSQRTPS	r,r/m	1	3	1	FMUL
<b>Other</b>					
LDMXCSR	m	12	12	10	
STMXCSR	m	3	12	11	

**Obsolete 3DNow instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution unit	Notes
<b>Move and convert instructions</b>						
PF2ID	mm,mm	1	5	1	FMISC	
PI2FD	mm,mm	1	5	1	FMISC	
PF2IW	mm,mm	1	5	1	FMISC	3DNow extension
PI2FW	mm,mm	1	5	1	FMISC	3DNow extension
PSWAPD	mm,mm	1	2	1/2	FA/M	3DNow extension
<b>Integer instructions</b>						
PAVGUSB	mm,mm	1	2	1/2	FA/M	
PMULHRW	mm,mm	1	3	1	FMUL	
<b>Floating point instructions</b>						
PFADD/SUB/SUBR	mm,mm	1	4	1	FADD	
PFCMPEQ/GE/GT	mm,mm	1	2	1	FADD	
PFMAX/MIN	mm,mm	1	2	1	FADD	
PFMUL	mm,mm	1	4	1	FMUL	
PFACC	mm,mm	1	4	1	FADD	
PFNACC, PFPNACC	mm,mm	1	4	1	FADD	3DNow extension
PFRCP	mm,mm	1	3	1	FMUL	

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PFRCPIT1/2	mm,mm	1	4	1	FMUL
PFRSQRT	mm,mm	1	3	1	FMUL
PFRSQIT1	mm,mm	1	4	1	FMUL
<b>Other</b>					
FEMMS	mm,mm	1		1/3	FANY

Thank you to Xucheng Tang for doing the measurements on the K10.

## AMD Bulldozer

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, x = 128 bit xmm register, y = 256 bit ymm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency listed does not include the memory operand where the listing for register and memory operand are joined (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution pipe:</b>	Indicates which execution pipe or unit is used for the macro-operations: Integer pipes: EX0: integer ALU, division EX1: integer ALU, multiplication, jump EX01: can use either EX0 or EX1 AG01: address generation unit 0 or 1 Floating point and vector pipes: P0: floating point add, mul, div, convert, shuffle, shift P1: floating point add, mul, div, shuffle, shift P2: move, integer add, boolean P3: move, integer add, boolean, store P01: can use either P0 or P1 P23: can use either P2 or P3 Two macro-operations can execute simultaneously if they go to different execution pipes
<b>Domain:</b>	Tells which execution unit domain is used: ivec: integer vector execution unit. fp: floating point execution unit. fma: floating point multiply/add subunit. inherit: the output operand inherits the domain of the input operand. ivec/fma means the input goes to the ivec domain and the output comes from the fma domain. There is an additional latency of 1 clock cycle if the output of an ivec instruction goes to the input of a fp or fma instruction, and when the output of a fp or fma instruction goes to the input of an ivec or store instruction. There is no latency between the fp and fma units. All other latencies after memory load and before memory store instructions are included in the latency counts. An fma instruction has a latency of 5 if the output goes to another fma instruction, 6 if the output goes to an fp instruction, and 6+1 if the output goes to an ivec or store instruction.

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**Integer instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	0.5	EX01	
MOV	r,i	1	1	0.5	EX01	
MOV	r,m	1	4	0.5	AG01	all addr. modes
MOV	m,r	1	4	1	EX01 AG01	all addr. modes
MOV	m,i	1		1		
MOVNTI	m,r	1	5	2		
MOVZX, MOVSX	r,r	1	1	0.5	EX01	
MOVSX	r,m	1	5	0.5	EX01	
MOVZX	r,m	1	4	0.5	EX01	
MOVSXD	r64,r32	1	1	0.5	EX01	
MOVSXD	r64,m32	1	5	0.5	EX01	
CMOVcc	r,r	1	1	0.5	EX01	
CMOVcc	r,m	1		0.5	EX01	
XCHG	r,r	2	1	1	EX01	
XCHG	r,m	2	~50	~50	EX01	Timing depends on hw
XLAT		2	6	2		
PUSH	r	1		1		
PUSH	i	1		1		
PUSH	m	2		1.5		
PUSHF(D/Q)		8		4		
PUSHA(D)		9		9		
POP	r	1		1		
POP	m	2		1		
POPF(D/Q)		34		19		
POPA(D)		14		8		
LEA	r16,[m]	2	2-3		EX01	any addr. size
LEA	r32,[m]	2	2-3		EX01	16 bit addr. size
LEA	r32/64,[m]	1	2	0.5	EX01	scale factor > 1
LEA	r32/64,[m]	1	1	0.5	EX01	or 3 operands
LAHF		4	3	2		all other cases
SAHF		2	2	1		
SALC		1	1	1		
BSWAP	r	1	1	0.5	EX01	
PREFETCHNTA	m	1		0.5		
PREFETCHT0/1/2	m	1		0.5		
PREFETCH/W	m	1		0.5		AMD 3DNow
SFENCE		6		89		
LFENCE		1		0,25		
MFENCE		6		89		
<b>Arithmetic instructions</b>						
ADD, SUB	r,r	1	1	0.5	EX01	
ADD, SUB	r,i	1	1	0.5	EX01	



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ADD, SUB	r,m	1		0.5	EX01
ADD, SUB	m,r	1	7-8	1	EX01
ADD, SUB	m,i	1	7-8	1	EX01
ADC, SBB	r,r	1	1		EX01
ADC, SBB	r,i	1	1		EX01
ADC, SBB	r,m	1	1	1	EX01
ADC, SBB	m,r	1	9	1	EX01
ADC, SBB	m,i	1	9	1	EX01
CMP	r,r	1	1	0.5	EX01
CMP	r,i	1	1	0.5	EX01
CMP	r,m	1		0.5	EX01
INC, DEC, NEG	r	1	1	0.5	EX01
INC, DEC, NEG	m	1	7-8	1	EX01
AAA, AAS		10	6		
DAA		16	9		
DAS		20	10		
AAD		4	6		
AAM		9	20	20	
MUL, IMUL	r8/m8	1	4	2	EX1
MUL, IMUL	r16/m16	2	4	2	EX1
MUL, IMUL	r32/m32	1	4	2	EX1
MUL, IMUL	r64/m64	1	6	4	EX1
IMUL	r16,r16/m16	1	4	2	EX1
IMUL	r32,r32/m32	1	4	2	EX1
IMUL	r64,r64/m64	1	6	4	EX1
IMUL	r16,(r16),i	2	5	2	EX1
IMUL	r32,(r32),i	1	4	2	EX1
IMUL	r64,(r64),i	1	6	4	EX1
IMUL	r16,m16,i	2		2	EX1
IMUL	r32,m32,i	2		2	EX1
IMUL	r64,m64,i	2		4	EX1
DIV	r8/m8	14	20	20	EX0
DIV	r16/m16	18	15-27	15-28	EX0
DIV	r32/m32	16	16-43	16-43	EX0
DIV	r64/m64	16	16-75	16-75	EX0
IDIV	r8/m8	33	23	20	EX0
IDIV	r16/m16	36	23-33	20-27	EX0
IDIV	r32/m32	36	22-48	20-43	EX0
IDIV	r64/m64	36	22-79	20-75	EX0
CBW, CWDE, CDQE		1	1		EX01
CDQ, CQO		1	1	0.5	EX01
CWD		2	1	1	EX01
<b>Logic instructions</b>					
AND, OR, XOR	r,r	1	1	0.5	EX01
AND, OR, XOR	r,i	1	1	0.5	EX01
AND, OR, XOR	r,m	1		0.5	EX01
AND, OR, XOR	m,r	1	7-8	1	EX01
AND, OR, XOR	m,i	1	7-8	1	EX01
TEST	r,r	1	1	0.5	EX01

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TEST	r,i	1	1	0.5	EX01	
TEST	m,r	1		0.5	EX01	
TEST	m,i	1		0.5	EX01	
NOT	r	1	1	0.5	EX01	
NOT	m	1	7	1	EX01	
SHL, SHR, SAR	r,i/CL	1	1	0.5	EX01	
ROL, ROR	r,i/CL	1	1	0.5	EX01	
RCL	r,1	1	1		EX01	
RCL	r,i	16	8		EX01	
RCL	r,cl	17	9		EX01	
RCR	r,1	1	1		EX01	
RCR	r,i	15	8		EX01	
RCR	r,cl	16	8		EX01	
SHLD, SHRD	r,r,i	6	3	3	EX01	
SHLD, SHRD	r,r,cl	7	4	3,5	EX01	
SHLD, SHRD	m,r,i/CL	8		3,5	EX01	
BT	r,r/i	1	1	0.5	EX01	
BT	m,i	1		0.5	EX01	
BT	m,r	7		3,5	EX01	
BTC, BTR, BTS	r,r/i	2	2	1	EX01	
BTC, BTR, BTS	m,i	4		2	EX01	
BTC, BTR, BTS	m,r	10		5	EX01	
BSF	r,r	6	3	3	EX01	
BSF	r,m	8	4	4	EX01	
BSR	r,r	7	4	4	EX01	
BSR	r,m	9		5	EX01	
LZCNT	r,r	1	2	2	EX0	SSE4.A
POPCNT	r,r/m	1	4	2	EX1	SSE4.2
SETcc	r	1	1	0.5	EX01	
SETcc	m	1		1	EX01	
CLC, STC		1		0.5	EX01	
CMC		1	1		EX01	
CLD		2		3		
STD		2		4		
POPCNT	r16/32,r16/32	1	4	2		SSE4A
POPCNT	r64,r64	1	4	4		SSE4A
LZCNT	r,r	2	2	2		SSE4A
EXTRQ	x,i,i	1	3	1	P1	SSE4A
EXTRQ	x,x	1	3	1	P1	SSE4A
INSERTQ	x,x,i,i	1	3	1	P1	SSE4A
INSERTQ	x,x	1	3	1	P1	SSE4A
<b>Control transfer instructions</b>						
JMP	short/near	1		2	EX1	
JMP	r	1		2	EX1	
JMP	m	1		2	EX1	
Jcc	short/near	1		1-2	EX1	2 if jumping
fused CMP+Jcc	short/near	1		1-2	EX1	2 if jumping
J(E/R)CXZ	short	1		1-2	EX1	2 if jumping
LOOP	short	1		1-2	EX1	2 if jumping
LOOPE LOOPNE	short	1		1-2	EX1	2 if jumping

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CALL	near	2		2	EX1	
CALL	r	2		2	EX1	
CALL	m	3		2	EX1	
RET		1		2	EX1	
RET	i	4		2-3	EX1	
BOUND	m	11		5		for no jump
INTO		4		24		for no jump
<b>String instructions</b>						
LODS		3		3		
REP LODS		6n		3n		
STOS		3		3		
REP STOS		2n		2n		small n
REP STOS		3 per 16B		3 per 16B		best case
MOVS		5		3		
REP MOVS		2n		2n		small n
REP MOVS		4 per 16B		3 per 16B		best case
SCAS		3		3		
REP SCAS		7n		4n		
CMPS		6		3		
REP CMPS		9n		4n		
<b>Synchronization</b>						
LOCK ADD	m,r	1	~55			
XADD	m,r	4	10			
LOCK XADD	m,r	4	~51			
CMPXCHG	m8,r8	5	15			
LOCK CMPXCHG	m8,r8	5	~51			
CMPXCHG	m,r16/32/64	6	14			
LOCK CMPXCHG	m,r16/32/64	6	~52			
CMPXCHG8B	m64	18	15			
LOCK CMPXCHG8B	m64	18	~53			
CMPXCHG16B	m128	22	52			
LOCK CMPXCHG16B	m128	22	~94			
<b>Other</b>						
NOP (90)		1		0.25	none	
Long NOP (0F 1F)		1		0.25	none	
PAUSE		40		43		
ENTER	a,0	13		22		
ENTER	a,b	11+5b		16+4b		
LEAVE		2		4		
CPUID		37-63		112-280		
RDTSC		36		42		
RDPMC		22		300		
CRC32	r32,r8	3	3	2		
CRC32	r32,r16	5	5	5		
CRC32	r32,r32	5	6	6		
XGETBV		4		31		

## Floating point x87 instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
FLD	r	1	2	0.5	P01	fp
FLD	m32/64	1	8	1		fp
FLD	m80	8	14	4		fp
FBLD	m80	60	61	40	P0 P1 P2 P3	fp
FST(P)	r	1	2	0.5	P01	fp
FST(P)	m32/64	2	8	1		fp
FSTP	m80	13	9	20		fp
FBSTP	m80	239	240	244	P0 P1 F3	fp
FXCH	r	1	0	0.5	P01	inherit
FILD	m	1	12	1	F3	fp
FIST(P)	m	2	8	1	P0 F3	fp
FLDZ, FLD1		1		0.5	P01	fp
FCMOVcc	st0,r	8	3	3	P0 P1 F3	fp
FFREE	r	1		0.25	none	
FINCSTP, FDECSTP		1	0	0.25	none	inherit
FNSTSW	AX	4	~13	22	P0 P2 P3	
FNSTSW	m16	3	~13	19	P0 P2 P3	
FLDCW	m16	1		3		
FNSTCW	m16	3		2		
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	5-6	1	P01	fma
FIADD,FISUB(R)	m	2		2	P01	fma
FMUL(P)	r/m	1	5-6	1	P01	fma
FIMUL	m	2		2	P01	fma
FDIV(R)(P)	r	1	10-42	5-18	P01	fp
FDIV(R)	m	2			P01	fp
FIDIV(R)	m	2			P01	fp
FABS, FCHS		1	2	0.5	P01	fp
FCOM(P), FUCOM(P)	r/m	1		0.5	P01	fp
FCOMPP, FUCOMPP		1		0.5	P01	fp
FCOMI(P)	r	2	2	1	P0 P1 F3	fp
FICOM(P)	m	2		1	P01	fp
FTST		1		0.5	P01	fp
FXAM		1	~20	0.5	P01	fp
FRNDINT		1	4	1	P0	fp
FPREM		1	19-62		P0	fp
FPREM1		1	19-65		P0	fp
<b>Math</b>						
FSQRT		1	10-53		P01	
FLDPI, etc.		1		0.5	P01	
FSIN		10-162	65-210	65-210	P0 P1 P3	
FCOS		160-170	~160	~160	P0 P1 P3	

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FSINCOS		12-166	95-160	95-160	P0 P1 P3
FPTAN		11-190	95-245	95-245	P0 P1 P3
FPATAN		10-355	60-440	60-440	P0 P1 P3
FSCALE		8	52		P0 P1 P3
FEXTRACT		12	10	5	P0 P1 P3
F2XM1		10	64-71		P0 P1 P3
FYL2X		10-175			P0 P1 P3
FYL2XP1		10-175			P0 P1 P3
<b>Other</b>					
FNOP		1		0.25	none
(F)WAIT		1		0.25	none
FNCLEX		18		57	P0
FNINIT		31		170	P0
FNSAVE	m864	103	300	300	P0 P1 P2 P3
FRSTOR	m864	76	312	312	P0 P3

**Integer vector instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOVD	r32/64, mm/x	1	8	1		
MOVD	mm/x, r32/64	2	10	1		
MOVD	mm/x,m32	1	6	0.5		
MOVD	m32,mm/x	1	5	1		
MOVQ	mm/x,mm/x	1	2	0.5	P23	
MOVQ	mm/x,m64	1	6	0.5		
MOVQ	m64,mm/x	1	5	1	P3	
MOVDQA	xmm,xmm	1	0	0.25	none	inherit domain
MOVDQA	xmm,m	1	6	0.5		
MOVDQA	m,xmm	1	5	1	P3	
VMOVDQA	ymm,ymm	2	2	0.5	P23	
VMOVDQA	ymm,m256	2	6	1		
VMOVDQA	m256,ymm	4	5	3	P3	
MOVDQU	xmm,xmm	1	0	0.25	none	inherit domain
MOVDQU	xmm,m	1	6	0.5		
MOVDQU	m,xmm	1	5	1	P3	
LDDQU	xmm,m	1	6	0.5		
VMOVDQU	ymm,m256	2	6	1-2		
VMOVDQU	m256,ymm	8	6	10	P2 P3	
MOVDQ2Q	mm,xmm	1	2	0.5	P23	
MOVQ2DQ	xmm,mm	1	2	0.5	P23	
MOVNTQ	m,mm	1	6	2	P3	
MOVNTDQ	m,xmm	1	6	2	P3	
MOVNTDQA	xmm,m	1	6	0.5		
PACKSSWB/DW	(x)mm,r/m	1	2	1	P1	
PACKUSWB	(x)mm,r/m	1	2	1	P1	
PUNPCKH/LBW/WD/DQ	(x)mm,r/m	1	2	1	P1	

Bulldozer

PUNPCKHQDQ	xmm,r/m	1	2	1	P1	
PUNPCKLQDQ	xmm,r/m	1	2	1	P1	
PSHUFB	(x)mm,r/m	1	3	1	P1	
PSHUFD	xmm,xmm,i	1	2	1	P1	
PSHUFW	mm,mm,i	1	2	1	P1	
PSHUFL/HW	xmm,xmm,i	1	2	1	P1	
PALIGNR	(x)mm,r/m,i	1	2	1	P1	
PBLENDW	xmm,r/m	1	2	0.5	P23	SSE4.1
MASKMOVQ	mm,mm	31	38	37	P3	
MASKMOVDQU	xmm,xmm	64	48	61	P1 P3	
PMOVMASKB	r32,mm/x	2	10	1	P1 P3	
PEXTRB/W/D/Q	r,x/mm,i	2	10	1	P1 P3	AVX
PINSRB/W/D/Q	x/mm,r,i	2	12	2	P1	
PMOVSBW/BD/BQ/W/D/WQ/DQ	xmm,xmm	1	2	1	P1	SSE4.1
PMOVZXBW/BD/BQ/W/D/WQ/DQ	xmm,xmm	1	2	1	P1	SSE4.1
VPCMOV	x,x,x,x/m	1	2	1	P1	AMD XOP
VPCMOV	y,y,y,y/m	2	2	2	P1	AMD XOP
VPPERM	x,x,x,x/m	1	2	1	P1	AMD XOP
<b>Arithmetic instructions</b>						
PADDB/W/D/Q/SB/SW/USB/USW	(x)mm,r/m	1	2	0.5	P23	
PSUBB/W/D/Q/SB/SW/USB/USW	(x)mm,r/m	1	2	0.5	P23	
PHADD/SUB(S)W/D	x,x	3	5	2	P1 P23	SSSE3
PHADD/SUB(S)W/D	x,m	4	5	2	P1 P23	SSSE3
PCMPEQ/GT B/W/D	(x)mm,r/m	1	2	0.5	P23	
PCMPEQQ	(x)mm,r/m	1	2	0.5	P23	SSE4.1
PCMPGTQ	(x)mm,r/m	1	2	0.5	P23	SSE4.2
PMULLW PMULHW PMULHUW PMULUDQ	(x)mm,r/m	1	4	1	P0	
PMULLD	xmm,r/m	1	5	2	P0	SSE4.1
PMULDQ	xmm,r/m	1	4	1	P0	SSE4.1
PMULHRSW	(x)mm,r/m	1	4	1	P0	SSSE3
PMADDWD	(x)mm,r/m	1	4	1	P0	
PMADDUBSW	(x)mm,r/m	1	4	1	P0	
PAVGB/W	(x)mm,r/m	1	2	0.5	P23	
PMIN/MAX SB/SW/ SD UB/UW/UD	(x)mm,r/m	1	2	0.5	P23	
PHMINPOSUW	xmm,r/m	2	4	1	P1 P23	SSE4.1
PABSB/W/D	(x)mm,r/m	1	2	0.5	P23	SSSE3
PSIGNB/W/D	(x)mm,r/m	1	2	0.5	P23	SSSE3
PSADBW	(x)mm,r/m	2	4	1	P23	
MPSADBW	x,x,i	8	8	4	P1 P23	SSE4.1
VPCOMB/W/D/Q	x,x,x/m,i	1	2	0.5	P23	AMD XOP latency 0 if i=6,7
VPCOMUB/W/D/Q	x,x,x/m,i	1	2	0.5	P23	AMD XOP latency 0 if i=6,7

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VPHADDBW/BD/BQ/WD/WQ/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPHADDUBW/BD/BQ/WD/WQ/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPHSUBBW/WD/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPMACSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSDD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSDD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
<b>Logic</b>						
PAND PANDN POR PXOR	(x)mm,r/m	1	2	0.5	P23	
PSLL/RL W/D/Q PSRAW/D	(x)mm,r/m	1	3	1	P1	
PSLL/RL W/D/Q PSRAW/D	(x)mm,i	1	2	1	P1	
PSLLDQ, PSRLDQ	xmm,i	1	2	1	P1	
PTEST	xmm,r/m	2		1	P1 P3	SSE4.1
VPROTB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPROTB/W/D/Q	x,x,i	1	2	1	P1	AMD XOP
VPSHAB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPSHLB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
<b>String instructions</b>						
PCMPESTRI	x,x,i	27	17	10	P1 P2 P3	SSE4.2
PCMPESTRM	x,x,i	27	10	10	P1 P2 P3	SSE4.2
PCMPISTRI	x,x,i	7	14	3	P1 P2 P3	SSE4.2
PCMPISTRM	x,x,i	7	7	4	P1 P2 P3	SSE4.2
<b>Encryption</b>						
PCLMULQDQ	x,x/m,i	5	12	7	P1	pclmul
AESDEC	x,x	2	5	2	P01	aes
AESDECLAST	x,x	2	5	2	P01	aes
AESENC	x,x	2	5	2	P01	aes
AESENCLAST	x,x	2	5	2	P01	aes
AESIMC	x,x	1	5	1	P0	aes
AESKEYGENASSIST	x,x,i	1	5	1	P0	aes
<b>Other</b>						
EMMS		1		0.25		

**Floating point XMM and YMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						

Bulldozer

MOVAPS/D						
MOVUPS/D	x,x	1	0	0.25	none	inherit domain
VMOVAPS/D	y,y	2	2	0.5	P23	ivec
MOVAPS/D						
MOVUPS/D	x,m128	1	6	0.5		
VMOVAPS/D						
VMOVUPS/D	y,m256	2	6	1-2		
MOVAPS/D						
MOVUPS/D	m128,x	1	5	1	P3	
VMOVAPS/D	m256,y	4	5	3	P3	
VMOVUPS/D	m256,y	8	6	10	P2 P3	
MOVSS/D	x,x	1	2	0.5	P01	fp
MOVSS/D	x,m32/64	1	6	0.5		
MOVSS/D	m32/64,x	1	5	1		
MOVHPS/D						
MOVLPS/D	x,m64	1	7	1		
MOVHPS/D	m64,x	2	8	1	P1 P3	
MOVLPS/D	m64,x	1	7	1	P3	
MOVLHPS MOVHLPS	x,x	1	2	1	P1	ivec
MOVMSKPS/D	r32,x	2	10	1	P1 P3	
VMOVMSKPS/D	r32,y					
MOVNTPS/D	m128,x	1	6	2	P3	
VMOVNTPS/D	m256,y					
MOVNTSS/SD	m,x	1		4	P3	SSE4A
SHUFPS/D	x,x/m,i	1	2	1	P1	ivec
VSHUFPS/D	y,y,y/m,i	2	2	2	P1	ivec
VPERMILPS/PD	x,x,x/m	1	3	1	P1	ivec
VPERMILPS/PD	y,y,y/m	2	3	2	P1	ivec
VPERMILPS/PD	x,x/m,i	1	2	1	P1	ivec
VPERMILPS/PD	y,y/m,i	2	2	2	P1	ivec
VPERM2F128	y,y,y,i	8	4	3	P23	ivec
VPERM2F128	y,y,m,i	10		4	P23	ivec
BLENDPS/PD	x,x/m,i	1	2	0.5	P23	ivec
VBLENDPS/PD	y,y,y/m,i	2	2	1	P23	ivec
BLENDVPS/PD	x,x/m,xmm0	1	2	1	P1	ivec
VBLENDVPS/PD	y,y,y/m,y	2	2	2	P1	ivec
MOVDDUP	x,x	1	2	1	P1	ivec
MOVDDUP	x,m64	1		0.5		
VMOVDDUP	y,y	2	2	2	P1	ivec
VMOVDDUP	y,m256	2		1		
VBROADCASTSS	x,m32	1	6	0.5		
VBROADCASTSS	y,m32	2	6	0.5	P23	
VBROADCASTSD	y,m64	2	6	0.5	P23	
VBROADCASTF128	y,m128	2	6	0.5	P23	
MOVSH/LDUP	x,x	1	2	1	P1	ivec
MOVSH/LDUP	x,m128	1		0.5		
VMOVSH/LDUP	y,y	2	2	2	P1	ivec
VMOVSH/LDUP	y,m256	2		1		
UNPCKH/LPS/D	x,x/m	1	2	1	P1	ivec
VUNPCKH/LPS/D	y,y,y/m	2	2	2	P1	ivec
EXTRACTPS	r32,x,i	2	10	1	P1 P3	



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EXTRACTPS	m32,x,i	2	14	1	P1 P3	
VEEXTRACTF128	x,y,i	1	2	1	P23	ivec
VEXTRACTF128	m128,y,i	2	7	1	P23	
INSERTPS	x,x,i	1	2	1	P1	
INSERTPS	x,m32,i	1		1	P1	
VINSERTF128	y,y,x,i	2	2	1	P23	ivec
VINSERTF128	y,y,m128,i	2	9	1	P23	
VMASKMOVPS/D	x,x,m128	1	9	0.5	P01	
VMASKMOVPS/D	y,y,m256	2	9	1	P01	
VMASKMOVPS/D	m128,x,x	18	22	7	P0 P1 P2 P3	
VMASKMOVPS/D	m256,y,y	34	25	13	P0 P1 P2 P3	
<b>Conversion</b>						
CVTPD2PS	x,x	2	7	1	P01	fp
VCVTPD2PS	x,y	4	7	2	P01	fp
CVTPS2PD	x,x	2	7	1	P01	fp
VCVTPS2PD	y,x	4	7	2	P01	fp
CVTSD2SS	x,x	1	4	1	P0	fp
CVTSS2SD	x,x	1	4	1	P0	fp
CVTDQ2PS	x,x	1	4	1	P0	fp
VCVTDQ2PS	y,y	2	4	2	P0	fp
CVT(T) PS2DQ	x,x	1	4	1	P0	fp
VCVT(T) PS2DQ	y,y	2	4	2	P0	fp
CVTDQ2PD	x,x	2	7	1	P01	fp
VCVTDQ2PD	y,x	4	8	2	P01	fp
CVT(T)PD2DQ	x,x	2	7	1	P01	fp
VCVT(T)PD2DQ	x,y	4	7	2	P01	fp
CVTPI2PS	x,mm	1	4	1	P0	fp
CVT(T)PS2PI	mm,x	1	4	1	P0	fp
CVTPI2PD	x,mm	2	7	1	P0 P1	fp
CVT(T) PD2PI	mm,x	2	7	1	P0 P1	fp
CVTSI2SS	x,r32	2	14	1	P0	fp
CVT(T)SS2SI	r32,x	2	13	1	P0	fp
CVTSI2SD	x,r32/64	2	14	1	P0	fp
CVT(T)SD2SI	r32/64,x	2	13	1	P0	fp
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	x,x/m	1	5-6	0.5	P01	fma
ADDPS/D SUBPS/D	x,x/m	1	5-6	0.5	P01	fma
VADDPS/D VSUBPS/D	y,y,y/m	2	5-6	1	P01	fma
ADDSUBPS/D	x,x/m	1	5-6	0.5	P01	fma
VADDSUBPS/D	y,y,y/m	2	5-6	1	P01	fma
HADDPS/D HSUBPS/D	x,x	3	10	2	P01 P1	ivec/fma
HADDPS/D HSUBPS/D	x,m128	4		2	P01 P1	ivec/fma
VHADDPS/D						
VHSUBPS/D	y,y,y	8	10	4	P01 P1	ivec/fma
VHADDPS/D						
VHSUBPS/D	y,y,m	10		4	P01 P1	ivec/fma

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MULSS MULSD	x,x/m	1	5-6	0.5	P01	fma
MULPS MULPD	x,x/m	1	5-6	0.5	P01	fma
VMULPS VMULPD	y,y,y/m	2	5-6	1	P01	fma
DIVSS DIVPS	x,x/m	1	9-24	4.5-9.5	P01	fp
VDIVPS	y,y,y/m	2	9-24	9-19	P01	fp
DIVSD DIVPD	x,x/m	1	9-27	4.5-11	P01	fp
VDIVPD	y,y,y/m	2	9-27	9-22	P01	fp
RCPSS/PS	x,x/m	1	5	1	P01	fp
VRCPPS	y,y/m	2	5	2	P01	fp
CMPSS/D						
CMPSS/D	x,x/m	1	2	0.5	P01	fp
VCMPPS/D	y,y,y/m	2	2	1	P01	fp
COMISS/D						
UCOMISS/D	x,x/m	2		1	P01 P3	fp
MAXSS/SD/PS/PD						
MINSS/SD/PS/PD	x,x/m	1	2	0.5	P01	fp
VMAXPS/D VMINPS/D	y,y,y/m	2	2	1	P01	fp
ROUNDSS/SD/PS/PD	x,x/m,i	1	4	1	P0	fp
VROUNDSS/SD/PS/ PD	y,y/m,i	2	4	2	P0	fp
DPPS	x,x,i	16	25	6	P01 P23	fma
DPPS	x,m128,i	18		7	P01 P23	fma
VDPPS	y,y,y,i	25	27	13	P01 P3	fma
VDPPS	y,m256,i	29		13	P01 P3	fma
DPPD	x,x,i	15	15	5	P01 P23	fma
DPPD	x,m128,i	17		6	P01 P23	fma
VFMADDSS/SD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	y,y,y,y/m	2	5-6	1	P01	AMD FMA4
All other FMA4 instructions: same as above						
<b>Math</b>						
SQRTSS/PS	x,x/m	1	14-15	4.5-12	P01	fp
VSQRTPS	y,y/m	2	14-15	9-24	P01	fp
SQRTSD/PD	x,x/m	1	24-26	4.5-16.5	P01	fp
VSQRTPD	y,y/m	2	24-26	9-33	P01	fp
RSQRTSS/PS	x,x/m	1	5	1	P01	fp
VRSQRTPS	y,y/m	2	5	2	P01	fp
VFRCZSS/SD/PS/PD	x,x	2	10	2	P01	AMD XOP
VFRCZSS/SD/PS/PD	x,m	3	10	2	P01	AMD XOP
<b>Logic</b>						
AND/ANDN/OR/XORPS/ PD	x,x/m	1	2	0.5	P23	ivec
VAND/ANDN/OR/XOR PS/PD	y,y,y/m	2	2	1	P23	ivec
<b>Other</b>						
VZEROUPPER		9		4		32 bit mode
VZEROUPPER		16		5		64 bit mode

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VZEROALL		17		6	P2 P3	32 bit mode
VZEROALL		32		10	P2 P3	64 bit mode
LDMXCSR	m32	1	10	4	P0 P3	
STMXCSR	m32	2	19	19	P0 P3	
FXSAVE	m4096	67	136	136	P0 P1 P2 P3	
FXRSTOR	m4096	116	176	176	P0 P1 P2 P3	
XSAVE	m	122	196	196	P0 P1 P2 P3	
XRSTOR	m	177	250	250	P0 P1 P2 P3	

## AMD Piledriver

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, x = 128 bit xmm register, y = 256 bit ymm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency listed does not include the memory operand where the listing for register and memory operand are joined (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution pipe:</b>	Indicates which execution pipe or unit is used for the macro-operations: Integer pipes: EX0: integer ALU, division EX1: integer ALU, multiplication, jump EX01: can use either EX0 or EX1 AG01: address generation unit 0 or 1 Floating point and vector pipes: P0: floating point add, mul, div, convert, shuffle, shift P1: floating point add, mul, div, shuffle, shift P2: move, integer add, boolean P3: move, integer add, boolean, store P01: can use either P0 or P1 P23: can use either P2 or P3 Two macro-operations can execute simultaneously if they go to different execution pipes
<b>Domain:</b>	Tells which execution unit domain is used: ivec: integer vector execution unit. fp: floating point execution unit. fma: floating point multiply/add subunit. inherit: the output operand inherits the domain of the input operand. ivec/fma means the input goes to the ivec domain and the output comes from the fma domain. There is an additional latency of 1 clock cycle if the output of an ivec instruction goes to the input of a fp or fma instruction, and when the output of a fp or fma instruction goes to the input of an ivec or store instruction. There is no latency between the fp and fma units. All other latencies after memory load and before memory store instructions are included in the latency counts. An fma instruction has a latency of 5 if the output goes to another fma instruction, 6 if the output goes to an fp instruction, and 6+1 if the output goes to an ivec or store instruction.

## Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOV	r8,r8	1	1	0.5	EX01	
MOV	r16,r16	1	1	0.5	EX01	
MOV	r32,r32	1	1	0.3	EX01 or AG01	
MOV	r64,r64	1	1	0.3	EX01 or AG01	
MOV	r,i	1	1	0.5	EX01	
MOV	r,m	1	4	0.5	AG01	all addr. modes
MOV	m,r	1	4	1	EX01 AG01	all addr. modes
MOV	m,i	1		1		
MOVNTI	m,r	1	4	2		
MOVZX, MOVZX	r16,r8	1	1	1	EX01	
MOVZX, MOVZX	r32,r	1	1	0.5	EX01	
MOVZX, MOVZX	r64,r	1	1	0.5	EX01	
MOVSX	r,m	1	5	0.5	EX01	
MOVZX	r,m	1	4	0.5	EX01	
MOVSXD	r64,r32	1	1	0.5	EX01	
MOVSXD	r64,m32	1	5	0.5	EX01	
CMOVcc	r,r	1	1	0.5	EX01	
CMOVcc	r,m	1		0.5	EX01	
XCHG	r8,r8	2	1	1	EX01	
XCHG	r16,r16	2	1	1	EX01	
XCHG	r32,r32	2	1	0.5	EX01	
XCHG	r64,r64	2	1	0.5	EX01	
XCHG	r,m	2	~40	~40	EX01	Timing depends on hw
XLAT		2	6	2		
PUSH	r	1		1		
PUSH	i	1		1		
PUSH	m	2		1		
PUSHF(D/Q)		8		4		
PUSHA(D)		9		9		
POP	r	1		1		
POP	m	2		1		
POPF(D/Q)		34		18		
POPA(D)		14		8		
LEA	r16,[m]	2	2-3		EX01	any addr. size
LEA	r32,[m]	2	2-3		EX01	16 bit addr. size
LEA	r32/64,[m]	1	2	0.5	EX01	scale factor > 1 or 3 operands
LEA	r32/64,[m]	1	1	0.5	EX01	all other cases
LAHF		4	3	2		
SAHF		2	2	1		
SALC		1	1	1		
BSWAP	r	1	1	0.5	EX01	
PREFETCHNTA	m	1		0.5		
PREFETCHT0/1/2	m	1		0.5		
PREFETCH/W	m	1		0.5		PREFETCHW
SFENCE		7		81		

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LFENCE		1		0,25	
MFENCE		7		81	
<b>Arithmetic instructions</b>					
ADD, SUB	r,r	1	1	0.5	EX01
ADD, SUB	r,i	1	1	0.5	EX01
ADD, SUB	r,m	1		0.5	EX01
ADD, SUB	m,r	1	7-8	1	EX01
ADD, SUB	m,i	1	7-8	1	EX01
ADC, SBB	r,r	1	1		EX01
ADC, SBB	r,i	1	1		EX01
ADC, SBB	r,m	1	1	1	EX01
ADC, SBB	m,r	1	9	1	EX01
ADC, SBB	m,i	1	9	1	EX01
CMP	r,r	1	1	0.5	EX01
CMP	r,i	1	1	0.5	EX01
CMP	r,m	1		0.5	EX01
CMP	m,i	1		0.5	EX01
INC, DEC, NEG	r	1	1	0.5	EX01
INC, DEC, NEG	m	1	7-8	1	EX01
AAA, AAS		10	6		
DAA		16	9		
DAS		20	10		
AAD		4	6		
AAM		10	15	15	
MUL, IMUL	r8/m8	1	4	2	EX1
MUL, IMUL	r16/m16	2	4	2	EX1
MUL, IMUL	r32/m32	1	4	2	EX1
MUL, IMUL	r64/m64	1	6	4	EX1
IMUL	r16,r16/m16	1	4	2	EX1
IMUL	r32,r32/m32	1	4	2	EX1
IMUL	r64,r64/m64	1	6	4	EX1
IMUL	r16,(r16),i	2	5	2	EX1
IMUL	r32,(r32),i	1	4	2	EX1
IMUL	r64,(r64),i	1	6	4	EX1
IMUL	r16,m16,i	2		2	EX1
IMUL	r32,m32,i	2		2	EX1
IMUL	r64,m64,i	2		4	EX1
DIV	r8/m8	9	17-22	13-22	EX0
DIV	r16/m16	7	13-26	13-25	EX0
DIV	r32/m32	2	12-40	12-40	EX0
DIV	r64/m64	2	13-71	13-71	EX0
IDIV	r8/m8	9	17-21	13-18	EX0
IDIV	r16/m16	7	13-26	13-25	EX0
IDIV	r32/m32	2	13-40	13-40	EX0
IDIV	r64/m64	2	13-71	13-71	EX0
CBW, CWDE, CDQE		1	1		EX01
CDQ, CQO		1	1	0.5	EX01
CWD		2	1	1	EX01
<b>Logic instructions</b>					
AND, OR, XOR	r,r	1	1	0.5	EX01
AND, OR, XOR	r,i	1	1	0.5	EX01

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AND, OR, XOR	r,m	1		0.5	EX01	
AND, OR, XOR	m,r	1	7-8	1	EX01	
AND, OR, XOR	m,i	1	7-8	1	EX01	
TEST	r,r	1	1	0.5	EX01	
TEST	r,i	1	1	0.5	EX01	
TEST	m,r	1		0.5	EX01	
TEST	m,i	1		0.5	EX01	
NOT	r	1	1	0.5	EX01	
NOT	m	1	7-8	1	EX01	
ANDN	r,r,r	1	1	0.5	EX01	BMI1
SHL, SHR, SAR	r,i/CL	1	1	0.5	EX01	
ROL, ROR	r,i/CL	1	1	0.5	EX01	
RCL	r,1	1	1		EX01	
RCL	r,i	16	7		EX01	
RCL	r,cl	17	7		EX01	
RCR	r,1	1	1		EX01	
RCR	r,i	15	7		EX01	
RCR	r,cl	16	6		EX01	
SHLD, SHRD	r,r,i	6	3	3	EX01	
SHLD, SHRD	r,r,cl	7	3	3	EX01	
SHLD, SHRD	m,r,i/CL	8		3,5	EX01	
BT	r,r/i	1	1	0.5	EX01	
BT	m,i	1		0.5	EX01	
BT	m,r	7		3,5	EX01	
BTC, BTR, BTS	r,r/i	2	2	1	EX01	
BTC, BTR, BTS	m,i	4	20		EX01	
BTC, BTR, BTS	m,r	10	21		EX01	
BSF	r,r	6	3	3	EX01	
BSF	r,m	8	4	4	EX01	
BSR	r,r	7	4	4	EX01	
BSR	r,m	9		5	EX01	
SETcc	r	1	1	0.5	EX01	
SETcc	m	1		1	EX01	
CLC, STC		1		0.5	EX01	
CMC		1	1		EX01	
CLD		2		3		
STD		2		4		
POPCNT	r16/32,r16/32	1	4	2		SSE4.2
POPCNT	r64,r64	1	4	4		SSE4.2
LZCNT	r,r	1	2	2	EX0	LZCNT
TZCNT	r,r	2	2	2		BMI1
BEXTR	r,r,r	2	2	0.67		BMI1
BEXTR	r,r,i	2	2	0.67		AMD TBM
BLSI	r,r	2	2	1		BMI1
BLSMSK	r,r	2	2	1		BMI1
BLSR	r,r	2	2	1		BMI1
BLCFILL	r,r	2	2	1		AMD TBM
BLCI	r,r	2	2	1		AMD TBM
BLCIC	r,r	2	2	1		AMD TBM
BLCMSK	r,r	2	2	1		AMD TBM
BLCS	r,r	2	2	1		AMD TBM
BLSFILL	r,r	2	2	1		AMD TBM
BLSI	r,r	2	2	1		AMD TBM

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BLSIC	r,r	2	2	1		AMD TBM
T1MSKC	r,r	2	2	1		AMD TBM
TZMSK	r,r	2	2	1		AMD TBM
<b>Control transfer instructions</b>						
JMP	short/near	1		2	EX1	
JMP	r	1		2	EX1	
JMP	m	1		2	EX1	
Jcc	short/near	1		1-2	EX1	2 if jumping
fused CMP+Jcc	short/near	1		1-2	EX1	2 if jumping
J(E/R)CXZ	short	1		1-2	EX1	2 if jumping
LOOP	short	1		1-2	EX1	2 if jumping
LOOPE LOOPNE	short	1		1-2	EX1	2 if jumping
CALL	near	2		2	EX1	
CALL	r	2		2	EX1	
CALL	m	3		2	EX1	
RET		1		2	EX1	
RET	i	4		2	EX1	
BOUND	m	11		5		for no jump
INTO		4		2		for no jump
<b>String instructions</b>						
LODS		3		3		
REP LODS	m8/m16	6n		3n		
REP LODS	m32/m64	6n		2.5n		
STOS		3		3		
REP STOS		1n		1n		small n
REP STOS		3 per 16B		3 per 16B		best case
MOVS		5		3		
REP MOVSB		1-3n		1n		small n
REP MOVSB		4.5 pr 16B		3 per 16B		best case
SCAS		3		3		
REP SCAS		7n		3-4n		
CMPS		6		3		
REP CMPS		9n		4n		
<b>Synchronization</b>						
LOCK ADD	m,r	1	~40			
XADD	m,r	4	20			
LOCK XADD	m,r	4	~39			
CMPXCHG	m,r8/16	5	23			
LOCK CMPXCHG	m,r8/16	5	~40			
CMPXCHG	m,r32/64	6	20			
LOCK CMPXCHG	m,r32/64	6	~40			
CMPXCHG8B	m64	18	25			
LOCK CMPXCHG8B	m64	18	~42			
CMPXCHG16B	m128	22	66			
LOCK CMPXCHG16B	m128	22	~80			
<b>Other</b>						
NOP (90)		1		0.25	none	
Long NOP (0F 1F)		1		0.25	none	
PAUSE		40		40		



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ENTER	a,0	13		21	
ENTER	a,b	20+3b		16+4b	
LEAVE		2		4	
CPUID		38-64		105-271	
XGETBV		4		30	
RDTSC		36		42	
RDPMC		21		310	
CRC32	r32,r8	3	3	2	
CRC32	r32,r16	5	5	5	
CRC32	r32,r32	5	6	6	

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
FLD	r	1	2	0.5	P01	fp
FLD	m32/64	1	7	1		fp
FLD	m80	8	20	4		fp
FBLD	m80	60	64	35	P0 P1 P2 P3	fp
FST(P)	r	1	2	0.5	P01	fp
FST(P)	m32/64	2	7	1		fp
FSTP	m80	13	22	20		fp
FBSTP	m80	239	220		P0 P1 F3	fp
FXCH	r	1	0	0.5	P01	inherit
FILD	m	1	11	1	F3	fp
FIST(T)(P)	m	2	7	1	P0 F3	fp
FLDZ, FLD1		1		0.5	P01	fp
FCMOVcc	st0,r	8	3	3	P0 P1 F3	fp
FFREE	r	1		0.25	none	
FINCSTP, FDECSTP		1	0	0.25	none	inherit
FNSTSW	AX	3		19	P0 P2 P3	
FNSTSW	m16	2		17	P0 P2 P3	
FLDCW	m16	1		3		
FNSTCW	m16	2		2		
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	5-6	1	P01	fma
FIADD,FISUB(R)	m	2		2	P01	fma
FMUL(P)	r/m	1	5-6	1	P01	fma
FIMUL	m	2		2	P01	fma
FDIV(R)(P)	r	1	9-40	4-16	P01	fp
FDIV(R)	m	1			P01	fp
FIDIV(R)	m	2			P01	fp
FABS, FCHS		1	2	0.5	P01	fp
FCOM(P), FUCOM(P)	r/m	1		0.5	P01	fp
FCOMPP, FUCOMPP		1		0.5	P01	fp
FCOMI(P)	r	2	2	1	P0 P1 F3	fp
FICOM(P)	m	2		1	P01	fp
FTST		1		0.5	P01	fp
FXAM		1	~20	0.5	P01	fp
FRNDINT		1	4	1	P0	fp

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FPREM		1	17-60		P0	fp
FPREM1		1	17-60		P0	fp
<b>Math</b>						
FSQRT		1	14-50	5-20	P01	
FLDPI, etc.		1		0.5	P01	
FSIN		10-162	60-210	60-146	P0 P1 P3	
FCOS		160-170	~154	~154	P0 P1 P3	
FSINCOS		12-166	86-141	86-141	P0 P1 P3	
FPTAN		11-190	166-231	86-204	P0 P1 P3	
FPATAN		10-355	60-352	60-352	P0 P1 P3	
FSCALE		8	44	5	P0 P1 P3	
FEXTRACT		12	7	5	P0 P1 P3	
F2XM1		10	60-73		P0 P1 P3	
FYL2X		10-176			P0 P1 P3	
FYL2XP1		10-176			P0 P1 P3	
<b>Other</b>						
FNOP		1		0.25	none	
(F)WAIT		1		0.25	none	
FNCLEX		18		54	P0	
FNINIT		31		134	P0	
FNSAVE	m864	103	300	300	P0 P1 P2 P3	
FRSTOR	m864	76	236	236	P0 P3	

**Integer vector instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOVD	r32/64, mm/x	1	8	1		P3
MOVD	mm/x, r32/64	2	10	1		
MOVD	mm/x,m32	1	6	0.5		
MOVD	m32,mm/x	1	5	1		P3
MOVQ	mm/x,mm/x	1	2	0.5	P23	
MOVQ	mm/x,m64	1	6	0.5		
MOVQ	m64,mm/x	1	5	1	P3	
MOVDQA	xmm,xmm	1	0	0.25	none	inherit domain
MOVDQA	xmm,m	1	6	0.5		
MOVDQA	m,xmm	1	5	1	P3	
VMOVDQA	ymm,ymm	2	2	0.5	P23	
VMOVDQA	ymm,m256	2	6	1		
VMOVDQA	m256,ymm	4	11	17	P3	
MOVDQU	xmm,xmm	1	0	0.25	none	inherit domain
MOVDQU	xmm,m	1	6	0.5		
MOVDQU	m,xmm	1	5	1	P3	
LDDQU	xmm,m	1	6	0.5		
VMOVDQU	ymm,m256	2	6	1		
VMOVDQU	m256,ymm	8	14	20	P2 P3	
MOVDQ2Q	mm,xmm	1	2	0.5	P23	
MOVQ2DQ	xmm,mm	1	2	0.5	P23	
MOVNTQ	m,mm	1	5	2	P3	

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MOVNTDQ	m,xmm	1	5	2	P3	
MOVNTDQA	xmm,m	1	6	0.5		
PACKSSWB/DW	(x)mm,r/m	1	2	1	P1	
PACKUSWB	(x)mm,r/m	1	2	1	P1	
PUNPCKH/LBW/WD/D Q	(x)mm,r/m	1	2	1	P1	
PUNPCKHQDQ	xmm,r/m	1	2	1	P1	
PUNPCKLQDQ	xmm,r/m	1	2	1	P1	
PSHUFB	(x)mm,r/m	1	3	1	P1	
PSHUFD	xmm,xmm,i	1	2	1	P1	
PSHUFW	mm,mm,i	1	2	1	P1	
PSHUFL/HW	xmm,xmm,i	1	2	1	P1	
PALIGNR	(x)mm,r/m,i	1	2	1	P1	
PBLENDW	xmm,r/m	1	2	0.5	P23	SSE4.1
MASKMOVQ	mm,mm	31	36	59	P3	
MASKMOVDQU	xmm,xmm	64	59	92	P1 P3	
PMOVMSKB	r32,mm/x	2	10	1	P1 P3	
PEXTRB/W/D/Q	r,x/mm,i	2	10	1	P1 P3	SSE4.1
PINSRB/W/D/Q	x/mm,r,i	2	12	2	P1	
EXTRQ	x,i,i	1	3	1	P1	AMD SSE4A
EXTRQ	x,x	1	1	1	P1	AMD SSE4A
INSERTQ	x,x,i,i	1	1	1	P1	AMD SSE4A
INSERTQ	x,x	1	1	1	P1	AMD SSE4A
PMOVSBW/BD/BQ/W D/WQ/DQ	x,x	1	2	1	P1	SSE4.1
PMOVZBW/BD/BQ/W D/WQ/DQ	x,x	1	2	1	P1	SSE4.1
VPCMOV	x,x,x,x/m	1	2	1	P1	AMD XOP
VPCMOV	y,y,y,y/m	2	2	2	P1	AMD XOP
VPPERM	x,x,x,x/m	1	2	1	P1	AMD XOP
<b>Arithmetic instructions</b>						
PADDB/W/D/Q/SB/SW/ USB/USW	(x)mm,r/m	1	2	0.5	P23	
PSUBB/W/D/Q/SB/SW/ USB/USW	(x)mm,r/m	1	2	0.5	P23	
PHADD/SUB(S)W/D	x,x	3	5	2	P1 P23	SSSE3
PHADD/SUB(S)W/D	x,m	4	5	2	P1 P23	SSSE3
PCMPEQ/GT B/W/D	(x)mm,r/m	1	2	0.5	P23	
PCMPEQQ	(x)mm,r/m	1	2	0.5	P23	SSE4.1
PCMPGTQ	(x)mm,r/m	1	2	0.5	P23	SSE4.2
PMULLW PMULHW PMULHUW PMULUDQ	(x)mm,r/m	1	4	1	P0	
PMULLD	x,r/m	1	5	2	P0	SSE4.1
PMULDQ	x,r/m	1	4	1	P0	SSE4.1
PMULHRSW	(x)mm,r/m	1	4	1	P0	SSSE3
PMADDWD	(x)mm,r/m	1	4	1	P0	
PMADDUBSW	(x)mm,r/m	1	4	1	P0	
PAVGB/W	(x)mm,r/m	1	2	0.5	P23	
PMIN/MAX SB/SW/ SD UB/UW/UD	(x)mm,r/m	1	2	0.5	P23	
PHMINPOSUW	x,r/m	2	4	1	P1 P23	SSE4.1

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PABSB/W/D	(x)mm,r/m	1	2	0.5	P23	SSSE3
PSIGNB/W/D	(x)mm,r/m	1	2	0.5	P23	SSSE3
PSADBW	(x)mm,r/m	2	4	1	P23	
MPSADBW	x,x,i	8	8	4	P1 P23	SSE4.1
VPCOMB/W/D/Q	x,x,x/m,i	1	2	0.5	P23	AMD XOP latency 0 if i=6,7
VPCOMUB/W/D/Q	x,x,x/m,i	1	2	0.5	P23	AMD XOP latency 0 if i=6,7
VPHADDBW/BD/BQ/ WD/WQ/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPHADDUBW/BD/BQ/ WD/WQ/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPHSUBBW/WD/DQ	x,x/m	1	2	0.5	P23	AMD XOP
VPMACSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSDD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
<b>Logic</b>						
PAND PANDN POR PXOR	(x)mm,r/m	1	2	0.5	P23	
PSLL/RL W/D/Q						
PSRAW/D	(x)mm,r/m	1	3	1	P1	
PSLL/RL W/D/Q						
PSRAW/D	(x)mm,i	1	2	1	P1	
PSLLDQ, PSRLDQ	x,i	1	2	1	P1	
PTEST	x,r/m	2		1	P1 P3	SSE4.1
VPROTB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPROTB/W/D/Q	x,x,i	1	2	1	P1	AMD XOP
VPSHAB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPSHLB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
<b>String instructions</b>						
PCMPESTRI	x,x,i	27	16	10	P1 P2 P3	SSE4.2
PCMPESTRM	x,x,i	27	10	10	P1 P2 P3	SSE4.2
PCMPISTRI	x,x,i	7	13	3	P1 P2 P3	SSE4.2
PCMPISTRM	x,x,i	7	7	4	P1 P2 P3	SSE4.2
<b>Encryption</b>						
PCLMULQDQ	x,x/m,i	5	12	7	P1	pclmul
VPCLMULQDQ	x,x,x,i	6	12	7	P1	pclmul
PCLMULQDQ	x,x,m,i	7	12	7	P1	pclmul
AESDEC	x,x	2	5	2	P01	aes
AESDECLAST	x,x	2	5	2	P01	aes
AESENC	x,x	2	5	2	P01	aes
AESENCLAST	x,x	2	5	2	P01	aes
AESIMC	x,x	1	5	1	P0	aes
AESKEYGENASSIST	x,x,i	1	5	1	P0	aes

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<b>Other</b>					
EMMS		1		0.25	

**Floating point XMM and YMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
MOVAPS/D						
MOVUPS/D	x,x	1	0	0.25	none	inherit domain
VMOVAPS/D	y,y	2	2	0.5	P23	ivec
MOVAPS/D						
MOVUPS/D	x,m128	1	6	0.5		
VMOVAPS/D						
VMOVUPS/D	y,m256	2	6	1		
MOVAPS/D						
MOVUPS/D	m128,x	1	5	1	P3	
VMOVAPS/D	m256,y	4	11	17	P3	
VMOVUPS/D	m256,y	8	15	20	P2 P3	
MOVSS/D	x,x	1	2	0.5	P01	fp
MOVSS/D	x,m32/64	1	6	0.5		
MOVSS/D	m32/64,x	1	5	1		
MOVHPS/D	x,m64	1	8	1	P1	
MOVLPS/D	x,m64	1	7	0.5	P01	
MOVHPS/D	m64,x	2	7	1	P1 P3	
MOVLPS/D	m64,x	1	6	1	P3	
MOVLHPS MOVHLPS	x,x	1	2	1	P1	ivec
MOVMSKPS/D	r32,x	2	10	1	P1 P3	
VMOVMSKPS/D	r32,y	2		1		
MOVNTPS/D	m128,x	1	5	2	P3	
VMOVNTPS/D	m256,y	4		18		
MOVNTSS/SD	m,x	1		4	P3	AMD SSE4A
SHUFPS/D	x,x/m,i	1	2	1	P1	ivec
VSHUFPS/D	y,y,y/m,i	2	2	2	P1	ivec
VPERMILPS/PD	x,x,x/m	1	3	1	P1	ivec
VPERMILPS/PD	y,y,y/m	2	3	2	P1	ivec
VPERMILPS/PD	x,x/m,i	1	2	1	P1	ivec
VPERMILPS/PD	y,y/m,i	2	2	2	P1	ivec
VPERM2F128	y,y,y,i	8	4	3	P23	ivec
VPERM2F128	y,y,m,i	10		4	P23	ivec
BLENDPS/PD	x,x/m,i	1	2	0.5	P23	ivec
VBLENDPS/PD	y,y,y/m,i	2	2	1	P23	ivec
BLENDVPS/PD	x,x/m,xmm0	1	2	1	P1	ivec
VBLENDVPS/PD	y,y,y/m,y	2	2	2	P1	ivec
MOVDDUP	x,x	1	2	1	P1	ivec
MOVDDUP	x,m64	1		0.5		
VMOVDDUP	y,y	2	2	2	P1	ivec
VMOVDDUP	y,m256	2		1		
VBROADCASTSS	x,m32	1	6	0.5		
VBROADCASTSS	y,m32	2	6	0.5	P23	
VBROADCASTSD	y,m64	2	6	0.5	P23	
VBROADCASTF128	y,m128	2	6	0.5	P23	

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MOVSH/LDUP	x,x	1	2	1	P1	ivec
MOVSH/LDUP	x,m128	1		0.5		
VMOVSH/LDUP	y,y	2	2	2	P1	ivec
VMOVSH/LDUP	y,m256	2		1		
UNPCKH/LPS/D	x,x/m	1	2	1	P1	ivec
VUNPCKH/LPS/D	y,y,y/m	2	2	2	P1	ivec
EXTRACTPS	r32,x,i	2		1	P1 P3	
EXTRACTPS	m32,x,i	2	6	1	P1 P3	
VEXTRACTF128	x,y,i	1	2	0.5	P23	ivec
VEXTRACTF128	m128,y,i	2	6	1	P23	
INSERTPS	x,x,i	1	2	1	P1	
INSERTPS	x,m32,i	1	7	2	P1	
VINSERTF128	y,y,x,i	2	2	1	P23	ivec
VINSERTF128	y,y,m128,i	2	13	1	P23	
VMASKMOVPS/D	x,x,m128	1	7	0.5	P01	
VMASKMOVPS/D	y,y,m256	2	13	1	P01	
VMASKMOVPS/D	m128,x,x	18	~100	~90	P0 P1 P2 P3	
VMASKMOVPS/D	m256,y,y	34	~190	~180	P0 P1 P2 P3	
<b>Conversion</b>						
CVTPD2PS	x,x	2	8	1	P01	ivec/fp
VCVTPD2PS	x,y	4	7	2	P01	ivec/fp
CVTPS2PD	x,x	2	8	1	P01	ivec/fp
VCVTPS2PD	y,x	4	8	2	P01	ivec/fp
CVTSD2SS	x,x	1	4	1	P0	fp
CVTSS2SD	x,x	1	4	1	P0	fp
CVTDQ2PS	x,x	1	4	1	P0	fp
VCVTDQ2PS	y,y	2	4	2	P0	fp
CVT(T) PS2DQ	x,x	1	4	1	P0	fp
VCVT(T) PS2DQ	y,y	2	4	2	P0	fp
CVTDQ2PD	x,x	2	8	1	P01	ivec/fp
VCVTDQ2PD	y,x	4	8	2	P01	ivec/fp
CVT(T)PD2DQ	x,x	2	8	1	P01	fp/ivec
VCVT(T)PD2DQ	x,y	4	7	2	P01	fp/ivec
CVTPI2PS	x,mm	2	8	1	P0 P23	ivec/fp
CVT(T)PS2PI	mm,x	1	4	1	P0	fp
CVTPI2PD	x,mm	2	7	1	P0 P1	ivec/fp
CVT(T) PD2PI	mm,x	2	7	1	P0 P1	fp/ivec
CVTSI2SS	x,r32	2	13	1	P0	fp
CVT(T)SS2SI	r32,x	2	12	1	P0 P3	fp
CVTSI2SD	x,r32/64	2	13	1	P0	fp
CVT(T)SD2SI	r32/64,x	2	12	1	P0 P3	fp
VCVTPS2PH	x/m,x,i	2	8	2	P0 P1	F16C
VCVTPS2PH	x/m,y,i	4	8	2	P0 P1	F16C
VCVTPH2PS	x,x/m	2	8	2	P0 P1	F16C
VCVTPH2PS	y,x/m	4	8	2	P0 P1	F16C
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	x,x/m	1	5-6	0.5	P01	fma
ADDPS/D SUBPS/D	x,x/m	1	5-6	0.5	P01	fma
VADDPS/D VSUBPS/D	y,y,y/m	2	5-6	1	P01	fma
ADDSUBPS/D	x,x/m	1	5-6	0.5	P01	fma

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VADDSUBPS/D	y,y,y/m	2	5-6	1	P01	fma
HADDPS/D HSUBPS/D	x,x	3	10	2	P01 P1	ivec/fma
HADDPS/D HSUBPS/D	x,m	4		2	P01 P1	ivec/fma
VHADDPS/D						
VHSUBPS/D	y,y,y/m	8	10	4	P01 P1	ivec/fma
MULSS MULSD	x,x/m	1	5-6	0.5	P01	fma
MULPS MULPD	x,x/m	1	5-6	0.5	P01	fma
VMULPS VMULPD	y,y,y/m	2	5-6	1	P01	fma
DIVSS DIVPS	x,x/m	1	9-24	5-10	P01	fp
VDIVPS	y,y,y/m	2	9-24	9-20	P01	fp
DIVSD DIVPD	x,x/m	1	9-27	5-10	P01	fp
VDIVPD	y,y,y/m	2	9-27	9-18	P01	fp
RCPSS/PS	x,x/m	1	5	1	P01	fp
VRCPPS	y,y/m	2	5	2	P01	fp
CMPSS/D						
CMPPS/D	x,x/m	1	2	0.5	P01	fp
VCMPPS/D	y,y,y/m	2	2	1	P01	fp
COMISS/D						
UCOMISS/D	x,x/m	2		1	P01 P3	fp
MAXSS/SD/PS/PD						
MINSS/SD/PS/PD	x,x/m	1	2	0.5	P01	fp
VMAXPS/D VMINPS/D	y,y,y/m	2	2	1	P01	fp
ROUNDSS/SD/PS/PD	x,x/m,i	1	4	1	P0	fp
VROUNDSS/SD/PS/ PD	y,y/m,i	2	4	2	P0	fp
DPPS	x,x,i	16	25	6	P01 P23	SSE4.1
DPPS	x,m,i	18		7	P01 P23	SSE4.1
VDPPS	y,y,y,i	25	27	13	P01 P3	SSE4.1
VDPPS	y,m,i	29		13	P01 P3	SSE4.1
DPPD	x,x,i	15	15	5	P01 P23	SSE4.1
DPPD	x,m,i	17		6	P01 P23	SSE4.1
VFMADD132SS/SD	x,x,x/m	1	5-6	1	P01	FMA3
VFMADD132PS/PD	x,x,x/m	1	5-6	1	P01	FMA3
VFMADD132PS/PD	y,y,y/m	2	5-6	1	P01	FMA3
All other FMA3 instructions: same as above						
VFMADDSS/SD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	y,y,y,y/m	2	5-6	1	P01	AMD FMA4
All other FMA4 instructions: same as above						
<b>Math</b>						
SQRTSS/PS	x,x/m	1	13-15	5-12	P01	fp
VSQRTPS	y,y/m	2	14-15	9-24	P01	fp
SQRTSD/PD	x,x/m	1	24-26	5-15	P01	fp
VSQRTPD	y,y/m	2	24-26	9-29	P01	fp
RSQRTSS/PS	x,x/m	1	5	1	P01	fp
VRSQRTPS	y,y/m	2	5	2	P01	fp
VFRCZSS/SD/PS/PD	x,x	2	10	2	P01	AMD XOP
VFRCZSS/SD/PS/PD	x,m	3	10	2	P01	AMD XOP

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<b>Logic</b>						
AND/ANDN/OR/XORPS/ PD	x,x/m	1	2	0.5	P23	ivec
VAND/ANDN/OR/XOR PS/PD	y,y,y/m	2	2	1	P23	ivec
<b>Other</b>						
VZEROUPPER		9		4	P2 P3	32 bit mode
VZEROUPPER		16		5	P2 P3	64 bit mode
VZEROALL		17		6	P2 P3	32 bit mode
VZEROALL		32		10	P2 P3	64 bit mode
LDMXCSR	m32	7		34	P0 P3	
STMXCSR	m32	2		17	P0 P3	
FXSAVE	m4096	67	136	136	P0 P1 P2 P3	
FXRSTOR	m4096	116	176	176	P0 P1 P2 P3	
XSAVE	m	122	196	196	P0 P1 P2 P3	
XRSTOR	m	177	250	250	P0 P1 P2 P3	



## AMD Steamroller

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, x = 128 bit xmm register, y = 256 bit ymm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of macro-operations issued from instruction decoder to schedulers. Instructions with more than 2 macro-operations use microcode.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. The latency listed does not include the memory operand where the listing for register and memory operand are joined (r/m).
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution pipe:</b>	Indicates which execution pipe or unit is used for the macro-operations: Integer pipes: EX0: integer ALU, division EX1: integer ALU, multiplication, jump EX01: can use either EX0 or EX1 AG01: address generation unit 0 or 1 Floating point and vector pipes: P0: floating point add, mul, div. Integer add, mul, bool P1: floating point add, mul, div. Shuffle, shift, pack P2: Integer add. Bool, store P01: can use either P0 or P1 P02: can use either P0 or P2 Two macro-operations can execute simultaneously if they go to different execution pipes
<b>Domain:</b>	Tells which execution unit domain is used: ivec: integer vector execution unit. fp: floating point execution unit. fma: floating point multiply/add subunit. inherit: the output operand inherits the domain of the input operand. ivec/fma means the input goes to the ivec domain and the output comes from the fma domain. There is an additional latency of 1 clock cycle if the output of an ivec instruction goes to the input of a fp or fma instruction, and when the output of a fp or fma instruction goes to the input of an ivec or store instruction. There is no latency between the fp and fma units. All other latencies after memory load and before memory store instructions are included in the latency counts. An fma instruction has a latency of 5 if the output goes to another fma instruction, 6 if the output goes to an fp instruction, and 6+1 if the output goes to an ivec or store instruction.

### Integer instructions

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Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOV	r8,r8	1	1	0.5	EX01	
MOV	r16,r16	1	1	0.5	EX01	
MOV	r32,r32	1	1	0.25	EX01 or AG01	
MOV	r64,r64	1	1	0.25	EX01 or AG01	
MOV	r,i	1	1	0.5	EX01	
MOV	r,m	1	3	0.5	AG01	all addr. modes
MOV	m,r	1	4	1	EX01 AG01	all addr. modes
MOV	m,i	1		1		
MOVNTI	m,r	1	4	1		
MOVZX, MOVSX	r,r	1	1	0.5	EX01	
MOVSX	r,m	1	5	0.5	EX01	
MOVZX	r,m	1	4	0.5	EX01	
MOVSXD	r64,r32	1	1	0.5	EX01	
MOVSXD	r64,m32	1	5	0.5	EX01	
CMOVcc	r,r	1	1	0.5	EX01	
CMOVcc	r,m	1		0.5	EX01	
XCHG	r8,r8	2	1	1	EX01	
XCHG	r16,r16	2	1	1	EX01	
XCHG	r32,r32	2	1	0.5	EX01	
XCHG	r64,r64	2	1	0.5	EX01	
XCHG	r,m	2	~38	~38	EX01	Timing depends on hw
XLAT		2	6	2		
PUSH	r	1		1		
PUSH	i	1		1		
PUSH	m	2		1		
PUSHF(D/Q)		8		4		
PUSHA(D)		9		9		
POP	r	1		1		
POP	m	2		1		
POPF(D/Q)		34		19		
POPA(D)		14		8		
POP	sp	1	2			
LEA	r16,[m]	2	2-3		EX01	any addr. size
LEA	r32,[m]	1	2		EX01	16 bit addr. size
LEA	r32/64,[m]	1	2	0.5	EX01	scale factor > 1
LEA	r32/64,[m]	1	1	0.5	EX01	or 3 operands
LAHF		4	3	2		all other cases
SAHF		2	2	1		
SALC		1	1	1		
BSWAP	r	1	1	0.5	EX01	
PREFETCHNTA	m	1		0.5		
PREFETCHT0/1/2	m	1		0.5		
PREFETCH/W	m	1		0.5		PREFETCHW
SFENCE		7		~80		
LFENCE		1		0,25		
MFENCE		7		~80		
<b>Arithmetic instructions</b>						

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ADD, SUB	r,r	1	1	0.5	EX01
ADD, SUB	r,i	1	1	0.5	EX01
ADD, SUB	r,m	1		0.5	EX01
ADD, SUB	m,r	1	7	1	EX01
ADD, SUB	m,i	1	7	1	EX01
ADC, SBB	r,r	1	1		EX01
ADC, SBB	r,i	1	1		EX01
ADC, SBB	r,m	1	1	1	EX01
ADC, SBB	m,r	1	9	1	EX01
ADC, SBB	m,i	1	9	1	EX01
CMP	r,r	1	1	0.5	EX01
CMP	r,i	1	1	0.5	EX01
CMP	r,m	1		0.5	EX01
CMP	m,i	1		0.5	EX01
INC, DEC, NEG	r	1	1	0.5	EX01
INC, DEC, NEG	m	1	7	1	EX01
AAA, AAS		10	6		
DAA		16	8		
DAS		20	10		
AAD		4	6		
AAM		10	15	15	
MUL, IMUL	r8/m8	1	4	2	EX1
MUL, IMUL	r16/m16	2	4	2	EX1
MUL, IMUL	r32/m32	1	4	2	EX1
MUL, IMUL	r64/m64	1	6	4	EX1
IMUL	r16,r16/m16	1	4	2	EX1
IMUL	r32,r32/m32	1	4	2	EX1
IMUL	r64,r64/m64	1	6	4	EX1
IMUL	r16,(r16),i	2	5	2	EX1
IMUL	r32,(r32),i	1	4	2	EX1
IMUL	r64,(r64),i	1	6	4	EX1
IMUL	r16,m16,i	2		2	EX1
IMUL	r32,m32,i	2		2	EX1
IMUL	r64,m64,i	2		4	EX1
DIV	r8/m8	9	17-22	13-17	EX0
DIV	r16/m16	7	15-25	15-25	EX0
DIV	r32/m32	2	13-39	13-39	EX0
DIV	r64/m64	2	13-70	13-70	EX0
IDIV	r8/m8	9	17-22	13-17	EX0
IDIV	r16/m16	7	14-25	14-24	EX0
IDIV	r32/m32	2	13-39	13-39	EX0
IDIV	r64/m64	2	13-70	13-70	EX0
CBW, CWDE, CDQE		1	1		EX01
CDQ, CQO		1	1	0.5	EX01
CWD		2	1	1	EX01
<b>Logic instructions</b>					
AND, OR, XOR	r,r	1	1	0.5	EX01
AND, OR, XOR	r,i	1	1	0.5	EX01
AND, OR, XOR	r,m	1		0.5	EX01
AND, OR, XOR	m,r	1	7	1	EX01
AND, OR, XOR	m,i	1	7	1	EX01
TEST	r,r	1	1	0.5	EX01

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TEST	r,i	1	1	0.5	EX01	
TEST	m,r	1		0.5	EX01	
TEST	m,i	1		0.5	EX01	
NOT	r	1	1	0.5	EX01	
NOT	m	1	7	1	EX01	
ANDN	r,r,r	1	1	0.5	EX01	BMI1
SHL, SHR, SAR	r,i/CL	1	1	0.5	EX01	
ROL, ROR	r,i/CL	1	1	0.5	EX01	
RCL	r,1	1	1		EX01	
RCL	r,i	16	7		EX01	
RCL	r,cl	17	7		EX01	
RCR	r,1	1	1		EX01	
RCR	r,i	15	7		EX01	
RCR	r,cl	16	7		EX01	
SHLD, SHRD	r,r,i	6	3	3	EX01	
SHLD, SHRD	r,r,cl	7-8	4	4	EX01	
SHLD, SHRD	m,r,i/CL	8		4	EX01	
BT	r,r/i	1	1	0.5	EX01	
BT	m,i	1		0.5	EX01	
BT	m,r	7		3,5	EX01	
BTC, BTR, BTS	r,r/i	2	2	1	EX01	
BTC, BTR, BTS	m,i	4		2	EX01	
BTC, BTR, BTS	m,r	10		5	EX01	
BSF	r,r	6	3	3	EX01	
BSF	r,m	8	4	4	EX01	
BSR	r,r	7	4	4	EX01	
BSR	r,m	9		5	EX01	
SETcc	r	1	1	0.5	EX01	
SETcc	m	1		1	EX01	
CLC, STC		1		0.5	EX01	
CMC		1	1		EX01	
CLD		2		3		
STD		2		4		
POPCNT	r16/32,r16/32	1	4	2		SSE4.2
POPCNT	r64,r64	1	4	4		SSE4.2
LZCNT	r,r	1	2	2	EX0	LZCNT
TZCNT	r,r	2	2	2		BMI1
BEXTR	r,r,r	2	2	1		BMI1
BEXTR	r,r,i	2	2	1		AMD TBM
BLSI	r,r	2	2	1		BMI1
BLSMSK	r,r	2	2	1		BMI1
BLSR	r,r	2	2	1		BMI1
BLCFILL	r,r	2	2	1		AMD TBM
BLCI	r,r	2	2	1		AMD TBM
BLCIC	r,r	2	2	1		AMD TBM
BLCMSK	r,r	2	2	1		AMD TBM
BLCS	r,r	2	2	1		AMD TBM
BLSFILL	r,r	2	2	1		AMD TBM
BLSI	r,r	2	2	1		AMD TBM
BLSIC	r,r	2	2	1		AMD TBM
T1MSKC	r,r	2	2	1		AMD TBM
TZMSK	r,r	2	2	1		AMD TBM

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<b>Control transfer instructions</b>						
JMP	short/near	1		2	EX1	
JMP	r	1		2	EX1	
JMP	m	1		2	EX1	
Jcc	short/near	1		1-2	EX1	2 if jumping
fused CMP+Jcc	short/near	1		1-2	EX1	2 if jumping
J(E/R)CXZ	short	1		1-2	EX1	2 if jumping
LOOP	short	1		1-2	EX1	2 if jumping
LOOPE LOOPNE	short	1		1-2	EX1	2 if jumping
CALL	near	2		2	EX1	
CALL	r	2		2	EX1	
CALL	m	3		2	EX1	
RET		1		2	EX1	
RET	i	4		2	EX1	
BOUND	m	11		5		for no jump
INTO		4		2		for no jump
<b>String instructions</b>						
LODS		3		3		
REP LODS	m8/m16	6n		3n		
REP LODS	m32/m64	6n		2.5n		
STOS		3		3		
REP STOS		1n		~1n		small n
REP STOS		3 per 16B		2 per 16B		best case
MOVS		5		3		
REP MOVS		~1n		~1n		small n
REP MOVS		4-5 pr 16B		~2 per 16B		best case
SCAS		3		3		
REP SCAS		7n		3-4n		
CMPS		6		3		
REP CMPS		9n		4n		
<b>Synchronization</b>						
LOCK ADD	m,r	1	~39			
XADD	m,r	4	9-12			
LOCK XADD	m,r	4	~39			
CMPXCHG	m,r8	5	15			
CMPXCHG	m,r16	6	15			
CMPXCHG	m,r32/64	6	13			
LOCK CMPXCHG	m8,r8	5	~40			
LOCK CMPXCHG	m16,r16	6	~40			
LOCK CMPXCHG	m,r32/64	6	~40			
CMPXCHG8B	m64	18	~14			
LOCK CMPXCHG8B	m64	18	~42			
CMPXCHG16B	m128	24	~47			
LOCK CMPXCHG16B	m128	24	~80			
<b>Other</b>						
NOP (90)		1		0.25	none	
Long NOP (0F 1F)		1		0.25	none	
PAUSE		8		4		
ENTER	a,0	13		21		
ENTER	a,b	11+5b		20-30		

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LEAVE		2		3	
CPUID		38-64		100-300	
XGETBV		4		30	
RDTSC		44		78	
RDTSCP		44		105	rdtscp
RDPMC		22		360	
CRC32	r32,r8	3	3	2	
CRC32	r32,r16	5	5	5	
CRC32	r32,r32	7	6	6	

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
FLD	r	1	2	0.5	P01	fp
FLD	m32/64	1	7	1		fp
FLD	m80	8	11	4		fp
FBLD	m80	60	52	34	P0 P1 P2	fp
FST(P)	r	1	2	0.5	P01	fp
FST(P)	m32/64	2	7	1		fp
FSTP	m80	13	14	19		fp
FBSTP	m80	239	222	222	P0 P1 P2	fp
FXCH	r	1	0	0.5	P01	inherit
FILD	m	1	11	1	P01	fp
FIST(T)(P)	m	2	7	1	P0 P2	fp
FLDZ, FLD1		1		0.5	P01	fp
FCMOVcc	st0,r	8	3	3	P0 P1 P2	fp
FFREE	r	1		0.25	none	
FINCSTP, FDECSTP		1	0	0.25	none	inherit
FNSTSW	AX	3	11	19	P0 P2	
FNSTSW	m16	2		17	P0 P2	
FLDCW	m16	1		3		
FNSTCW	m16	2		2		
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	5	1	P01	fma
FIADD,FISUB(R)	m	2		2	P01	fma
FMUL(P)	r/m	1	5	1	P01	fma
FIMUL	m	2		2	P01	fma
FDIV(R)(P)	r	1	9-37	4-16	P01	fp
FDIV(R)	m	1			P01	fp
FIDIV(R)	m	2		4	P01	fp
FABS, FCHS		1	2	0.5	P01	fp
FCOM(P), FUCOM(P)	r/m	1		0.5	P01	fp
FCOMPP, FUCOMPP		1		0.5	P01	fp
FCOMI(P)	r	2	2	1	P01 P2	fp
FICOM(P)	m	2		1	P01	fp
FTST		1		0.5	P01	fp
FXAM		1	26	0.5	P01	fp
FRNDINT		1	4	1	P0	fp
FPREM FPREM1		1	17-60	12-53	P0	fp

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<b>Math</b>						
FSQRT		1	10-50	5-20		P01
FLDPI, etc.		1		0.5		P01
FSIN		10-164	60-210	60-165		P0 P1 P2
FCOS		18-166	76-158			P0 P1 P2
FSINCOS		12-168		90-165		P0 P1 P2
FPTAN		11-192	90-245	90-210		P0 P1 P2
FPATAN		10-365	60-440	60-365		P0 P1 P2
FSCALE		10	49	5		P0 P1 P2
FEXTRACT		12	8	5		P0 P1 P2
F2XM1		10-18	60-74			P0 P1 P2
FYL2X		9-183	60-280			P0 P1 P2
FYL2XP1		206	~390			P0 P1 P2
<b>Other</b>						
FNOP		1		0.25		none
(F)WAIT		1		0.25		none
FNCLEX		18		63		P0
FNINIT		31		131		P0
FNSAVE	m864	98	256	256		P0 P1 P2
FRSTOR	m864	73	166	166		P0 P2

### Integer vector instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOVD	r32/64, mm/x	1	4	1	P2	
MOVD	mm/x, r32/64	2	5	1		
MOVD	mm/x, m32	1	2	0.5		
MOVD	m32, mm/x	1	3	1		
MOVQ	mm/x, mm/x	1	2	0.5	P02	
MOVQ	mm/x, m64	1	2	0.5		
MOVQ	m64, mm/x	1	3	1		
MOVDQA	xmm, xmm	1	0	0.25	none	inherit domain
MOVDQA	xmm, m	1	2	0.5		
MOVDQA	m, xmm	1	3	1	P2	
VMOVDQA	ymm, ymm	2	2	0.5	P02	
VMOVDQA	ymm, m256	2	3	1		
VMOVDQA	m256, ymm	2	4	1	P2	
MOVDQU	xmm, xmm	1	0	0.25	none	inherit domain
MOVDQU	xmm, m	1	2	0.5		
MOVDQU	m, xmm	1	3	1	P2	
LDDQU	xmm, m	1	2	0.5		
VMOVDQU	ymm, m256	2	3	1		
VMOVDQU	m256, ymm	2	4	1		
MOVDQ2Q	mm, xmm	1	1	0.5	P02	
MOVQ2DQ	xmm, mm	1	1	0.5	P02	
MOVNTQ	m, mm	1	3	1	P2	
MOVNTDQ	m, xmm	1	3	1	P2	
MOVNTDQA	xmm, m	1	2	0.5		

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PACKSSWB/DW	(x)mm,r/m	1	2	1	P1	
PACKUSWB	(x)mm,r/m	1	2	1	P1	
PUNPCKH/LBW/WD/D Q	(x)mm,r/m	1	2	1	P1	
PUNPCKHQDQ	xmm,r/m	1	2	1	P1	
PUNPCKLQDQ	xmm,r/m	1	2	1	P1	
PSHUFB	(x)mm,r/m	1	3	1	P1	
PSHUFD	xmm,xmm,i	1	2	1	P1	
PSHUFW	mm,mm,i	1	2	1	P1	
PSHUFL/HW	xmm,xmm,i	1	2	1	P1	
PALIGNR	(x)mm,r/m,i	1	2	1	P1	
PBLENDW	xmm,r/m	1	2	0.5	P02	SSE4.1
MASKMOVQ	mm,mm	31	32	16	P2	
MASKMOVDQU	xmm,xmm	65	45	31	P0 P1 P2	
PMOVMSKB	r32,mm/x	2	5	1	P1 P2	
PEXTRB/W/D/Q	r,x/mm,i	2	5	1	P1 P2	SSE4.1
PINSRB/W/D/Q	x/mm,r,i	2	6	1	P1	
EXTRQ	x,i,i	1	3	1	P1	AMD SSE4A
EXTRQ	x,x	1	1	1	P1	AMD SSE4A
INSERTQ	x,x,i,i	1	1	1	P1	AMD SSE4A
INSERTQ	x,x	1	1	1	P1	AMD SSE4A
PMOVSBW/BD/BQ/W D/WQ/DQ	x,x	1	2	1	P1	SSE4.1
PMOVZXBW/BD/BQ/W D/WQ/DQ	x,x	1	2	1	P1	SSE4.1
VPCMOV	x,x,x,x/m	1	2	1	P1	AMD XOP
VPCMOV	y,y,y,y/m	2	2	2	P1	AMD XOP
VPPERM	x,x,x,x/m	1	2	1	P1	AMD XOP
<b>Arithmetic instructions</b>						
PADDB/W/D/Q/SB/SW/ USB/USW	(x)mm,r/m	1	2	0.5	P02	
PSUBB/W/D/Q/SB/SW/ USB/USW	(x)mm,r/m	1	2	0.5	P02	
PHADD/SUB(S)W/D	x,x	3	5	2	P02 2P1	SSSE3
PCMPEQ/GT B/W/D	(x)mm,r/m	1	2	0.5	P02	
PCMPEQQ	(x)mm,r/m	1	2	0.5	P02	SSE4.1
PCMPGTQ	(x)mm,r/m	1	2	0.5	P02	SSE4.2
PMULLW PMULHW PMULHUW PMULUDQ	(x)mm,r/m	1	4	1	P0	
PMULLD	x,r/m	1	5	2	P0	SSE4.1
PMULDQ	x,r/m	1	4	1	P0	SSE4.1
PMULHRSW	(x)mm,r/m	1	4	1	P0	SSSE3
PMADDWD	(x)mm,r/m	1	4	1	P0	
PMADDUBSW	(x)mm,r/m	1	4	1	P0	
PAVGB/W	(x)mm,r/m	1	2	0.5	P02	
PMIN/MAX SB/SW/ SD UB/UW/UD	(x)mm,r/m	1	2	0.5	P02	
PHMINPOSUW	x,r/m	2	4	1	P1 P02	SSE4.1
PABSB/W/D	(x)mm,r/m	1	2	0.5	P02	SSSE3
PSIGNB/W/D	(x)mm,r/m	1	2	0.5	P02	SSSE3
PSADBW	(x)mm,r/m	2	4	1	P02	



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MPSADBW	x,x,i	8	8	4	P1 P02	SSE4.1
VPCOMB/W/D/Q	x,x,x/m,i	1	2	0.5	P02	AMD XOP latency 0 if i=6,7
VPCOMUB/W/D/Q	x,x,x/m,i	1	2	0.5	P02	AMD XOP latency 0 if i=6,7
VPHADDBW/BD/BQ/ WD/WQ/DQ	x,x/m	1	2	0.5	P02	AMD XOP
VPHADDUBW/BD/BQ/ WD/WQ/DQ	x,x/m	1	2	0.5	P02	AMD XOP
VPHSUBBW/WD/DQ	x,x/m	1	2	0.5	P02	AMD XOP
VPMACSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSWW/WD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMACSSD	x,x,x/m,x	1	5	2	P0	AMD XOP
VPMACSSDQH/L	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
VPMADCSSWD	x,x,x/m,x	1	4	1	P0	AMD XOP
<b>Logic</b>						
PAND PANDN POR PXOR	(x)mm,r/m	1	2	0.5	P02	
PSLL/RL W/D/Q PSRAW/D	(x)mm,r/m	1	3	1	P1	
PSLL/RL W/D/Q PSRAW/D	(x)mm,i	1	2	1	P1	
PSLLDQ, PSRLDQ	x,i	1	2	1	P1	
PTEST	x,r/m	2	14	1	P1 P2	SSE4.1
VPROTB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPROTB/W/D/Q	x,x,i	1	2	1	P1	AMD XOP
VPSHAB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
VPSHLB/W/D/Q	x,x,x/m	1	3	1	P1	AMD XOP
<b>String instructions</b>						
PCMPESTRI	x,x,i	30	11	11	P0 P1 P2	SSE4.2
PCMPESTRM	x,x,i	30	10	10	P0 P1 P2	SSE4.2
PCMPISTRI	x,x,i	9	5	5	P0 P1 P2	SSE4.2
PCMPISTRM	x,x,i	8	6	6	P0 P1 P2	SSE4.2
<b>Encryption</b>						
PCLMULQDQ	x,x/m,i	7	11	7	P1	pclmul
VPCLMULQDQ	x,x,x,i	7	11	7	P1	pclmul
PCLMULQDQ	x,x,m,i	8		7	P1	pclmul
AESDEC	x,x	2	5	1	P01	aes
AESDECLAST	x,x	2	5	1	P01	aes
AESENC	x,x	2	5	1	P01	aes
AESENCLAST	x,x	2	5	1	P01	aes
AESIMC	x,x	1	5	1	P0	aes
AESKEYGENASSIST	x,x,i	1	5	1	P0	aes
<b>Other</b>						
EMMS		1		0.25		

## Floating point XMM and YMM instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
MOVAPS/D						
MOVUPS/D	x,x	1	0	0.25	none	inherit domain
VMOVAPS/D	y,y	2	2	0.5	P02	ivec
MOVAPS/D						
MOVUPS/D	x,m128	1	2	0.5		
VMOVAPS/D						
VMOVUPS/D	y,m256	2	2	1		
MOVAPS/D						
MOVUPS/D	m128,x	1	3	1	P2	
VMOVAPS/D	m256,y	2	3	2	P2	
VMOVUPS/D	m256,y	2	3	2	P2	
MOVSS/D	x,x	1	2	0.5	P01	fp
MOVSS/D	x,m32/64	1	2	0.5		
MOVSS/D	m32/64,x	1	3	1	P2	
MOVHPS/D	x,m64	1	3	1	P1	
MOVLPS/D	x,m64	1	3	0.5	P01	
MOVHPS/D	m64,x	2	4	1	P1 P2	
MOVLPS/D	m64,x	1	3	1	P2	
MOVLHPS MOVHLPS	x,x	1	2	1	P1	ivec
MOVMSKPS/D	r32,x	2	5	1	P1 P2	
VMOVMSKPS/D	r32,y	2	15	1	P1 P2	
MOVNTPS/D	m128,x	1	3	1	P2	
VMOVNTPS/D	m256,y	2	3	2-3	P2	
MOVNTSS/SD	m,x	1		3	P2	AMD SSE4A
SHUFPS/D	x,x/m,i	1	2	1	P2	ivec
VSHUFPS/D	y,y,y/m,i	2	2	2	P2	ivec
VPERMILPS/PD	x,x,x/m	1	3	1	P1	ivec
VPERMILPS/PD	y,y,y/m	2	3	2	P1	ivec
VPERMILPS/PD	x,x/m,i	1	2	1	P1	ivec
VPERMILPS/PD	y,y/m,i	2	2	2	P1	ivec
VPERM2F128	y,y,y,i	8	4	3.5	P0 P2	ivec
VPERM2F128	y,y,m,i	12		4	P0 P2	ivec
BLENDPS/PD	x,x/m,i	1	2	0.5	P01	fp
VBLENDPS/PD	y,y,y/m,i	2	2	1	P01	fp
BLENDVPS/PD	x,x/m,xmm0	1	2	0.5	P01	
VBLENDVPS/PD	y,y,y/m,y	2	2	1	P01	
MOVDDUP	x,x	1	2	1	P1	ivec
MOVDDUP	x,m64	1		0.5		
VMOVDDUP	y,y	2	2	2	P1	ivec
VMOVDDUP	y,m256	2		1		
VBROADCASTSS	x,m32	1	8	0.5		
VBROADCASTSS	y,m32	2	8	0.5	P02	
VBROADCASTSD	y,m64	2	8	0.5	P02	
VBROADCASTF128	y,m128	2	8	0.5	P02	
MOVSH/LDUP	x,x	1	2	1	P1	ivec
MOVSH/LDUP	x,m128	1		0.5		

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VMOVSH/LDUP	y,y	2	2	2	P1	ivec
VMOVSH/LDUP	y,m256	2		1		
UNPCKH/LPS/D	x,x/m	1	2	1	P1	ivec
VUNPCKH/LPS/D	y,y,y/m	2	2	2	P1	ivec
EXTRACTPS	r32,x,i	2		1	P1 P2	
EXTRACTPS	m32,x,i	2	10	1	P1 P2	
VEXTRACTF128	x,y,i	1	2	0.5	P02	ivec
VEXTRACTF128	m128,y,i	2	10	1	P0 P2	
INSERTPS	x,x,i	1	2	1	P1	
INSERTPS	x,m32,i	1	9	2	P1	
VINSERTF128	y,y,x,i	2	2	1	P02	ivec
VINSERTF128	y,y,m128,i	2	10	1	P02	
VMASKMOVPS/D	x,x,m128	1	9	0.5	P01	
VMASKMOVPS/D	y,y,m256	2	9	1	P01	
VMASKMOVPS/D	m128,x,x	20	~35	8	P0 P1 P2	
VMASKMOVPS/D	m256,y,y	41	~35	16	P0 P1 P2	
<b>Conversion</b>						
CVTPD2PS	x,x	2	6	1	P01	ivec/fp
VCVTPD2PS	x,y	4	6	2	P01	ivec/fp
CVTPS2PD	x,x	2	6	1	P01	ivec/fp
VCVTPS2PD	y,x	4	6	2	P01	ivec/fp
CVTSD2SS	x,x	1	4	1	P0	fp
CVTSS2SD	x,x	1	4	1	P0	fp
CVTDQ2PS	x,x	1	4	1	P0	fp
VCVTDQ2PS	y,y	2	4	2	P0	fp
CVT(T) PS2DQ	x,x	1	4	1	P0	fp
VCVT(T) PS2DQ	y,y	2	4	2	P0	fp
CVTDQ2PD	x,x	2	7	1	P01	ivec/fp
VCVTDQ2PD	y,x	4	7	2	P01	ivec/fp
CVT(T)PD2DQ	x,x	2	7	1	P01	fp/ivec
VCVT(T)PD2DQ	x,y	4	7	2	P01	fp/ivec
CVTPI2PS	x,mm	2	6	1	P0 P2	ivec/fp
CVT(T)PS2PI	mm,x	1	5	1	P0	fp
CVTPI2PD	x,mm	2	7	1	P0 P1	ivec/fp
CVT(T) PD2PI	mm,x	2	7	1	P0 P1	fp/ivec
CVTSI2SS	x,r32	2	13	1	P0	fp
CVT(T)SS2SI	r32,x	2	12	1	P0 P2	fp
CVTSI2SD	x,r32/64	2	12	1	P0	fp
CVT(T)SD2SI	r32/64,x	2	12	1	P0 P2	fp
VCVTPS2PH	x/m,x,i	2	7	2	P0 P1	F16C
VCVTPS2PH	x/m,y,i	4	7	2	P0 P1	F16C
VCVTPH2PS	x,x/m	2	7	2	P0 P1	F16C
VCVTPH2PS	y,x/m	4	7	2	P0 P1	F16C
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	x,x/m	1	5-6	1	P01	fma
ADDPS/D SUBPS/D	x,x/m	1	5-6	1	P01	fma
VADDPS/D VSUBPS/D	y,y,y/m	2	5-6	2	P01	fma
ADDSUBPS/D	x,x/m	1	5-6	1	P01	fma
VADDSUBPS/D	y,y,y/m	2	5-6	1	P01	fma

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HADDPS/D HSUBPS/D	x,x	4	10	2	P0 P1	ivec/fma
VHADDPS/D						
VHSUBPS/D	y,y,y/m	8	10	4	P01 P1	ivec/fma
MULSS MULSD	x,x/m	1	5-6	0.5	P01	fma
MULPS MULPD	x,x/m	1	5-6	0.5	P01	fma
VMULPS VMULPD	y,y,y/m	2	5-6	1	P01	fma
DIVSS DIVPS	x,x/m	1	9-17	4-6	P01	fp
VDIVPS	y,y,y/m	2	9-17	9-12	P01	fp
DIVSD DIVPD	x,x/m	1	9-32	4-13	P01	fp
VDIVPD	y,y,y/m	2	9-32	9-27	P01	fp
RCPSS/PS	x,x/m	1	5	1	P01	fp
VRCPPS	y,y/m	2	5	2	P01	fp
CMPSS/D						
CMPPS/D	x,x/m	1	2	0.5	P01	fp
VCMPPS/D	y,y,y/m	2	2	1	P01	fp
COMISS/D						
UCOMISS/D	x,x/m	2		1	P01 P2	fp
MAXSS/SD/PS/PD						
MINSS/SD/PS/PD	x,x/m	1	2	0.5	P01	fp
VMAXPS/D VMINPS/D	y,y,y/m	2	2	1	P01	fp
ROUNDSS/SD/PS/PD	x,x/m,i	1	4	1	P0	fp
VROUNDSS/SD/PS/ PD	y,y/m,i	2	4	2	P0	fp
DPPS	x,x,i	9	25	4	P0 P1	SSE4.1
DPPS	x,m,i	10		5	P0 P1	SSE4.1
VDPPS	y,y,y,i	13	25	8	P0 P1	SSE4.1
VDPPS	y,m,i	15		8	P0 P1	SSE4.1
DPPD	x,x,i	7	14	3	P0 P1	SSE4.1
DPPD	x,m,i	8		4	P0 P1	SSE4.1
VFMADD132SS/SD	x,x,x/m	1	5-6	0.5	P01	FMA3
VFMADD132PS/PD	x,x,x/m	1	5-6	0.5	P01	FMA3
VFMADD132PS/PD	y,y,y/m	2	5-6	1	P01	FMA3
All other FMA3 instructions: same as above						FMA3
VFMADDSS/SD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	x,x,x,x/m	1	5-6	0.5	P01	AMD FMA4
VFMADDPS/PD	y,y,y,y/m	2	5-6	1	P01	AMD FMA4
All other FMA4 instructions: same as above						AMD FMA4
<b>Math</b>						
SQRTSS/PS	x,x/m	1	12-13	4-9	P01	fp
VSQRTPS	y,y/m	2	12-13	9-18	P01	fp
SQRTSD/PD	x,x/m	1	26-29	4-18	P01	fp
VSQRTPD	y,y/m	2	27-28	9-37	P01	fp
RSQRTSS/PS	x,x/m	1	5	1	P01	fp
VRSQRTPS	y,y/m	2	5	2	P01	fp
VFRCZSS/SD/PS/PD	x,x	2	10	2	P01	AMD XOP
VFRCZSS/SD/PS/PD	x,m	4		2	P01	AMD XOP
<b>Logic</b>						
AND/ANDN/OR/XORPS/ PD	x,x/m	1	2	0.5	P02	ivec

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VAND/ANDN/OR/XOR PS/PD	y,y,y/m	2	2	1	P02	ivec
<b>Other</b>						
VZEROUPPER		9		4		32 bit mode
VZEROUPPER		16		5		64 bit mode
VZEROALL		17		6	P02	32 bit mode
VZEROALL		32		10	P02	64 bit mode
LDMXCSR	m32	9		36	P0 P2	
STMXCSR	m32	2		17	P0 P2	
FXSAVE	m4096	59-67		78	P0 P1 P2	
FXRSTOR	m4096	104-112		160	P0 P1 P2	
XSAVE	m	121-137		147-166	P0 P1 P2	
XRSTOR	m	191-209		291-297	P0 P1 P2	

## AMD Ryzen

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

**Instruction:** Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.

**Operands:** i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, x = 128 bit xmm register, y = 256 bit ymm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.

**Ops:** Number of macro-operations issued from instruction decoder to schedulers.

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. The latency listed does not include the memory operand where the listing for register and memory operand are joined (r/m).

**Reciprocal throughput:** This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/3 indicates that the execution units can handle 3 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.

**Execution pipe:** Indicates which execution pipe or unit is used for the macro-operations:  
 P0: Floating point and vector pipe 0  
 P1: Floating point and vector pipe 1  
 P2: Floating point and vector pipe 2  
 P3: Floating point and vector pipe 3  
 P0 P1: Uses both P0 and P1  
 P01: Uses either P0 and P1  
 Where no unit is specified, it uses one or more integer pipe or address generation units.  
 Two micro-operations can execute simultaneously if they go to different execution pipes

**Domain:** Tells which execution unit domain is used:  
 ivec: integer vector execution unit.  
 fp: floating point execution unit.  
 inherit: the output operand inherits the domain of the input operand.  
 There is an additional latency of 1 clock cycle if the output of an ivec instruction goes to the input of a fp instruction, and when the output of a fp instruction goes to the input of an ivec instruction. All other latencies after memory load and before memory store instructions are included in the latency counts.

### Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOV	r8,r8	1	1	0.25		
MOV	r16,r16	1	1	0.25		
MOV	r32,r32	1	0	0.3		renaming
MOV	r64,r64	1	0	0.2		renaming
MOV	r8,i	1		0.25		
MOV	r16,i	1		0.25		
MOV	r32,i	1		0.25		

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MOV	r64,i	1		0.25	
MOV	r,m	1	3	0.5	
MOV	m,r	1	4	1	
MOV	m,i	1		1	
MOVNTI	m,r	1	high	1	
MOVZX, MOVZX	r,r	1	1	0.5	
MOVZX, MOVZX	r,m	1	3	0.5	
MOVSXD	r64,r32	1	1	0.5	
MOVSXD	r64,m32	1	3	0.5	
CMOVcc	r,r	1	1	0.25	
CMOVcc	r,m	1		0.5	
XCHG	r8,r8	2	1	1	
XCHG	r16,r16	2	1	1	
XCHG	r32,r32	2	0	0.33	renaming
XCHG	r64,r64	2	0	0.33	renaming
XCHG	r,m	2	~30	~30	depends on hw
XLAT		2	5	2	
PUSH	r	1		1	
PUSH	i	1		1	
PUSH	m	2		1	
PUSHF(D/Q)		9		4	
PUSH	sp	2		1	
PUSHA(D)		9		8	
POP	r	1		0.5	
POP	m	2		1	
POPF(D/Q)		35		13	
POPA(D)		9		4	
POP	sp	1	2	2	
LEA	r16,[m]	2	2-3	1	
LEA	r32/64,[m]	1	2	0.5	scale factor > 1 or 3 operands
LEA	r32,[m]	1	2	0.5	64 bit mode
LEA	r32/64,[m]		1	0.5	rip relative
LEA	r32/64,[m]	1	1	0.25	all other cases
LAHF		4	3	2	
SAHF		2	2	0.5	
SALC		1	1	1	
BSWAP	r	1	1	0.25	
MOVBE	r,[m]	1		0.5	MOVBE
MOVBE	[m],r	1		1	MOVBE
PREFETCHNTA	m	1		0.5	
PREFETCHT0/1/2	m	1		0.5	
PREFETCH/W	m	1		0.5	PREFETCHW
SFENCE		4		~20	
LFENCE		1		0,25	
MFENCE		7		~70	
<b>Arithmetic instructions</b>					
ADD, SUB	r,r	1	1	0.25	
ADD, SUB	r,i	1	1	0.25	
ADD, SUB	r,m	1		0.5	
ADD, SUB	m,r	1	6	1	
ADD, SUB	m,i	1	6	1	

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ADC, SBB	r,r	1	1		
ADC, SBB	r,i	1	1		
ADC, SBB	r,m	1	1	1	
ADC, SBB	m,r	1	6	1	
ADC, SBB	m,i	1	6	1	
ADCX ADOX	r,r	1	1	1	ADX
CMP	r,r	1	1	0.25	
CMP	r,i	1	1	0.25	
CMP	r,m	1		0.5	
CMP	m,i	1		0.5	
INC, DEC, NEG	r	1	1	0.25	
INC, DEC, NEG	m	1	6	1	
AAA, AAS		10	6		
DAA		16	8		
DAS		20	9		
AAD		4	5		
AAM		4	13		
MUL, IMUL	r8/m8	1	3	1	
MUL, IMUL	r16/m16	3	3	2	
MUL, IMUL	r32/m32	2	3	2	
MUL, IMUL	r64/m64	2	3	2	
IMUL	r,r	1	3	1	
IMUL	r,m	1		1	
IMUL	r16,r16,i	2	4	1	
IMUL	r32,r32,i	1	3	1	
IMUL	r64,r64,i	1	3		
IMUL	r16,m16,i	2		1	
IMUL	r32,m32,i	1		1	
IMUL	r64,m64,i	1		1	
MULX	r,r,r	2	4	2	BMI2
DIV	r8/m8	1	13-16	13-16	
DIV	r16/m16	2	14-21	14-21	depends on operand values
DIV	r32/m32	2	14-30	14-30	
DIV	r64/m64	2	14-46	14-45	
IDIV	r8/m8	1	13-16	13-16	
IDIV	r16/m16	2	13-21	14-22	
IDIV	r32/m32	2	14-30	14-30	
IDIV	r64/m64	2	14-47	14-45	
CBW		1	1	1	
CWDE, CDQE		1	1	0.5	
CDQ, CQO		1	1	0.25	
CWD		2	1	1	
<b>Logic instructions</b>					
AND, OR, XOR	r,r	1	1	0.25	
AND, OR, XOR	r,i	1	1	0.25	
AND, OR, XOR	r,m	1		0.5	
AND, OR, XOR	m,r	1	6	1	
AND, OR, XOR	m,i	1	6	1	
TEST	r,r	1	1	0.25	
TEST	r,i	1	1	0.25	
TEST	m,r	1		0.5	
TEST	m,i	1		0.5	



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NOT	r	1	1	0.25	
NOT	m	1	6	1	
ANDN	r,r,r	1	1	0.25	BMI1
SHL, SHR, SAR	r,i/CL	1	1	0.25	
ROL, ROR	r,i/CL	1	1	0.25	
RCL	r,1	1	1	1	
RCL	r,i	9	4	4	
RCL	r,cl	9	4	4	
RCR	r,1	1	1	1	
RCR	r,i	7	3	3	
RCR	r,cl	7	3	3	
SHLD, SHRD	r,r,i	6	3	3	
SHLD, SHRD	r,r,cl	7	3	3	
SHLD, SHRD	m,r,i/CL	8		3	
SARX	r,r,r	1	1	0.25	BMI2
SHLX	r,r,r	1	1	0.25	BMI2
SHRX	r,r,r	1	1	0.25	BMI2
RORX	r,r,i	1	1	0.25	BMI2
BT	r,r/i	1	1	0.25	
BT	m,i	1		0.5	
BT	m,r	5		3	
BTC, BTR, BTS	r,r/i	2	2	0.5	
BTC, BTR, BTS	m,i	4		2	
BTC, BTR, BTS	m,r	8		3	
BSF	r,r	6	3	3	
BSF	r,m	8	4	4	
BSR	r,r	6	4	4	
BSR	r,m	8	4	4	
SETcc	r	1	1	0.5	
SETcc	m	1		2	
CLC, STC		1		0.25	
CMC		1	1		
CLD		2		3	
STD		2		4	
POPCNT	r,r	1	1	0.25	SSE4.2
LZCNT	r,r	1	1	0.25	LZCNT
TZCNT	r,r	2	2	0.5	BMI1
BEXTR	r,r,r	1	1	0.25	BMI1
BLSI	r,r	2	2	0.5	BMI1
BLSMSK	r,r	2	2	0.5	BMI1
BLSR	r,r	2	2	0.5	BMI1
PDEP	r,r,r	6	18	18	BMI2
PEXT	r,r,r	7	18	18	BMI2
BZHI	r,r,r	1	1	0.25	BMI2
<b>Control transfer instructions</b>					
JMP	short/near	1		2	
JMP	r	1		2	
JMP	m	1		2	
Jcc	short/near	1		0.5-2	2 if jumping
fused CMP+Jcc	short/near	1		0.5-2	2 if jumping
J(E/R)CXZ	short	1		0.5-2	2 if jumping

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LOOP	short	1		2		2 if jumping
LOOPE LOOPNE	short	1		2		2 if jumping
CALL	near	2		2		
CALL	r	2		2		
CALL	m	6		2		
RET		1		2		
RET	i	2		2		
BOUND	m	11		3		for no jump
INTO		4		2		for no jump
<b>String instructions</b>						
LODS		3		3		
REP LODS	m	6n		2n		
STOS		3		3		
REP STOS		1n		~1n		small n
REP STOS		3 per 16B		1 per 16B		best case
MOVS		5		3		
REP MOVS		~1n		~1n		small n
REP MOVS		4 pr 16B		1 per 16B		best case
SCAS		3		3		
REP SCAS		7n		2n		
CMPS		6		3		
REP CMPS		9n		3n		
<b>Synchronization</b>						
LOCK ADD	m,r	1	~17			
XADD	m,r	4	7			
LOCK XADD	m,r	4	~23			
CMPXCHG	m,r8	5	8			
CMPXCHG	m,r16	6	8			
CMPXCHG	m,r32/64	6	8			
LOCK CMPXCHG	m8,r8	5	~22			
LOCK CMPXCHG	m16,r16	6	~22			
LOCK CMPXCHG	m,r32/64	6	~22			
CMPXCHG8B	m64	18	8			
LOCK CMPXCHG8B	m64	18	~22			
CMPXCHG16B	m128	27	13			
LOCK CMPXCHG16B	m128	27	~21			
<b>Other</b>						
NOP (90)		1		0.2		
Long NOP (0F 1F)		1		0.2		
PAUSE		8		3		
ENTER	a,0	12		16		
ENTER	a,b	11+3b		~18+b		
LEAVE		2		3		
CPUID		37-50		125-133		
XGETBV				42		
RDTSC		37		36		
RDTSCP		64		64		rdtscp
RDPMSR		20		20		
CRC32	r32,r8	3	3	3		

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CRC32	r32,r16	3	3	3	
CRC32	r32,r32	3	3	3	
RDRAND RDSEED	r16/32	13		~1200	
RDRAND RDSEED	r64	19		~2500	

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						
FLD	r	1	1	1	P3	
FLD	m32/64	1	6	1	P1	
FLD	m80	8	7	4		
FBLD	m80	24		24	P2 P3	
FST(P)	r	1	1	1	P3	
FST(P)	m32/64	2	5	1	P2 P3	
FSTP	m80	15	8			
FBSTP	m80	274		~145	P2 P3	
FXCH	r	1	0	0.25		
FILD	m	1	8	1	P3	
FIST(T)(P)	m	2	5	1	P2 P3	
FLDZ, FLD1		1		1	P3	
FCMOVcc	st0,r	7	3	3	P0 P1 P2 P3	
FFREE	r	1	0	0.25		
FINCSTP, FDECSTP		1	0	0.25		
FNSTSW	AX	3		16	P2 P3	
FNSTSW	m16	2		14	P2 P3	
FLDCW	m16	1		2	P3	
FNSTCW	m16	2		2	P2 P3	
<b>Arithmetic instructions</b>						
FADD(P),FSUB(R)(P)	r/m	1	5	1	P0	
FIADD,FISUB(R)	m	2		1	P0 P3	
FMUL(P)	r/m	1	5	1	P0	
FIMUL	m	2		1	P0 P3	
FDIV(R)(P)	r	1	8-15	4-6	P3	
FDIV(R)	m	1			P3	
FIDIV(R)	m	2			P3	
FABS, FCHS		1	1	1	P3	
FCOM(P), FUCOM(P)	r/m	1		1	P0	
FCOMPP, FUCOMPP		1		1	P0	
FCOMI(P)	r	2		1	P2	
FICOM(P)	m	2		1	P0 P3	
FTST		1		1	P0	
FXAM		1		1	P3	
FRNDINT		1	4	3		
FPREM FPREM1		2		12-50		
<b>Math</b>						
FSQRT		1	8-21	4-10	P3	
FLDPI, etc.		1		1	P3	
FSIN		11-60	50-170		P0 P3	

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FCOS		55	50-115			
FSINCOS		80-140	60-120		P0 P3	
FPTAN		11-52	~90	50-80		
FPATAN		11-82	50-160	45-150		
FSCALE		8	9	4	P0 P2 P3	
FXTRACT		13	10	7	P0 P2 P3	
F2XM1		10	~50		P2 P3	
FYL2X		10-25	~50	~50	P0 P2 P3	
FYL2XP1		69	~135	~135	P0 P2 P3	
<b>Other</b>						
FNOP		1		0.25		
(F)WAIT		1		0.25		
FNCLEX		20		45		
FNINIT		34		85		
FNSAVE	m864	99		~160		
FRSTOR	m864	77		~130		

**Integer vector instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Notes
<b>Move instructions</b>						
MOVD	r32, mm	1	3	1		
MOVD	mm, r32	2	3	1		
MOVD	r32/64, x	1	3	1		
MOVD	x, r32/64	1	3	1		
MOVD	mm/x,m32	1	4	0.5		
MOVD	m32,mm/x	1	4	1	P2	
MOVQ	mm/x,mm/x	1	1	0.25	P0123	
MOVQ	mm/x,m64	1	4	0.5		
MOVQ	m64,mm/x	1	4	1	P2	
MOVDQA	x,x	1	0	0.25		renaming
MOVDQA	x,m	1	3	0.5		
MOVDQA	m,x	1	4	1	P2	
VMOVDQA	y,y	2	1	0.5		lower half renamed
VMOVDQA	y,m256	2	3	1		
VMOVDQA	m256,y	2	4	2	P2	
MOVDQU	x,x	1	0	0.25		renaming
MOVDQU	x,m	1	3	0.5		
MOVDQU	m,x	1	4	1	P2	
LDDQU	x,m	1	3	0.5		
VMOVDQU	yymm,m256	2	3	1		
VMOVDQU	m256,yymm	2	4	2	P2	
MOVDQ2Q	mm,xmm	1	1	0.25	P0123	
MOVQ2DQ	xmm,mm	1	1	0.25	P0123	
MOVNTQ	m,mm	1	~900	1	P2	
MOVNTDQ	m,xmm	1	~900	1	P2	
MOVNTDQA	xmm,m	1	3	0.5		
PACKSSWB/DW	(x)mm,r/m	1	1	0.5	P12	
PACKUSWB	(x)mm,r/m	1	1	0.5	P12	
VPACKSSWB/DW	y,r/m	2	1	1	P12	

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VPACKUSWB	y,r/m	2	1	1	P12	
PUNPCKH/LBW/WD/DQ	(x)mm,r/m	1	1	0.5	P12	ivec
PUNPCKL/HQDQ	xmm,r/m	1	1	0.5	P12	
VPUNPCKL/HQDQ	y,r/m	2	1	1	P12	
PSHUFB	(x)mm,r/m	1	1	0.5	P12	
VPSHUFB	y,r/m	2	1	1	P12	
PSHUFD	x,x,i	1	1	0.5	P12	
VPSHUFD	y,y,i	2	1	1	P12	
PSHUFW	mm,mm,i	1	1	0.5	P12	
PSHUFL/HW	x,x,i	1	1	0.5	P12	
VPSHUFL/HW	y,y,i	2	1	1	P12	
PALIGNR	(x)mm,r/m,i	1	1	0.5	P12	
VPALIGNR	y,r/m,i	2	1	1	P12	
PBLENDW	x,r/m,i	1	1	0.33	P013	SSE4.1
PBLENDW	y,r/m,i	2	1	0.67	P013	
MASKMOVQ	mm,mm	30	~3000	~9		
MASKMOVDQU	x,x	60	~3000	~18		
PMOVMASKB	r32,mm/x	1	3	1	P2	
VPMOVMASKB	r32,y	2	3	2	P2	
PEXTRB/W/D/Q	r,x/mm,i	2	3	1	P1 P2	SSE4.1
PINSRB/W/D/Q	x/mm,r,i	2	3	1	P12	
EXTRQ	x,i,i	2	6	4		AMD SSE4A
EXTRQ	x,x	1	4	4	P1	AMD SSE4A
INSERTQ	x,x,i,i	2	4	4	P0 P1	AMD SSE4A
INSERTQ	x,x	1	4	4	P1	AMD SSE4A
PMOVSXBW/BD/BQ/W/D/WQ/DQ	x,x	1	1	0.5	P12	SSE4.1
PMOVZXBW/BD/BQ/W/D/WQ/DQ	x,x	1	1	0.5	P12	SSE4.1
VINSERTI128	y,y,x,i	2	1	.67	P013	AVX2
VINSERTI128	y,y,m,i	2	4	1	P013	AVX2
VPBROADCAST B/W/D/Q	x,x	1	1	0.5	P12	AVX2
VPBROADCAST B/W/D/Q	x,m	1	4	1		AVX2
VPBROADCAST B/W/D/Q	y,x	2	1	1	P12	AVX2
VPBROADCAST B/W/D/Q	y,m	2		0.5		AVX2
VBROADCASTI128	y,m128	2	3	0.5		AVX2
VPGATHERDD	x,[r+s*x],x	38		13	P0 P1 P2	AVX2
VPGATHERDD	y,[r+s*y],y	66		20	P0 P1 P2	AVX2
VPGATHERQD	x,[r+s*x],x	24		9	P0 P1 P2	AVX2
VPGATHERQD	x,[r+s*y],x	36		12	P0 P1 P2	AVX2
VPGATHERDQ	x,[r+s*x],x	23		9	P0 P1 P2	AVX2
VPGATHERDQ	y,[r+s*x],y	35		12	P0 P1 P2	AVX2
VPGATHERQQ	x,[r+s*x],x	23		9	P0 P1 P2	AVX2
VPGATHERQQ	y,[r+s*y],y	35		12	P0 P1 P2	AVX2
<b>Arithmetic instructions</b>						
PADDB/W/D/Q/SB/SW/USB/USW	(x)mm,r/m	1	1	0.33		ivec

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VPADD..	y,y,r/m	2	1	0.67		
PSUBB/W/D/Q/SB/SW/ USB/USW	(x)mm,r/m	1	1	0.33		
VPSUB..	y,y,r/m	2	1	0.67		
PHADD/SUB(S)W/D	x,x	4	2	2	P0 P1 P2 P3	SSSE3
VPHADD/SUB(S)W/D	y,y,y	8	3	3	P0 P1 P2 P3	
PCMPEQ B/W/D	(x)mm,r/m	1	1	0.33	P013	
VPCMPEQ B/W/D	y,y,r/m	2	2	0.67	P013	
PCMPEQQ	(x)mm,r/m	1	1	0.5	P03	
VPCMPEQQ	y,y,r/m	2	2	1	P03	
PCMPGT B/W/D	(x)mm,r/m	1	1	0.33	P013	
VPCMPGT B/W/D	y,y,r/m	2	2	0.67	P013	
PCMPGTQ	(x)mm,r/m	1	1	1	P0	
VPCMPGTQ	y,y,r/m	2		2	P0	
PMULLW PMULHW PMULHUW PMULDQ PMULUDQ	(x)mm,r/m	1	3	1	P0	
VPMULLW VPMULHW VPMULHUW VPMULDQ VPMULUDQ	y,y,r/m	2	3	2	P0	
PMULLD	x,r/m	1	4	2	P0	SSE4.1
VPMULLD	y,y,r/m	2	4	4	P0	
PMULHRWSW	(x)mm,r/m	1	4	1	P0	SSSE3
VPMULHRWSW	y,y,r/m	2	4	2	P0	
PMADDWD	(x)mm,r/m	1	3	1	P0	
VPMADDWD	y,y,r/m	2	3	2	P0	
PMADDUBSW	(x)mm,r/m	1	4	1	P0	
VPMADDUBSW	y,y,r/m	2	4	2	P0	
PAVGB/W	(x)mm,r/m	1	1	0.5	P03	
VPAVGB/W	(x)mm,r/m	2	1	1	P03	
PMIN/MAX SB/SW/ SD UB/UW/UD	(x)mm,r/m	1	1	0.33	P013	
VPMIN/MAX SB/SW/ SD UB/UW/UD	y,y,r/m	2	1	0.67	P013	
PHMINPOSUW	x,r/m	1	3	2		SSE4.1
PABSB/W/D	(x)mm,r/m	1	1	0.5	P03	SSSE3
VPABSB/W/D	y,r/m	2	1	1	P03	
PSIGNB/W/D	(x)mm,r/m	1	1	0.5	P03	SSSE3
VPSIGNB/W/D	y,r/m	2	1	1	P03	SSSE3
PSADBW	(x)mm,r/m	1	3	1	P0	
VPSADBW	y,y,r/m	1	3	2	P0	
MPSADBW	x,x,i	4	4	2	P0 P1 P2	SSE4.1
VMPSADBW	y,y,y,i	8	4	3		
<b>Logic</b>						
PAND PANDN POR PXOR	(x)mm,r/m	1	1	0.25	P0123	ivec
VPAND VPANDN VPOR VPXOR	y,y,r/m	2	1	0.5	P0123	
PSLL/RL W/D/Q PSRAW/D	(x)mm,r/m	1	1	1	P2	

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VPSLL/RL W/D/Q VP-SRAW/D	y,y,x/m	2	1	2	P2	
PSLL/RL W/D/Q PSRAW/D	(x)mm,i	1	1	1	P2	
VPSLL/RL W/D/Q VP-SRAW/D	y,y,i	2	1	2	P2	
PSLLDQ, PSRLDQ	x,i	1	1	0.5	P12	
VPSLLDQ VPSRLDQ	y,y,i	2	1	1	P12	
VPSLLVD/Q VPSRAVD VPSRLVD/Q	x,x,x	1	3	2	P1	AVX2
VPSLLVD/Q VPSRAVD VPSRLVD/Q	y,y,y	2	3	4	P1	AVX2
PTEST	x,r/m	1	2	1	P2	SSE4.1
VPTEST	y,y/m	3	4	2	P1 P2	
<b>String instructions</b>						
PCMPESTRI	x,x,i	6	8	3	P1 P2	SSE4.2
PCMPESTRI	x,m,i	12		4		SSE4.2
PCMPESTRM	x,x,i	7	8	3	P0 P1 P2	SSE4.2
PCMPESTRM	x,m,i	12		4		SSE4.2
PCMPISTRI	x,x,i	2	11	2	P1 P2	SSE4.2
PCMPISTRI	x,m,i	3		2		SSE4.2
PCMPISTRM	x,x,i	3	7	2	P1 P2	SSE4.2
PCMPISTRM	x,m,i	4		2		SSE4.2
<b>Encryption</b>						
PCLMULQDQ	x,x/m,i	4	4	2		pclmul
AESDEC	x,x	1	4	0.5	P01	aes
AESDECLAST	x,x	1	4	0.5	P01	aes
AESENC	x,x	1	4	0.5	P01	aes
AESENCLAST	x,x	1	4	0.5	P01	aes
AESIMC	x,x	1	4	0.5	P01	aes
AESKEYGENASSIST	x,x,i	1	4	0.5	P01	aes
SHA1RNDS4	x,x,i	1	6	4	P1	sha
SHA1NEXTE	x,x	1	1	1	P1	sha
SHA1MSG1	x,x	2	2	1	multi	sha
SHA1MSG2	x,x	1	1	0.5	P12	sha
SHA256RNDS2	x,x	1	4	2	P1	sha
SHA256MSG1	x,x	2	2	0.5	P0123	sha
SHA256MSG2	x,x	4	3	2	P0123	sha
<b>Other</b>						
EMMS		1		0.25		

**Floating point XMM and YMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipes	Domain, notes
<b>Move instructions</b>						

## Ryzen

MOVAPS/D						
MOVUPS/D	x,x	1	0	0.25	none	inherit
VMOVAPS/D	y,y	2	1	0.5		inherit
MOVAPS/D						
MOVUPS/D	x,m128	1	3	0.5		
VMOVAPS/D						
VMOVUPS/D	y,m256	2	5	1		
MOVAPS/D						
MOVUPS/D	m128,x	1	4	1	P2	
VMOVAPS/D						
VMOVUPS/D	m256,y	2	3	2	P2	
MOVSS/D	x,x	1	1	0.25	P0123	
MOVSS/D	x,m32/64	1	4	0.5		
MOVSS/D	m32/64,x	1	4	1	P2	
MOVHPS/D	x,m64	1	4	0.5	P12	
MOVLPS/D	x,m64	1	4	0.5	P12	
MOVHPS/D	m64,x	2	5	1	P1 P2	
MOVLPS/D	m64,x	1	4	1	P1 P2	
MOVLHPS MOVHLPS	x,x	1	1	0.5	P12	ivec
MOVMSKPS/D	r32,x	1	3	1	P2	
VMOVMSKPS/D	r32,y	1	3	1	P2	
MOVNTPS/D	m128,x	1	~950	1	P2	
VMOVNTPS/D	m256,y	2	~950	2	P2	
MOVNTSS/SD	m,x	1		4	P2	AMD SSE4A
SHUFPS/D	x,x/m,i	1	1	0.5	P12	ivec
VSHUFPS/D	y,y,y/m,i	2	1	1	P2	ived
VPERMILPS/PD	x,x,x/m	1	3	2	P1	
VPERMILPS/PD	y,y,y/m	2	4	4	P1	
VPERMILPS/PD	x,x/m,i	1	1	0.5	P12	
VPERMILPS/PD	y,y/m,i	2	1	1	P12	
VPERM2F128	y,y,y,i	8	3	3	P0 P1 P3	
VPERM2F128	y,y,m,i	12		4	P0 P1 P3	
VPERMPS	y,y,y	3	5	4	P0 P1 P2	AVX2
VPERMPS	y,y,m	4		4		AVX2
VPERMPD	y,y,i	3	2	2	P0 P1 P2 P3	AVX2
VPERMPD	y,m,i	4		2	P0 P1 P2 P3	AVX2
BLENDPS/PD	x,x/m,i	1	1	0.5	P01	fp
VBLENDPS/PD	y,y,y/m,i	2	1	1	P01	
BLENDVPS/PD	x,x/m,xmm0	1	1	0.5	P01	
VBLENDVPS/PD	y,y,y/m,y	2	1	1	P01	
MOVDDUP	x,x	1	1	0.5	P12	ivec
MOVDDUP	x,m64	1		0.5		
VMOVDDUP	y,y	2	1	1	P12	
VMOVDDUP	y,m256	2		1		
VBROADCASTSS/D	x,x	1	1	0.5	P12	
VBROADCASTSS/D	y,x	2	1	1	P12	
VBROADCASTSS/D	x,m	2	3	0.5		
VBROADCASTSS	y,m32	2	3	1		
VBROADCASTF128	y,m128	2	4	5		
MOVSH/LDUP	x,x/m	1	1	0.5	P12	ivec
VMOVSH/LDUP	y,y/m	2		1	P12	
UNPCKH/LPS/D	x,x/m	1	1	0.5	P12	
VUNPCKH/LPS/D	y,y,y/m	2	1	1	P12	



## Ryzen

EXTRACTPS	r32,x,i	2	3	1	P1 P2	
EXTRACTPS	m32,x,i	2	6	1	P1 P2	
VEXTRACTF128	x,y,i	1	1	0.33	P013	
VEXTRACTF128	m128,y,i	2	7	1	P01 P2	
INSERTPS	x,x,i	1	1	0.5	P12	ivec
INSERTPS	x,m32,i	1	4	1	P12	
VINSERTF128	y,y,x,i	2	1	0.5	P013	
VINSERTF128	y,y,m128,i	2	5	1	P013	
VMASKMOVPS/D	x,x,m128	1	4	1	P01	
VMASKMOVPS/D	y,y,m256	2	4	1	P01	
VMASKMOVPS/D	m128,x,x	19	~50	5	P1 P2	
VMASKMOVPS/D	m256,y,y	42	~50	11	P1 P2	
VGATHERDPS	x,[r+s*x],x	38		13	P0 P1 P2	AVX2
VGATHERDPS	y,[r+s*y],y	66		20	P0 P1 P2	AVX2
VGATHERQPS	x,[r+s*x],x	24		9	P0 P1 P2	AVX2
VGATHERQPS	x,[r+s*y],x	36		12	P0 P1 P2	AVX2
VGATHERDPD	x,[r+s*x],x	23		9	P0 P1 P2	AVX2
VGATHERDPD	y,[r+s*x],y	35		12	P0 P1 P2	AVX2
VGATHERQPD	x,[r+s*x],x	23		9	P0 P1 P2	AVX2
VGATHERQPD	y,[r+s*y],y	35		12	P0 P1 P2	AVX2
<b>Conversion</b>						
CVTPD2PS	x,x	1	3	1	P3	fp
VCVTPD2PS	x,y	2	5	2	P3	
CVTPS2PD	x,x	1	3	1	P3	
VCVTPS2PD	y,x	2	5	2	P3	
CVTSD2SS	x,x	1	3	1	P3	
CVTSS2SD	x,x	1	3	1	P3	
CVTDQ2PS	x,x	1	4	1	P3	
VCVTDQ2PS	y,y	2	4	2	P3	
CVT(T) PS2DQ	x,x	1	4	1	P3	mixed domain
VCVT(T) PS2DQ	y,y	2	4	2	P3	
CVTDQ2PD	x,x	2	6	1	P12 P3	
VCVTDQ2PD	y,x	4	6	2	P12 P3	
CVT(T)PD2DQ	x,x	2	6	1	P12 P3	
VCVT(T)PD2DQ	x,y	4	6	2	P12 P3	
CVTPI2PS	x,mm	2	6	1	P12 P3	
CVT(T)PS2PI	mm,x	2	6	1	P12 P3	
CVTPI2PD	x,mm	2	6	1	P12 P3	
CVT(T) PD2PI	mm,x	2	6	1	P12 P3	
CVTSI2SS	x,r32	2	8	1		
CVT(T)SS2SI	r32,x	2	7	1	P2 P3	
CVTSI2SD	x,r32/64	2	8	1		
CVT(T)SD2SI	r32/64,x	2	7	1	P2 P3	
VCVTPS2PH	x/m,x,i	2	6	2	P1 P3	
VCVTPS2PH	x/m,y,i	4	6	2	P12 P3	
VCVTPH2PS	x,x/m	2	6	2	P1 P3	
VCVTPH2PS	y,x/m	4	6	2	P12 P3	
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	x,x/m	1	3	0.5	P23	fp
ADDP/D SUBP/D	x,x/m	1	3	0.5	P23	fp

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VADDPS/D VSUBPS/D	y,y,y/m	2	3	1	P23	fp
ADDSUBPS/D	x,x/m	1	3	0.5	P23	fp
VADDSUBPS/D	y,y,y/m	2	3	1	P23	
HADDPS/D HSUBPS/D	x,x	4	7	2	P1 P2 P3	
VHADDPS/D						
VHSUBPS/D	y,y,y/m	8	7	3	P1 P2 P3	mixed domain
MULSS MULPS	x,x/m	1	3	0.5	P01	fp
MULSD MULPD	x,x/m	1	4	0.5	P01	fp
VMULPS	y,y,y/m	2	3	1	P01	fp
VMULPD	y,y,y/m	2	4	1	P01	fp
DIVSS DIVPS	x,x/m	1	10	3	P3	
VDIVPS	y,y,y/m	2	10	6	P3	
DIVSD DIVPD	x,x/m	1	8-13	4-5	P3	
VDIVPD	y,y,y/m	2	8-13	8-9	P3	
RCPSS/PS	x,x/m	1	5	1	P01	
VRCPPS	y,y/m	2	5	2	P01	
CMPSS/D						
CMPSS/D	x,x/m	1	1	0.5	P01	
VCMPPS/D	y,y,y/m	2	1	1	P01	
COMISS/D						
UCOMISS/D	x,x/m	2	4	1	P012	
MAXSS/SD/PS/PD						
MINSS/SD/PS/PD	x,x/m	1	1	0.5	P01	fp
VMAXPS/D VMINPS/D	y,y,y/m	2	1	1	P01	
ROUNDSS/SD/PS/PD	x,x/m,i	1	4	1	P3	fp
VROUNDSS/SD/PS/PD	y,y/m,i	2	4	2	P3	fp
DPPS	x,x,i	8	15	4	P0 P1 P2 P3	SSE4.1
DPPS	x,m,i	10		5	P0 P1 P2 P3	SSE4.1
VDPPS	y,y,y,i	13	16	5	P0 P1 P2 P3	SSE4.1
VDPPS	y,m,i	14		5	P0 P1 P2 P3	SSE4.1
DPPD	x,x,i	3	10	3	P0 P1 P2 P3	SSE4.1
DPPD	x,m,i	5		4	P0 P1 P2 P3	SSE4.1
VFMADD132SS/SD	x,x,x/m	1	5	0.5	P01	FMA3
VFMADD132PS/PD	x,x,x/m	1	5	0.5	P01	FMA3
VFMADD132PS/PD	y,y,y/m	2	5	1	P01	FMA3
All other FMA3 instructions: same as above					P01	FMA3
VFMADDSS/SD	x,x,x,x/m	1	5	0.5	P01	Not officially supported.
VFMADDPS/PD	x,x,x,x/m	1	5	0.5	P01	supported.
VFMADDPS/PD	y,y,y,y/m	2	5	1	P01	Don't use!
All other FMA4 instructions: same as above						
<b>Math</b>						
SQRTSS/PS	x,x/m	1	9-10	4-5	P3	fp
VSQRTPS	y,y/m	2	9-10	8-10		
SQRTSD/PD	x,x/m	1	14-15	4-8		
VSQRTPD	y,y/m	2	14-15	8-16		
RSQRTSS/PS	x,x/m	1	5	1	P01	
VRSQRTPS	y,y/m	2	5	2	P01	
<b>Logic</b>						

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AND/ANDN/OR/XORPS/ PD	x,x/m	1	1	0.25	P0123	fp
VAND/ANDN/OR/XOR PS/PD	y,y,y/m	2	1	0.5	P0123	
<b>Other</b>						
VZEROUPPER		10		4		32 bit mode
VZEROUPPER		17		6		64 bit mode
VZEROALL		18		6		32 bit mode
VZEROALL		33		11		64 bit mode
LDMXCSR	m32	1		16		
STMXCSR	m32	2		14		
FXSAVE	m4096	87		90		
FXRSTOR	m4096	121		140		
XSAVE	m	160		166		
XSAVEOPT	m	97		130		
XRSTOR	m	213		340		
XSAVEC	m	111		150		

## AMD Bobcat

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of micro-operations issued from instruction decoder to schedulers. Instructions with more than 2 micro-operations are micro-coded.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latencies listed do not include memory operands where the operand is listed as register or memory (r/m).
	The clock frequency varies dynamically, which makes it difficult to measure latencies. The values listed are measured after the execution of millions of similar instructions, assuming that this will make the processor boost the clock frequency to the highest possible value.
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/2 indicates that the execution units can handle 2 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution pipe:</b>	Indicates which execution pipe is used for the micro-operations. I0 means integer pipe 0. I0/1 means integer pipe 0 or 1. FP0 means floating point pipe 0 (ADD). FP1 means floating point pipe 1 (MUL). FP0/1 means either one of the two floating point pipes. Two micro-operations can execute simultaneously if they go to different execution pipes.

### Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	0.5	I0/1	
MOV	r,i	1		0.5	I0/1	
MOV	r,m	1	4	1	AGU	Any addr. mode
MOV	m,r	1	4	1	AGU	Any addr. mode
MOV	m8,r8H	1	7	1	AGU	AH, BH, CH, DH
MOV	m,i	1		1	AGU	
MOVNTI	m,r	1	6	1	AGU	
MOVZX, MOVSX	r,r	1	1	0.5	I0/1	
MOVZX, MOVSX	r,m	1	5	1		
MOVSXD	r64,r32	1	1	0.5		
MOVSXD	r64,m32	1	5	1		
CMOVcc	r,r	1	1	0.5	I0/1	
CMOVcc	r,m	1		1		
XCHG	r,r	2	1	1	I0/1	
XCHG	r,m	3	20			Timing dep. on hw

Bobcat

XLAT		2	5			
PUSH	r	1		1		
PUSH	i	1		1		
PUSH	m	3		2		
PUSHF(D/Q)		9		6		
PUSHA(D)		9		9		
POP	r	1		1		
POP	m	4		4		
POPF(D/Q)		29		22		
POPA(D)		9		8		
LEA	r16,[m]	2	3	2	I0	Any address size
LEA	r32/64,[m]	1	1	0.5	I0/1	no scale, no offset
LEA	r32/64,[m]	1	2-4	1	I0	w. scale or offset
LEA	r64,[m]	1		0.5	I0/1	RIP relative
LAHF		4	4	2		
SAHF		1	1	0.5	I0/1	
SALC		1	1			
BSWAP	r	1	1	0.5	I0/1	
PREFETCHNTA	m	1		1	AGU	
PREFETCHT0/1/2	m	1		1	AGU	
PREFETCH	m	1		1	AGU	AMD only
SFENCE		4		~45	AGU	
LFENCE		1		1	AGU	
MFENCE		4		~45	AGU	
<b>Arithmetic instructions</b>						
ADD, SUB	r,r/i	1	1	0.5	I0/1	
ADD, SUB	r,m	1		1		
ADD, SUB	m,r	1		1		
ADC, SBB	r,r/i	1	1	1	I0/1	
ADC, SBB	r,m	1		1		
ADC, SBB	m,r/i	1	6-7			
CMP	r,r/i	1	1	0.5	I0/1	
CMP	r,m	1		1		
INC, DEC, NEG	r	1	1	0.5	I0/1	
INC, DEC, NEG	m	1	6			
AAA		9	5			
AAS		9	10			
DAA		12	7			
DAS		16	8			
AAD		4	5			
AAM		33	23	23		
MUL, IMUL	r8/m8	1	3	1	I0	
MUL, IMUL	r16/m16	3	3-5		I0	latency ax=3, dx=5
MUL, IMUL	r32/m32	2	3-4	2	I0	latency eax=3, edx=4
MUL, IMUL	r64/m64	2	6-7		I0	latency rax=6, rdx=7
IMUL	r16,r16/m16	1	3	1	I0	
IMUL	r32,r32/m32	1	3	1	I0	
IMUL	r64,r64/m64	1	6	4	I0	
IMUL	r16,(r16),i	2	4	3	I0	
IMUL	r32,(r32),i	1	3	1	I0	
IMUL	r64,(r64),i	1	7	4	I0	
DIV	r8/m8	1	27	27	I0	

## Bobcat

DIV	r16/m16	1	33	33	I0	
DIV	r32/m32	1	49	49	I0	
DIV	r64/m64	1	81	81	I0	
IDIV	r8/m8	1	29	29	I0	
IDIV	r16/m16	1	37	37	I0	
IDIV	r32/m32	1	55	55	I0	
IDIV	r64/m64	1	81	81	I0	
CBW, CWDE, CDQE		1	1		I0/1	
CWD, CDQ, CQO		1	1		I0/1	
<b>Logic instructions</b>						
AND, OR, XOR	r,r	1	1	0.5	I0/1	
AND, OR, XOR	r,m	1		1		
AND, OR, XOR	m,r	1		1		
TEST	r,r	1	1	0.5	I0/1	
TEST	r,m	1		1		
NOT	r	1	1	0.5	I0/1	
NOT	m	1		1		
SHL, SHR, SAR	r,i/CL	1	1	0.5	I0/1	
ROL, ROR	r,i/CL	1	1	0.5	I0/1	
RCL, RCR	r,1	1	1	1	I0/1	
RCL	r,i	9	5	5		
RCR	r,i	7	4	4		
RCL	r,CL	9	6	5		
RCR	r,CL	9	5	4		
SHL,SHR,SAR,ROL, ROR	m,i /CL	1	7	1		
RCL, RCR	m,1	1	7	1		
RCL	m,i	10		~15		
RCR	m,i	9	18	~14		
RCL	m,CL	9		15		
RCR	m,CL	8		15		
SHLD, SHRD	r,r,i	6	3	3		
SHLD, SHRD	r,r,cl	7	4	4		
SHLD, SHRD	m,r,i/CL	8	18	15		
BT	r,r/i	1		0.5		
BT	m,i	1		1		
BT	m,r	5		3		
BTC, BTR, BTS	r,r/i	2	2	1		
BTC	m,i	5		15		
BTR, BTS	m,i	4-5		15		
BTC	m,r	8	16	13		
BTR, BTS	m,r	8	15	15		
BSF, BSR	r,r	11	6	6		
BSF, BSR	r,m	11		6		
POPCNT	r,r/m	9	12	5		SSE4.A/SSE4.2
LZCNT	r,r/m	8	5			SSE4.A, AMD only
SETcc	r	1	1	0.5		
SETcc	m	1		1		
CLC, STC		1		0.5	I0/1	
CMC		1	1	0.5	I0/1	
CLD		1		1	I0	
STD		2		2	I0,I1	

Bobcat

<b>Control transfer instructions</b>						
JMP	short/near	1		2		
JMP	r	1		2		
JMP	m(near)	1		2		
Jcc	short/near	1		1/2 - 2		recip. t. = 2 if jump
J(E/R)CXZ	short	2		1 - 2		recip. t. = 2 if jump
LOOP	short	8		4		
CALL	near	2		2		
CALL	r	2		2		
CALL	m(near)	5		2		
RET		1		~3		
RET	i	4		~4		
BOUND	m	8		4		values for no jump
INTO		4		2		values for no jump
<b>String instructions</b>						
LODS		4		~3		
REP LODS		5		~3		values are per count
STOS		4		2		
REP STOS		2				best case 6-7 B/clock
MOVS		7		5		
REP MOVS		2				best case 5 B/clock
SCAS		5		3		
REP SCAS		6		3		values are per count
CMPS		7		4		
REP CMPS		6		3		values are per count
<b>Other</b>						
NOP (90)		1	0	0.5		I0/1
Long NOP (0F 1F)		1	0	0.5		I0/1
PAUSE		6		6		
ENTER	i,0		12			36
ENTER	a,b		10+6b			34+6b
LEAVE		2		3		32 bit mode
CPUID		30-52	70-830			
RDTSC		26		87		
RDPMSR		14		8		

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
FLD	r	1	2	0.5	FP0/1	
FLD	m32/64	1	6	1	FP0/1	
FLD	m80	7	14	5		
FBLD	m80	21	30	35		
FST(P)	r	1	2	0.5	FP0/1	
FST(P)	m32/64	1	6	1	FP1	
FSTP	m80	16	19	9		
FBSTP	m80	217	177	180		
FXCH	r	1	0	1	FP1	

Bobcat

FILD	m	1	9	1	FP1
FIST(T)(P)	m	1	6	1	
FLDZ, FLD1		1		1	FP1
FCMOVcc	st0,r	12	7	7	FP0/1
FFREE	r	1		1	FP1
FINCSTP, FDECSTP		1	1	1	FP1
FNSTSW	AX	2	~20	10	FP1
FNSTSW	m16	2	~20	10	FP1
FNSTCW	m16	3		2	FP0
FLDCW	m16	12		10	FP1
<b>Arithmetic instructions</b>					
FADD(P),FSUB(R)(P)	r	1	3	1	FP0
FADD(P),FSUB(R)(P)	m	1	3	1	FP0
FIADD,FISUB(R)	m	2		3	FP0,FP1
FMUL(P)	r	1	5	3	FP1
FMUL(P)	m	1	5	3	FP1
FIMUL	m	2			FP1
FDIV(R)(P)	r	1	19	19	FP1
FDIV(R)(P)	m	1		19	FP1
FIDIV(R)	m	2		19	FP1
FABS, FCHS		1	2	2	FP1
FCOM(P), FUCOM(P)	r	1		1	FP0
FCOM(P), FUCOM(P)	m	1		1	FP0
FCOMPP, FUCOMPP		1		1	FP0
FCOMI(P)	r	1	2	2	FP0
FICOM(P)	m	2		1	FP0, FP1
FTST		1		1	FP0
FXAM		2		2	FP1
FRNDINT		5	11		FP0, FP1
FPREM		1	11-16		FP1
FPREM1		1	11-19		FP1
<b>Math</b>					
FSQRT		1	31		FP1
FLDPI, etc.		1		1	FP0
FSIN		4-44	27-105	27-105	FP0, FP1
FCOS		11-51	51-94	51-94	FP0, FP1
FSINCOS		11-75	48-110	48-110	FP0, FP1
FPTAN		~45	~113	~113	FP0, FP1
FPATAN		9-75	49-163	49-163	FP0, FP1
FSCALE		5	8		FP0, FP1
FXTRACT		7	9		FP0, FP1
F2XM1		30-56	~60		FP0, FP1
FYL2X		8	29		FP0, FP1
FYL2XP1		12	44		FP0, FP1
<b>Other</b>					
FNOP		1	0	0.5	FP0, FP1
(F)WAIT		1	0	0.5	ALU
FNCLEX		9		30	FP0, FP1
FNINIT		26		78	FP0, FP1
FNSAVE	m	85		163	FP0, FP1



Bobcat

FRSTOR	m	80		123	FP0, FP1
FXSAVE	m	71		105	FP0, FP1
FXRSTOR	m	111		118	FP0, FP1

**Integer MMX and XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOVD	r32, mm	1	7	1	FP0	
MOVD	mm, r32	1	7	3	FP0/1	
MOVD	mm, m32	1	5	1	FP0/1	
MOVD	r32, xmm	1	6	1	FP0	
MOVD	xmm, r32	3	6	3	FP1	
MOVD	xmm, m32	2	5	1	FP1	
MOVD	m32, (x)mm	1	6	2	FP1	
MOVD (MOVQ)	r64, (x)mm	1	7	1	FP0	Moves 64 bits. Name differs
MOVD (MOVQ)	mm, r64	2	7	3	FP0/1	do.
MOVD (MOVQ)	xmm, r64	3	7	3	FP0/1	do.
MOVQ	mm, mm	1	1	0.5	FP0/1	
MOVQ	xmm, xmm	2	1	1	FP0/1	
MOVQ	mm, m64	1	5	1	FP0/1	
MOVQ	xmm, m64	2	5	1	FP1	
MOVQ	m64, (x)mm	1	6	2	FP1	
MOVDQA	xmm, xmm	2	1	1	FP0/1	
MOVDQA	xmm, m	2	6	2	AGU	
MOVDQA	m, xmm	2	6	3	FP1	
MOVDQU, LDDQU	xmm, m	2	6-9	2-5.5	AGU	
MOVDQU	m, xmm	2	6-9	3-6	FP1	
MOVDQ2Q	mm, xmm	1	1	0.5	FP0/1	
MOVQ2DQ	xmm, mm	2	1	1	FP0/1	
MOVNTQ	m, mm	1	13	1.5	FP1	
MOVNTDQ	m, xmm	2	13	3	FP1	
PACKSSWB/DW						
PACKUSWB	mm, r/m	1	1	0.5	FP0/1	
PACKSSWB/DW						
PACKUSWB	xmm, r/m	3	2	2	FP0/1	
PUNPCKH/LBW/WD/DQ						
PUNPCKH/LBW/WD/DQ	mm, r/m	1	1	0.5		
PUNPCKH/LBW/WD/DQ						
PUNPCKH/LBW/WD/DQ	xmm, r/m	2	1	1		
PUNPCKHQDQ	xmm, r/m	2	1	1	FP0, FP1	
PUNPCKQLDQ	xmm, r/m	1	1	0.5	FP0/1	
PSHUFB	mm, mm	1	2	1	FP0/1	Suppl. SSE3
PSHUFB	xmm, xmm	6	3	3	FP0/1	Suppl. SSE3
PSHUFD	xmm, xmm, i	3	2	2	FP0/1	
PSHUFW	mm, mm, i	1	1	0.5	FP0/1	
PSHUFL/HW	xmm, xmm, i	2	2	2	FP0/1	
PALIGNR	xmm, xmm, i	20	19	12	FP0/1	Suppl. SSE3
MASKMOVQ	mm, mm	32	146-1400	130-1170	FP0, FP1	
MASKMOVDQU	xmm, xmm	64	279-3000	260-2300	FP0, FP1	
PMOVMASKB	r32, (x)mm	1	8	2	FP0	

Bobcat

PEXTRW	r32,(x)mm,i	2	12	2	FP0, FP1	
PINSRW	mm,r32,i	2	10	6	FP0/1	
PINSRW	xmm,r32,i	3	10		FP0/1	
INSERTQ	xmm,xmm	3	3-4	3	FP0, FP1	SSE4.A, AMD only
INSERTQ	xmm,xmm,i,i	3	3-4	3	FP0, FP1	SSE4.A, AMD only
EXTRQ	xmm,xmm	1	1	1	FP0/1	SSE4.A, AMD only
EXTRQ	xmm,xmm,i,i	1	2	2	FP0/1	SSE4.A, AMD only
<b>Arithmetic instructions</b>						
PADDB/W/D/Q						
PADDSB/W						
PADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	mm,r/m	1	1	0.5	FP0/1	
PADDB/W/D/Q						
PADDSB/W						
ADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	xmm,r/m	2	1	1	FP0/1	
PHADD/SUBW/SW/D	mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PHADD/SUBW/SW/D	xmm,r/m	2	4	1	FP0/1	Suppl. SSE3
PCMPEQ/GT B/W/D	mm,r/m	1	1	0.5	FP0/1	
PCMPEQ/GT B/W/D	xmm,r/m	2	1	1	FP0/1	
PMULLW PMULHW						
PMULHUW						
PMULUDQ	mm,r/m	1	2	1	FP0	
PMULLW PMULHW						
PMULHUW						
PMULUDQ	xmm,r/m	2	2	2	FP0	
PMULHRSW	mm,r/m	1	2	1	FP0	Suppl. SSE3
PMULHRSW	xmm,r/m	2	2	2	FP0	Suppl. SSE3
PMADDWD	mm,r/m	1	2	1	FP0	
PMADDWD	xmm,r/m	2	2	2	FP0	
PMADDUBSW	mm,r/m	1	2	1	FP0	Suppl. SSE3
PMADDUBSW	xmm,r/m	2	2	2	FP0	Suppl. SSE3
PAVGB/W	mm,r/m	1	1	0.5	FP0/1	
PAVGB/W	xmm,r/m	2	1	1	FP0/1	
PMIN/MAX SW/UB	mm,r/m	1	1	0.5	FP0/1	
PMIN/MAX SW/UB	xmm,r/m	2	1	1	FP0/1	
PABSB/W/D	mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PABSB/W/D	xmm,r/m	2	1	1	FP0/1	Suppl. SSE3
PSIGNB/W/D	mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PSIGNB/W/D	xmm,r/m	2	1	1	FP0/1	Suppl. SSE3
PSADBW	mm,r/m	1	2	2	FP0	
PSADBW	xmm,r/m	2	2	2	FP0, FP1	
<b>Logic</b>						
PAND PANDN POR PXOR	mm,r/m	1	1	0.5	FP0/1	
PAND PANDN POR PXOR	xmm,r/m	2	1	1	FP0/1	

## Bobcat

PSLL/RL W/D/Q PSRAW/D	mm,i/mm/m	1	1	1	FP0/1
PSLL/RL W/D/Q PSRAW/D	xmm,i/xmm/m	2	1	1	FP0/1
PSLLDQ, PSRLDQ	xmm,i	2	1	1	FP0/1
<b>Other</b>					
EMMS		1		0.5	FP0/1

## Floating point XMM instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOVAPS/D	r,r	2	1	1	FP0/1	
MOVAPS/D	r,m	2	6	2	AGU	
MOVAPS/D	m,r	2	6	3	FP1	
MOVUPS/D	r,r	2	1	1	FP0/1	
MOVUPS/D	r,m	2	6-9	2-6	AGU	
MOVUPS/D	m,r	2	6-9	3-6	FP1	
MOVSS/D	r,r	1	1	0.5	FP0/1	
MOVSS/D	r,m	2	6	2	FP1	
MOVSS/D	m,r	1	5	2	FP1	
MOVHPLS, MOVLHPS	r,r	1	1	0.5	FP0/1	
MOVHPS/D, MOVLPS/D	r,m	1	6	2	AGU	
MOVHPS/D, MOVLPS/D	m,r	1	5	3	FP1	
MOVNTPS/D	m,r	2	12	3	FP1	
MOVNTSS/D	m,r	1	12	2	FP1	SSE4.A, AMD only
MOVDDUP	r,r	2	2	1	FP0/1	SSE3
MOVDDUP	r,m64	2	7	2	FP0/1	SSE3
MOVSHDUP, MOVSLDUP	r,r	2	1	1	FP0/1	
MOVSHDUP, MOVSLDUP	r,m	2	12	3	AGU	
MOVMSKPS/D	r32,r	1	~6	2	FP0	
SHUFPS/D	r,r/m,i	3	2	2	FP0/1	
UNPCK H/L PS/D	r,r/m	2	1	1	FP0/1	
<b>Conversion</b>						
CVTPS2PD	r,r/m	2	5	2	FP1	
CVTPD2PS	r,r/m	4	5	3	FP0, FP1	
CVTSD2SS	r,r/m	3	5	3	FP0, FP1	
CVTSS2SD	r,r/m	1	4	1	FP1	
CVTDQ2PS	r,r/m	2	4	4	FP1	
CVTDQ2PD	r,r/m	2	5	2	FP1	
CVT(T)PS2DQ	r,r/m	2	4	4	FP1	
CVT(T)PD2DQ	r,r/m	4	6	3	FP0, FP1	
CVTPI2PS	xmm,mm	1	4	2	FP1	
CVTPI2PD	xmm,mm	2	5	2	FP1	
CVT(T)PS2PI	mm,xmm	1	4	1	FP1	

## Bobcat

CVT(T)PD2PI	mm,xmm	3	6	2	FP0, FP1	
CVTSI2SS	xmm,r32	3	12	3	FP0, FP1	
CVTSI2SD	xmm,r32	2	11	3	FP1	
CVT(T)SS2SI	r32,xmm	2	12	1	FP0, FP1	
CVT(T)SD2SI	r32,xmm	2	11	1	FP0, FP1	
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	r,r/m	1	3	1	FP0	
ADDPSS/D SUBPSS/D	r,r/m	2	3	2	FP0	
ADDSUBPSS/D	r,r/m	2	3	2	FP0	SSE3
HADDPSS/D						
HSUBPSS/D	r,r/m	2	3	2	FP0	SSE3
MULSS	r,r/m	1	2	1	FP1	
MULSD	r,r/m	1	4	2	FP1	
MULPSS	r,r/m	2	2	2	FP1	
MULPD	r,r/m	2	4	4	FP1	
DIVSS	r,r/m	1	13	13	FP1	
DIVPSS	r,r/m	2	38	38	FP1	
DIVSD	r,r/m	1	17	17	FP1	
DIVPD	r,r/m	2	34	34	FP1	
RCPSS	r,r/m	1	3	1	FP1	
RCPPS	r,r/m	2	3	2	FP1	
MAXSS/D MINSS/D	r,r/m	1	2	1	FP0	
MAXPSS/D MINPSS/D	r,r/m	2	2	2	FP0	
CMPccSS/D	r,r/m	1	2	1	FP0	
CMPccPSS/D	r,r/m	2	2	2	FP0	
COMISS/D						
UCOMISS/D	r,r/m	1		1	FP0	
<b>Logic</b>						
ANDPSS/D ANDNPSS/D						
ORPSS/D XORPSS/D	r,r/m	2	1	1	FP0/1	
<b>Math</b>						
SQRTSS	r,r/m	1	14	14	FP1	
SQRTPSS	r,r/m	2	48	48	FP1	
SQRTSD	r,r/m	1	24	24	FP1	
SQRTPD	r,r/m	2	48	48	FP1	
RSQRTSS	r,r/m	1	3	1	FP1	
RSQRTPS	r,r/m	2	3	2	FP1	
<b>Other</b>						
LDMXCSR	m	12		10	FP0, FP1	
STMXCSR	m	3		11	FP0, FP1	

## AMD Jaguar

### List of instruction timings and macro-operation breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b>Ops:</b>	Number of micro-operations issued from instruction decoder to schedulers. Instructions with more than 2 micro-operations are micro-coded.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latencies listed do not include memory operands where the operand is listed as register or memory (r/m).  The clock frequency varies dynamically, which makes it difficult to measure latencies. The values listed are measured after the execution of millions of similar instructions, assuming that this will make the processor boost the clock frequency to the highest possible value.
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the average number of clock cycles from the execution of an instruction begins to a subsequent independent instruction of the same kind can begin to execute. A value of 1/2 indicates that the execution units can handle 2 instructions per clock cycle in one thread. However, the throughput may be limited by other bottlenecks in the pipeline.
<b>Execution pipe:</b>	Indicates which execution pipe is used for the micro-operations. I0 means integer pipe 0. I0/1 means integer pipe 0 or 1. FP0 means floating point pipe 0 (ADD). FP1 means floating point pipe 1 (MUL). FP0/1 means either one of the two floating point pipes. Two micro-operations can execute simultaneously if they go to different execution pipes.

### Integer instructions

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOV	r,r	1	1	0.5	I0/1	
MOV	r,i	1		0.5	I0/1	
MOV	r8/16,m	1	4	1	AGU	Any addressing mode
MOV	m,r8/16	1	4	1	AGU	Any addressing mode
MOV	r32/64,m	1	3	1	AGU	Any addressing mode
MOV	m,r32/64	1	0	1	AGU	Any addressing mode
MOV	m,i	1		1	AGU	
MOVNTI	m,r	1	6	1	AGU	
MOVZX, MOVSX	r,r	1	1	0.5	I0/1	
MOVZX, MOVSX	r,m	1	4	1		
MOVSXD	r64,r32	1	1	0.5		

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MOVSXD	r64,m32	1	3	1		
CMOVcc	r,r	1	1	0.5	I0/1	
CMOVcc	r,m	1		1		
XCHG	r8,r8	3	2	2	I0/1	
XCHG	r,r	2	1	1	I0/1	
XCHG	r,m	3	16			Timing depends on hw
XLAT		2	5	3		
PUSH	r	1		1		
PUSH	i	1		1		
PUSH	m	2		1		
PUSH	SP	2		1		
PUSHF(D/Q)		9		6		
PUSHA(D)		9		8		
POP	r	1		1		
POP	m	3		2		
POP	SP	1		2		
POPF(D/Q)		29		18		
POPA(D)		9		8		
LEA	r16,[m]	2	3	2	I0	Any address size
LEA	r32/64,[m]	1	1	0.5	I0/1	1-2 comp., no scale
LEA	r32/64,[m]	1	2	1	I0	3 comp. or scale
LEA	r64,[m]	1		0.5	I0/1	RIP relative
LAHF		4	3	2		
SAHF		1	1	0.5	I0/1	
SALC		1	1	1		
BSWAP	r	1	1	0.5	I0/1	
MOVBE	r,m	1		1		MOVBE
MOVBE	m,r	1		1		MOVBE
PREFETCHNTA	m	1		~100	AGU	
PREFETCHT0/1/2	m	1		~100	AGU	
PREFETCHW	m	1		~100	AGU	
LFENCE		1		0.5	AGU	
MFENCE		4		~45	AGU	
SFENCE		4		~45	AGU	
<b>Arithmetic instructions</b>						
ADD, SUB	r,r/i	1	1	0.5	I0/1	
ADD, SUB	r,m	1		1		
ADD, SUB	m,r	1	6	1		
ADC, SBB	r,r/i	1	1	1	I0/1	
ADC, SBB	r,m	1		1		
ADC, SBB	m,r/i	1	8			
CMP	r,r/i	1	1	0.5	I0/1	
CMP	r,m	1		1		
INC, DEC, NEG	r	1	1	0.5	I0/1	
INC, DEC, NEG	m	1	6	1		
AAA		9	5			
AAS		9	8			
DAA		12	6			
DAS		16	8			
AAD		4	5			
AAM		8	14	13		

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MUL, IMUL	r8/m8	1	3	1	IO	
MUL, IMUL	r16/m16	3	3	3	IO	
MUL, IMUL	r32/m32	2	3	2	IO	
MUL, IMUL	r64/m64	2	6	5	IO	
IMUL	r16,r16/m16	1	3	1	IO	
IMUL	r32,r32/m32	1	3	1	IO	
IMUL	r64,r64/m64	1	6	4	IO	
IMUL	r16,(r16),i	2	4	1	IO	
IMUL	r32,(r32),i	1	3	1	IO	
IMUL	r64,(r64),i	1	6	4	IO	
DIV	r8/m8	1	11-14	11-14	IO	
DIV	r16/m16	2	12-19	12-19	IO	
DIV	r32/m32	2	12-27	12-27	IO	
DIV	r64/m64	2	12-43	12-43	IO	
IDIV	r8/m8	1	11-14	11-14	IO	
IDIV	r16/m16	2	12-19	12-19	IO	
IDIV	r32/m32	2	12-27	12-27	IO	
IDIV	r64/m64	2	12-43	12-43	IO	
CBW, CWDE, CDQE		1	1		IO/1	
CWD, CDQ, CQO		1	1		IO/1	
<b>Logic instructions</b>						
AND, OR, XOR	r,i	1	1	0.5	IO/1	
AND, OR, XOR	r,r	1	1	0.5	IO/1	
AND, OR, XOR	r,m	1		1		
AND, OR, XOR	m,r	1	6	1		
ANDN	r,r,r	1	1	0.5		BMI1
ANDN	r,r,m	2		1		BMI1
TEST	r,i	1	1	0.5	IO/1	
TEST	r,r	1	1	0.5	IO/1	
TEST	r,m	1		1		
NOT	r	1	1	0.5	IO/1	
NOT	m	1	6	1		
SHL, SHR, SAR	r,i/CL	1	1	0.5	IO/1	
ROL, ROR	r,i/CL	1	1	0.5	IO/1	
RCL, RCR	r,1	1	1	1	IO/1	
RCL	r,i	9	5	5		
RCR	r,i	7	4	4		
RCL	r,CL	9	5	5		
RCR	r,CL	7	4	4		
SHL,SHR,SAR,ROL, ROR	m,i /CL	1	6	1		
RCL, RCR	m,1	1		1		
RCL	m,i	10		11		
RCR	m,i	9		11		
RCL	m,CL	9		11		
RCR	m,CL	8		11		
SHLD, SHRD	r,r,i	6	3	3		
SHLD, SHRD	r,r,cl	7	4	4		
SHLD, SHRD	m,r,i/CL	8		11		
BT	r,r/i	1		0.5		
BT	m,i	1		1		
BT	m,r	5		3		

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BTC, BTR, BTS	r,r/i	2	2	1	
BTC	m,i	5		11	
BTR, BTS	m,i	4		11	
BTC, BTR, BTS	m,r	8		11	
BSF	r,r	7	4	4	
BSR	r,r	8	4	4	
BSF, BSR	r,m	8		4	
POPCNT	r,r/m	1	1	0.5	SSE4A/SSE4.2
LZCNT	r,r	1	1	0.5	SSE4A/LZCNT
TZCNT	r,r	2	2	1	BMI1
BLSI BLSR	r,r	2	2	1	BMI1
BLSI BLSR	r,m	3		2	BMI1
BLSMSK	r,r	2	2	1	BMI1
BLSMSK	r,m	3		2	BMI1
BEXTR	r,r,r	1	1	0.5	BMI1
BEXTR	r,m,r	2		1	BMI1
SETcc	r	1	1	0.5	
SETcc	m	1		1	
CLC, STC		1		0.5	I0/1
CMC		1	1		I0/1
CLD		1		1	I0
STD		2		2	I0,I1
<b>Control transfer instructions</b>					
JMP	short/near	1		2	
JMP	r	1		2	
JMP	m(near)	1		2	
Jcc	short/near	1		0.5 - 2	2 if jumping
J(E/R)CXZ	short	2		1 - 2	2 if jumping
LOOP	short	8		5	
LOOPE LOOPNE	short	10		6	
CALL	near	2		2	
CALL	r	2		2	
CALL	m(near)	5		2	
RET		1		3	
RET	i	4		3	
BOUND	m	8		4	values are for no jump
INTO		4		2	values are for no jump
<b>String instructions</b>					
LODS		4		2	
REP LODS		~5n		~3n	
STOS		4		2	
REP STOS		~2n		~n	for small n
REP STOS		2/16B		1/16B	best case
MOVS		7		4	
REP MOVS		~2n		~1.5n	for small n
REP MOVS		2/16B		1/16B	best case
SCAS		5		3	
REP SCAS		~6n		~3n	
CMPS		7		4	



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Instruction	Operands	~6n	~3n		
REP CMPS					
<b>Synchronization</b>					
LOCK ADD	m,r	1	19		
XADD	m,r	4	11		
LOCK XADD	m,r	4	16		
CMPXCHG	m,r8	5	11		
LOCK CMPXCHG	m,r8	5	16		
CMPXCHG	m,r16/32/64	6	11		
LOCK CMPXCHG	m,r16/32/64	6	17		
CMPXCHG8B	m64	18	11		
LOCK CMPXCHG8B	m64	18	19		
CMPXCHG16B	m128	28	32		
LOCK CMPXCHG16B	m128	28	38		
<b>Other</b>					
NOP (90)		1		0.5	I0/1
Long NOP (0F 1F)		1		0.5	I0/1
PAUSE		37		46	
ENTER		i,0	12		18
ENTER		a,b	10+6b	17+3b	
LEAVE		2		3	
CPUID		30-59	70-230		
XGETBV		5		5	
RDTSC		34		41	
RDTSCP		34		42	
RDPMSR		30		27	
CRC32	r,r	3	3	2	
CRC32	r,m	4		2	

32 bit mode

rdtscp

**Floating point x87 instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
FLD	r	1	2	0.5	FP0/1	
FLD	m32/64	1	4	1	FP0/1	
FLD	m80	7	9	5		
FBLD	m80	21	24	29		
FST(P)	r	1	2	0.5	FP0/1	
FST(P)	m32/64	1	3	1	FP1	
FSTP	m80	10	9	7		
FBSTP	m80	217	167	168		
FXCH	r	1	0	1	FP1	
FILD	m	1	8	1	FP1	
FIST(T)(P)	m	1	4	1	FP1	
FLDZ, FLD1		1		1	FP1	
FCMOVcc	st0,r	12	7	7	FP0/1	
FFREE	r	1		1	FP1	
FINCSTP, FDECSTP		1	1	1	FP1	
FNSTSW	AX	2		11	FP1	
FNSTSW	m16	2		11	FP1	
FNSTCW	m16	3		2	FP0	

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FLDCW	m16	12		9	FP1
<b>Arithmetic instructions</b>					
FADD(P),FSUB(R)(P)	r	1	3	1	FP0
FADD(P),FSUB(R)(P)	m	1		1	FP0
FIADD,FISUB(R)	m	2		2	FP0,FP1
FMUL(P)	r	1	5	3	FP1
FMUL(P)	m	1		3	FP1
FIMUL	m	1			FP1
FDIV(R)(P)	r	1	22	22	FP1
FDIV(R)(P)	m	1		22	FP1
FIDIV(R)	m	2		22	FP1
FABS, FCHS		1	2	2	FP1
FCOM(P), FUCOM(P)	r	1		1	FP0
FCOM(P), FUCOM(P)	m	1		1	FP0
FCOMPP, FUCOMPP		1		1	FP0
FCOMI(P)	r	1		2	FP0
FICOM(P)	m	2		1	FP0, FP1
FTST		1		1	FP0
FXAM		2		2	1FP1
FRNDINT		5	8	4	FP0, FP1
FPREM		1	11-54		FP1
FPREM1		1	11-56		FP1
<b>Math</b>					
FSQRT		1	35	35	FP1
FLDPI, etc.		1		1	FP0
FSIN		4-44	30-139	30-151	FP0, FP1
FCOS		11-51	38-93		FP0, FP1
FSINCOS		11-76	55-122	55-180	FP0, FP1
FPTAN		11-45	55-177	55-177	FP0, FP1
FPATAN		9-75	44-167	44-167	FP0, FP1
FSCALE		5	27		FP0, FP1
FEXTRACT		7	9	6	FP0, FP1
F2XM1		8	32-37		FP0, FP1
FYL2X		8-51	30-120	30-120	FP0, FP1
FYL2XP1		61	~160	~160	FP0, FP1
<b>Other</b>					
FNOP		1		0.5	FP0/1
(F)WAIT		1	0	0.5	ALU
FNCLEX		9		32	FP0, FP1
FNINIT		27		78	FP0, FP1
FNSAVE	m	88	138-150	138-150	FP0, FP1
FRSTOR	m	80	136	136	FP0, FP1

**Integer vector instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOVD	r32, mm	1	4	1	FP0	
MOVD	mm, r32	2	6	1	FP0/1	

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MOVD	mm,m32	1	4	1	AGU	
MOVD	r32, x	1	4	1	FP0	
MOVD	x, r32	2	6	1	FP1	
MOVD	x,m32	1	4	1	AGU	
MOVD	m32,(x)mm	1	3	1	FP1	
MOVD / MOVQ	r64,(x)mm	1	4	1	FP0	Moves 64 bits.Name of instruction differs
MOVQ	mm,r64	2	6	1	FP0/1	do.
MOVQ	x,r64	2	6	1	FP0/1	do.
MOVQ	mm,mm	1	1	0.5	FP0/1	
MOVQ	x,x	1	1	0.5	FP0/1	
MOVQ	(x)mm,m64	1	4	1	AGU	
MOVQ	m64,(x)mm	1	3	1	FP1	
MOVDQA	x,x	1	1	0.5	FP0/1	
VMOVDQA	y,y	2	1	1	FP0/1	AVX
MOVDQA	x,m	1	4	1	AGU	
VMOVDQA	y,m	2	4	2	AGU	AVX
MOVDQA	m,x	1	3	1	FP1	
VMOVDQA	m,y	2	3	2	FP1	AVX
MOVDQU, LDDQU	x.m	1	4	1	AGU	
MOVDQU	m,x	1	3	1	FP1	
MOVDQ2Q	mm,x	1	1	0.5	FP0/1	
MOVQ2DQ	x,mm	1	1	0.5	FP0/1	
MOVNTQ	m,mm	1	429	2	FP1	
MOVNTDQ	m,x	1	429	2	FP1	
PACKSSWB/DW						
PACKUSWB	mm,r/m	1	1	0.5	FP0/1	
PACKSSWB/DW						
PACKUSWB	x,r/m	1	2	0.5	FP0/1	
PUNPCKH/LBW/WD/DQ	mm,r/m	1	1	0.5	FP0/1	
PUNPCKH/LBW/WD/DQ	x,r/m	1	2	0.5	FP0/1	
PUNPCKH/LQDQ	x,r/m	1	2	0.5	FP0/1	
PSHUFB	mm,mm	1	1	0.5	FP0/1	Suppl. SSE3
PSHUFB	x,x	3	4	2	FP0/1	Suppl. SSE3
PSHUFD	x,x,i	1	2	0.5	FP0/1	
PSHUFW	mm,mm,i	1	1	0.5	FP0/1	
PSHUFL/HW	x,x,i	1	1	0.5	FP0/1	
PALIGNR	x,x,i	1	2	0.5	FP0/1	Suppl. SSE3
PBLENDW	x,r/m	1	1	0.5	FP0/1	SSE4.1
MASKMOVQ	mm,mm	32	432	17	FP0, FP1	
MASKMOVDQU	x,x	64	43-2210	34	FP0, FP1	
PMOVMASKB	r32,(x)mm	1	3	1	FP0	
PEXTRW	r32,(x)mm,i	1	4	1	FP0	
PINSRW	mm,r32,i	2	8	1	FP0/1	
PINSRB/W/D/Q	x,r,i	2	7	1	FP0/1	
PINSRB/W/D/Q	x,m,i	1		1	FP0/1	
PEXTRB/W/D/Q	r,x,i	1	3	1	FP0	SSE4.1
PEXTRB/W/D/Q	m,x,i	1		1	FP1	SSE4.1
INSERTQ	x,x	3	2	2	FP0, FP1	SSE4A, AMD only
INSERTQ	x,x,i,i	3	2	2	FP0, FP1	SSE4A, AMD only
EXTRQ	x,x	1	1	0.5	FP0/1	SSE4A, AMD only

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EXTRQ	x,x,i,i	1	1	0.5	FP0/1	SSE4A, AMD only
PMOVSBW/BD/BQ/ WD/WQ/DQ	x,x	1	2	0.5	FP0/1	SSE4.1
PMOVZXBW/BD/BQ/ WD/WQ/DQ	x,x	1	2	0.5	FP0/1	SSE4.1
<b>Arithmetic instructions</b>						
PADDB/W/D/Q						
PADDSB/W						
ADDUSB/W						
PSUBB/W/D/Q						
PSUBSB/W						
PSUBUSB/W	(x)mm,r/m	1	1	0.5	FP0/1	
PHADD/SUBW/SW/D	mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PHADD/SUBW/SW/D	x,r/m	1	2	0.5	FP0/1	Suppl. SSE3
PCMPEQ/GT B/W/D	mm,r/m	1	1	0.5	FP0/1	
PCMPEQ/GT B/W/D	x,r/m	1	1	0.5	FP0/1	
PCMPEQQ	(x)mm,r/m	1	1	0.5	FP0/1	SSE4.1
PCMPGTQ	(x)mm,r/m	1	1	0.5	FP0/1	SSE4.2
PMULLW PMULHW						
PMULHUW						
PMULUDQ	(x)mm,r/m	1	2	1	FP0	
PMULLD	x,r/m	3	4	2	FP0 FP1	SSE4.1
PMULDQ	x,r/m	1	2	1	FP0	SSE4.1
PMULHRSW	(x)mm,r/m	1	2	1	FP0	Suppl. SSE3
PMADDWD	(x)mm,r/m	1	2	1	FP0	
PMADDUBSW	(x)mm,r/m	1	2	1	FP0	Suppl. SSE3
PAVGB/W	(x)mm,r/m	1	1	0.5	FP0/1	
PMIN/MAX SW/UB	(x)mm,r/m	1	1	0.5	FP0/1	
PASB/W/D	(x)mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PSIGNB/W/D	(x)mm,r/m	1	1	0.5	FP0/1	Suppl. SSE3
PSADBW	(x)mm,r/m	1	2	0.5	FP0/1	
MPSADBW	x,x,i	3	4	1	FP0/1	SSE4.1
<b>Logic</b>						
PAND PANDN POR						
PXOR	(x)mm,r/m	1	1	0.5	FP0/1	
PSLL/RL W/D/Q						
PSRAW/D	mm,i/mm/m	1	1	0.5	FP0/1	
PSLL/RL W/D/Q						
PSRAW/D	x,x	1	2	0.5	FP0/1	
PSLL/RL W/D/Q						
PSRAW/D	x,i	1	1	0.5	FP0/1	
PSLLDQ, PSRLDQ	x,i	1	2	0.5	FP0/1	
PTEST	x,x/m	1	3	1	FP0	SSE4.1
<b>String instructions</b>						
PCMPESTRI	x,x,i	9	5	5	FP0/1	SSE4.2
PCMPESTRI	x,m,i	10		5	FP0/1	SSE4.2
PCMPESTRM	x,x,i	9	9	9	FP0/1	SSE4.2
PCMPESTRM	x,m,i	10		9	FP0/1	SSE4.2
PCMPISTRI	x,x,i	3	2	2	FP0/1	SSE4.2
PCMPISTRI	x,m,i	4		2	FP0/1	SSE4.2

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PCMPISTRM	x,x,i	3	8	8	FP0/1	SSE4.2
PCMPISTRM	x,m,i	4		2	FP0/1	SSE4.2
<b>Encryption</b>						
PCLMULQDQ	x,x/m,i	1	3	1	FP0	PCLMUL
AESDEC	x,x	2	5	1	FP0/1	AES
AESDECLAST	x,x	2	5	1	FP0/1	AES
AESENC	x,x	2	5	1	FP0/1	AES
AESENCLAST	x,x	2	5	1	FP0/1	AES
AESIMC	x,x	1	2	1	FP0/1	AES
AESKEYGENASSIST	x,x,i	1	2	1	FP0/1	AES
<b>Other</b>						
EMMS		1		0.5	FP0/1	

**Floating point XMM instructions**

Instruction	Operands	Ops	Latency	Reciprocal throughput	Execution pipe	Notes
<b>Move instructions</b>						
MOVAPS/D	x,x	1	1	0.5	FP0/1	
VMOVAPS/D	y,y	2	1	1	FP0/1	
MOVAPS/D	x,m	1	4	1	AGU	
VMOVAPS/D	y,m	2	4	2	AGU	
MOVAPS/D	m,x	1	3	1	FP1	
VMOVAPS/D	m,y	2	3	2	FP1	
MOVUPS/D	x,x	1	1	0.5	FP0/1	
VMOVUPS/D	y,y	2	1	1	FP0/1	
MOVUPS/D	x,m	1	4	1	AGU	
VMOVUPS/D	y,m	2	4	2	AGU	
MOVUPS/D	m,x	1	3	1	FP1	
VMOVUPS/D	m,y	2	3	2	FP1	
MOVSS/D	x,x	1	1	0.5	FP0/1	
MOVSS/D	x,m	1	4	1	AGU	
MOVSS/D	m,x	1	3	1	FP1	
MOVHPLS, MOVLHPS	x,x	1	2	2	FP0/1	
MOVHPS/D, MOVLPS/D	x,m	1	5	1	FP0/1	
MOVHPS/D, MOVLPS/D	m,x	1	4	1	FP1	
MOVNTPS/D	m,x	1	429	1	FP1	
MOVNTSS/D	m,x	1		1	FP1	SSE4A, AMD only
MOVDDUP	x,x	1	2	0.5	FP0/1	SSE3
MOVDDUP	x,m64	1		1	AGU	SSE3
VMOVDDUP	y,y	2	2	1	FP0/1	AVX
VMOVDDUP	y,m	2		2	AGU	AVX
MOVSH/LDUP	x,x	1	1	0.5	FP0/1	
MOVSH/LDUP	x,m	1		1	AGU	
VMOVSH/LDUP	y,y	2	1	1	FP0/1	AVX
VMOVSH/LDUP	y,m	2		2	AGU	AVX
MOVMSKPS/D	r32,x	1	3	1	FP0	
VMOVMSKPS/D	r32,y	1	3	1	FP0	AVX

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SHUFPS/D	x,x/m,i	1	2	0.5	FP0/1	
VSHUFPS/D	y,y,y,i	2	2	1	FP0/1	AVX
UNPCK H/L PS/D	x,x/m	1	2	0.5	FP0/1	
VUNPCK H/L PS/D	y,y,y	2	2	1	FP0/1	AVX
EXTRACTPS	r32,x,i	1	3	1	FP0	
EXTRACTPS	m32,x,i	1	3	1	FP1	
VEXTRACTF128	x,y,i	1	1	0.5	FP0/1	AVX
VEXTRACTF128	m128,y,i	1	12	1	FP1	AVX
INSERTPS	x,x,i	1		1	FP0/1	
INSERTPS	x,m32,i	1	6	1	FP0/1	
VINSERTF128	y,y,x,i	2	1	1	FP0/1	AVX
VINSERTF128	y,y,m128,i	2	13	2	FP0/1	AVX
VMASKMOVPS/D	x,x,m128	1	15	1	FP0/1	>300 clk if mask=0
VMASKMOVPS/D	y,y,m256	2	15	2	FP0/1	>300 clk if mask=0
VMASKMOVPS/D	m128,x,x	19	21	16	FP1	AVX
VMASKMOVPS/D	m256,y,y	36	32	22	FP1	AVX
<b>Conversion</b>						
CVTPS2PD	x,x/m	1	3	1	FP1	
VCVTPS2PD	y,x/m	2	4	2	FP1	
CVTPD2PS	x,x/m	1	4	1	FP1	
VCVTPD2PS	x,y	3	6	2	FP0, FP1	
CVTSD2SS	x,x/m	2	5	8	FP1	
CVTSS2SD	x,x/m	2	4	7	FP1	
CVTDQ2PS/PD	x,x/m	1	4	1	FP1	
VCVTDQ2PS/PD	y,y	2	4	2	FP1	
CVT(T)PS2DQ	x,x/m	1	4	1	FP1	
VCVT(T)PS2DQ	y,y	2	4	2	FP1	
CVT(T)PD2DQ	x,x/m	1	4	1	FP1	
VCVT(T)PD2DQ	y,y	3	7	2	FP1	
CVTPI2PS	xmm,mm	1	4	1	FP1	
CVTPI2PD	xmm,mm	1	4	1	FP1	
CVT(T)PS2PI	mm,xmm	1	4	1	FP1	
CVT(T)PD2PI	mm,xmm	1	4	1	FP1	
CVTSI2SS	xmm,r32	2	9	1	FP1	
CVTSI2SD	xmm,r32	2	9	1	FP1	
CVT(T)SS2SI	r32,xmm	2	8	1	FP1	
CVT(T)SD2SI	r32,xmm	2	8	1	FP1	
VCVTPS2PH	x/m,x,i	1	4	1	FP1	F16C
VCVTPS2PH	x/m,y,i	3	6	2	FP0, FP1	F16C
VCVTPH2PS	x,x/m	1	4	1	FP1	F16C
VCVTPH2PS	y,x/m	2	5	2	FP1	F16C
<b>Arithmetic</b>						
ADDSS/D SUBSS/D	x,x/m	1	3	1	FP0	
ADDPS/D SUBPS/D	x,x/m	1	3	1	FP0	
VADDPS/D VSUBPS/D	y,y/m	2	3	2	FP0	
ADDSUBPS/D	x,x/m	1	3	1	FP0	SSE3
VADDSUBPS/D	y,y/m	2	3	2	FP0	
HADD/SUBPS/D	x,x/m	1	4	1	FP0	SSE3
VHADD/SUBPS/D	y,y/m	2	4	2	FP0	
MULSS/PS	x,x/m	1	2	1	FP1	
VMULPS	y,y/m	2	2	2	FP1	

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MULSD/PD	x,x/m	1	4	2	FP1	
VMULPD	y,y/m	2	4	2	FP1	
DIVSS	x,x/m	1	14	14	FP1	
DIVPS	x,x/m	1	19	19	FP1	
VDIVPS	y,y/m	2	38	38	FP1	
DIVSD	x,x/m	1	19	19	FP1	
DIVPD	x,x/m	1	19	19	FP1	
VDIVPD	y,y/m	2	38	38	FP1	
RCPSS	x,x/m	1	2	1	FP1	
RCPPS	x,x/m	1	2	1	FP1	
VRCPPS	y,y/m	2	2	2	FP1	
MAXSS/D MINSS/D	x,x/m	1	2	1	FP0	
MAXPS/D MINPS/D	x,x/m	1	2	1	FP0	
VMAXPS/D VMINPS/D	y,y/m	2	2	2	FP0	
CMPccSS/D	x,x/m	1	2	1	FP0	
CMPccPS/D	x,x/m	1	2	1	FP0	
VCMPccPS/D	y,y/m	2	2	2	FP0	
(U)COMISS/D	x,x/m	1		1	FP0	
ROUNDSS/SD/PS/PD	x,x/m,i	1	4	1	FP1	
VROUNDSS/D/PS/D	y,y/m,i	2	4	2	FP1	
DPPS	x,x,i	5	11	4	FP0, FP1	SSE4.1
DPPS	x,m,i	6		4	FP0, FP1	SSE4.1
VDPPS	y,y,y,i	10	12	7	FP0, FP1	SSE4.1
VDPPS	y,m,i	12		7	FP0, FP1	SSE4.1
DPPD	x,x,i	3	9	3	FP0, FP1	SSE4.1
DPPD	x,m,i	4		3	FP0, FP1	SSE4.1
<b>Logic</b>						
ANDPS/D ANDNPS/D						
ORPS/D XORPS/D	x,x/m	1	1	0.5	FP0/1	
VANDPS/D, etc.	y,y/m	2	1	1	FP0/1	
<b>Math</b>						
SQRTSS	x,x/m	1	16	16	FP1	
SQRTPS	x,x/m	2	21	21	FP1	
VSQRTPS	y,y/m	2	42	42	FP1	
SQRTSD	x,x/m	1	27	27	FP1	
SQRTPD	x,x/m	2	27	27	FP1	
VSQRTPD	y,y/m	2	54	54	FP1	
RSQRTSS/PS	x,x/m	1	2	1	FP1	
VRSQRTPS	y,y/m	2	2	2	FP1	
<b>Other</b>						
LDMXCSR	m	12	9	8	FP0, FP1	
STMXCSR	m	3	13	12	FP0, FP1	
VZEROUPPER		21		30		32 bit mode
VZEROUPPER		37		46		64 bit mode
VZEROALL		41		58		32 bit mode
VZEROALL		73		90		64 bit mode
FXSAVE		66	66	66		32 bit mode
FXSAVE		58	58	58		64 bit mode
FXRSTOR		115	189	189		32 bit mode
FXRSTOR		123	198	197		64 bit mode

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XSAVE	130	145	145	32 bit mode
XSAVE	114	129	129	64 bit mode
XRSTOR	219	342	342	32 bit mode
XRSTOR	251	375	375	64 bit mode



**Intel Pentium and Pentium MMX****List of instruction timings***Explanation of column headings:*

<b>Operands</b>	r = register, accum = al, ax or eax, m = memory, i = immediate data, sr = segment register, m32 = 32 bit memory operand, etc.
<b>Clock cycles</b>	The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably.
<b>Pairability</b>	u = pairable in u-pipe, v = pairable in v-pipe, uv = pairable in either pipe, np = not pairable.

**Integer instructions (Pentium and Pentium MMX)**

Instruction	Operands	Clock cycles	Pairability
NOP		1	uv
MOV	r/m, r/m/i	1	uv
MOV	r/m, sr	1	np
MOV	sr, r/m	>= 2 b)	np
MOV	m, accum	1	uv h)
XCHG	(E)AX, r	2	np
XCHG	r, r	3	np
XCHG	r, m	>15	np
XLAT		4	np
PUSH	r/i	1	uv
POP	r	1	uv
PUSH	m	2	np
POP	m	3	np
PUSH	sr	1 b)	np
POP	sr	>= 3 b)	np
PUSHF		3-5	np
POPF		4-6	np
PUSHA POPA		5-9 i)	np
PUSHAD POPAD		5	np
LAHF SAHF		2	np
MOVSX MOVZX	r, r/m	3 a)	np
LEA	r, m	1	uv
LDS LES LFS LGS LSS	m	4 c)	np
ADD SUB AND OR XOR	r, r/i	1	uv
ADD SUB AND OR XOR	r, m	2	uv
ADD SUB AND OR XOR	m, r/i	3	uv
ADC SBB	r, r/i	1	u
ADC SBB	r, m	2	u
ADC SBB	m, r/i	3	u
CMP	r, r/i	1	uv
CMP	m, r/i	2	uv
TEST	r, r	1	uv
TEST	m, r	2	uv
TEST	r, i	1	f)
TEST	m, i	2	np
INC DEC	r	1	uv
INC DEC	m	3	uv
NEG NOT	r/m	1/3	np

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MUL IMUL	r8/r16/m8/m16	11	np
MUL IMUL	all other versions	9 d)	np
DIV	r8/m8	17	np
DIV	r16/m16	25	np
DIV	r32/m32	41	np
IDIV	r8/m8	22	np
IDIV	r16/m16	30	np
IDIV	r32/m32	46	np
CBW CWDE		3	np
CWD CDQ		2	np
SHR SHL SAR SAL	r, i	1	u
SHR SHL SAR SAL	m, i	3	u
SHR SHL SAR SAL	r/m, CL	4/5	np
ROR ROL RCR RCL	r/m, 1	1/3	u
ROR ROL	r/m, i(><1)	1/3	np
ROR ROL	r/m, CL	4/5	np
RCR RCL	r/m, i(><1)	8/10	np
RCR RCL	r/m, CL	7/9	np
SHLD SHRD	r, i/CL	4 a)	np
SHLD SHRD	m, i/CL	5 a)	np
BT	r, r/i	4 a)	np
BT	m, i	4 a)	np
BT	m, i	9 a)	np
BTR BTS BTC	r, r/i	7 a)	np
BTR BTS BTC	m, i	8 a)	np
BTR BTS BTC	m, r	14 a)	np
BSF BSR	r, r/m	7-73 a)	np
SETcc	r/m	1/2 a)	np
JMP CALL	short/near	1 e)	v
JMP CALL	far	>= 3 e)	np
conditional jump	short/near	1/4/5/6 e)	v
CALL JMP	r/m	2/5 e)	np
RETN		2/5 e)	np
RETN	i	3/6 e)	np
RETF		4/7 e)	np
RETF	i	5/8 e)	np
J(E)CXZ	short	4-11 e)	np
LOOP	short	5-10 e)	np
BOUND	r, m	8	np
CLC STC CMC CLD STD		2	np
CLI STI		6-9	np
LODS		2	np
REP LODS		7+3*n g)	np
STOS		3	np
REP STOS		10+n g)	np
MOVS		4	np
REP MOVS		12+n g)	np
SCAS		4	np
REP(N)E SCAS		9+4*n g)	np
CMPS		5	np
REP(N)E CMPS		8+4*n g)	np
BSWAP	r	1 a)	np
CPUID		13-16 a)	np

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RDTSC		6-13 a) j)	np
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**Notes:**

- a This instruction has a 0FH prefix which takes one clock cycle extra to decode on a P1 unless preceded by a multi-cycle instruction.
- b versions with FS and GS have a 0FH prefix. see note a.
- c versions with SS, FS, and GS have a 0FH prefix. see note a.
- d versions with two operands and no immediate have a 0FH prefix, see note a.
- e RPL values are for mispredicted jumps/branches.
- f only pairable if register is AL, AX or EAX.
- g add one clock cycle for decoding the repeat prefix unless preceded by a multi-cycle instruction (such as CLD).
- h pairs as if it were writing to the accumulator.
- i 9 if SP divisible by 4 (imperfect pairing).
- j on P1: 6 in privileged or real mode; 11 in non-privileged; error in virtual mode. On PMMX: 8 and 13 clocks respectively.

**Floating point instructions (Pentium and Pentium MMX)**

*Explanation of column headings*

- Operands** r = register, m = memory, m32 = 32-bit memory operand, etc.
- Clock cycles** The numbers are minimum values. Cache misses, misalignment, denormal operands, and exceptions may increase the clock counts considerably.
- Pairability** + = pairable with FXCH, np = not pairable with FXCH.
- i-ov** Overlap with integer instructions. i-ov = 4 means that the last four clock cycles can overlap with subsequent integer instructions.
- fp-ov** Overlap with floating point instructions. fp-ov = 2 means that the last two clock cycles can overlap with subsequent floating point instructions. (WAIT is considered a floating point instruction here)

Instruction	Operand	Clock cycles	Pairability	i-ov	fp-ov
FLD	r/m32/m64	1	0	0	0
FLD	m80	3	np	0	0
FBLD	m80	48-58	np	0	0
FST(P)	r	1	np	0	0
FST(P)	m32/m64	2 m)	np	0	0
FST(P)	m80	3 m)	np	0	0
FBSTP	m80	148-154	np	0	0
FILD	m	3	np	2	2
FIST(P)	m	6	np	0	0
FLDZ FLD1		2	np	0	0
FLDPI FLDL2E etc.		5 s)	np	2	2
FNSTSW	AX/m16	6 q)	np	0	0
FLDCW	m16	8	np	0	0
FNSTCW	m16	2	np	0	0
FADD(P)	r/m	3	0	2	2
FSUB(R)(P)	r/m	3	0	2	2
FMUL(P)	r/m	3	0	2	2 n)
FDIV(R)(P)	r/m	19/33/39 p)	0	38 o)	2
FCHS FABS		1	0	0	0

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FCOM(P)(P) FUCOM	r/m	1	0	0	0
FIADD FISUB(R)	m	6	np	2	2
FIMUL	m	6	np	2	2
FIDIV(R)	m	22/36/42 p)	np	38 o)	2
FICOM	m	4	np	0	0
FTST		1	np	0	0
FXAM		17-21	np	4	0
FPREM		16-64	np	2	2
FPREM1		20-70	np	2	2
FRNDINT		9-20	np	0	0
FSCALE		20-32	np	5	0
FEXTRACT		12-66	np	0	0
FSQRT		70	np	69 o)	2
FSIN FCOS		65-100 r)	np	2	2
FSINCOS		89-112 r)	np	2	2
F2XM1		53-59 r)	np	2	2
FYL2X		103 r)	np	2	2
FYL2XP1		105 r)	np	2	2
FPTAN		120-147 r)	np	36 o)	0
FPATAN		112-134 r)	np	2	2
FNOP		1	np	0	0
FXCH	r	1	np	0	0
FINCSTP FDECSTP		2	np	0	0
FFREE	r	2	np	0	0
FNCLEX		6-9	np	0	0
FNINIT		12-22	np	0	0
FNSAVE	m	124-300	np	0	0
FRSTOR	m	70-95	np	0	0
WAIT		1	np	0	0

**Notes:**

- m The value to store is needed one clock cycle in advance.
- n 1 if the overlapping instruction is also an FMUL.
- o Cannot overlap integer multiplication instructions.
- p FDIV takes 19, 33, or 39 clock cycles for 24, 53, and 64 bit precision respectively. FIDIV takes 3 clocks more. The precision is defined by bit 8-9 of the floating point control word.
- q The first 4 clock cycles can overlap with preceding integer instructions.
- r Clock counts are typical. Trivial cases may be faster, extreme cases may be slower.
- s May be up to 3 clocks more when output needed for FST, FCHS, or FABS.

**MMX instructions (Pentium MMX)**

A list of MMX instruction timings is not needed because they all take one clock cycle, except the MMX multiply instructions which take 3. MMX multiply instructions can be pipelined to yield a throughput of one multiplication per clock cycle.

The EMMS instruction takes only one clock cycle, but the first floating point instruction after an EMMS takes approximately 58 clocks extra, and the first MMX instruction after a floating point instruction takes approximately 38 clocks extra. There is no penalty for an MMX instruction after EMMS on the PMMX.

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There is no penalty for using a memory operand in an MMX instruction because the MMX arithmetic unit is one step later in the pipeline than the load unit. But the penalty comes when you store data from an MMX register to memory or to a 32-bit register: The data have to be ready one clock cycle in advance. This is analogous to the floating point store instructions.

All MMX instructions except EMMS are pairable in either pipe. Pairing rules for MMX instructions are described in manual 3: "The microarchitecture of Intel, AMD and VIA CPUs".

## **Intel Pentium II and Pentium III**

### List of instruction timings and $\mu$ op breakdown

*Explanation of column headings:*

- Operands:** i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
- $\mu$ ops:** The number of  $\mu$ ops that the instruction generates for each execution port.
- p0:** Port 0: ALU, etc.
- p1:** Port 1: ALU, jumps
- p01:** Instructions that can go to either port 0 or 1, whichever is vacant first.
- p2:** Port 2: load data, etc.
- p3:** Port 3: address generation for store
- p4:** Port 4: store data
- Latency:** This is the delay that the instruction generates in a dependency chain. (This is not the same as the time spent in the execution unit. Values may be inaccurate in situations where they cannot be measured exactly, especially with memory operands). The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays by 50-150 clocks, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.
- Reciprocal throughput:** The average number of clock cycles per instruction for a series of independent instructions of the same kind.

### Integer instructions (Pentium Pro, Pentium II and Pentium III)

Instruction	Operands	$\mu$ ops						Latency	Reciprocal throughput
		p0	p1	p01	p2	p3	p4		
MOV	r,r/i			1					
MOV	r,m				1				
MOV	m,r/i					1	1		
MOV	r,sr			1					
MOV	m,sr			1		1	1		
MOV	sr,r	8						5	
MOV	sr,m	7			1			8	
MOVSX MOVZX	r,r			1					
MOVSX MOVZX	r,m				1				
CMOVcc	r,r	1		1					
CMOVcc	r,m	1		1	1				
XCHG	r,r			3					
XCHG	r,m			4	1	1	1	high b)	
XLAT				1	1				
PUSH	r/i			1		1	1		
POP	r			1	1				
POP	(E)SP			2	1				
PUSH	m			1	1	1	1		
POP	m			5	1	1	1		
PUSH	sr			2		1	1		
POP	sr			8	1				

## Pentium II and III

PUSHF(D)		3		11		1	1		
POPF(D)		10		6	1				
PUSHA(D)				2		8	8		
POPA(D)				2	8				
LAHF SAHF				1					
LEA	r,m	1						1 c)	
LDS LES LFS LGS									
LSS	m			8	3				
ADD SUB AND OR XOR	r,r/i			1					
ADD SUB AND OR XOR	r,m			1	1				
ADD SUB AND OR XOR	m,r/i			1	1	1	1		
ADC SBB	r,r/i			2					
ADC SBB	r,m			2	1				
ADC SBB	m,r/i			3	1	1	1		
CMP TEST	r,r/i			1					
CMP TEST	m,r/i			1	1				
INC DEC NEG NOT	r			1					
INC DEC NEG NOT	m			1	1	1	1		
AAA AAS DAA DAS			1						
AAD		1		2				4	
AAM		1	1	2				15	
IMUL	r,(r),(i)	1						4	1
IMUL	(r),m	1			1			4	1
DIV IDIV	r8	2		1				19	12
DIV IDIV	r16	3		1				23	21
DIV IDIV	r32	3		1				39	37
DIV IDIV	m8	2		1	1			19	12
DIV IDIV	m16	2		1	1			23	21
DIV IDIV	m32	2		1	1			39	37
CBW CWDE				1					
CWD CDQ		1							
SHR SHL SAR ROR									
ROL	r,i/CL	1							
SHR SHL SAR ROR									
ROL	m,i/CL	1			1	1	1		
RCR RCL	r,1	1		1					
RCR RCL	r8,i/CL	4		4					
RCR RCL	r16/32,i/CL	3		3					
RCR RCL	m,1	1		2	1	1	1		
RCR RCL	m8,i/CL	4		3	1	1	1		
RCR RCL	m16/32,i/CL	4		2	1	1	1		
SHLD SHRD	r,r,i/CL	2							
SHLD SHRD	m,r,i/CL	2		1	1	1	1		
BT	r,r/i			1					
BT	m,r/i	1		6	1				
BTR BTS BTC	r,r/i			1					
BTR BTS BTC	m,r/i	1		6	1	1	1		
BSF BSR	r,r		1	1					
BSF BSR	r,m		1	1	1				
SETcc	r			1					

Pentium II and III

SETcc	m			1		1	1	
JMP	short/near		1					2
JMP	far	21			1			
JMP	r		1					2
JMP	m(near)		1		1			2
JMP	m(far)	21			2			
conditional jump	short/near		1					2
CALL	near		1	1		1	1	2
CALL	far	28			1	2	2	
CALL	r		1	2		1	1	2
CALL	m(near)		1	4	1	1	1	2
CALL	m(far)	28			2	2	2	
RETN			1	2	1			2
RETN	i		1	3	1			2
RETF		23			3			
RETF	i	23			3			
J(E)CXZ	short		1	1				
LOOP	short	2	1	8				
LOOP(N)E	short	2	1	8				
ENTER	i,0			12		1	1	
ENTER	a,b	ca.	18	+4b		b-1	2b	
LEAVE				2	1			
BOUND	r,m	7		6	2			
CLC STC CMC				1				
CLD STD				4				
CLI		9						
STI		17						
INTO				5				
LODS					2			
REP LODS			10+6n					
STOS					1	1	1	
REP STOS			ca. 5n		a)			
MOVS				1	3	1	1	
REP MOVS			ca. 6n		a)			
SCAS				1	2			
REP(N)E SCAS			12+7n					
CMPS				4	2			
REP(N)E CMPS			12+9n					
BSWAP	r	1		1				
NOP (90)				1				0,5
Long NOP (0F 1F)				1				1
CPUID		23-48						
RDTSC		31						
IN		18						>300
OUT		18						>300
PREFETCHNTA d)	m				1			
PREFETCHT0/1/2 d)	m				1			
SFENCE d)						1	1	6

Notes



Pentium II and III

- a) Faster under certain conditions: see manual 3: "The microarchitecture of Intel, AMD and VIA CPUs".
- b) Has an implicit LOCK prefix.
- c) 3 if constant without base or index register
- d) P3 only.

**Floating point x87 instructions (Pentium Pro, II and III)**

Instruction	Operands	μops						Latency	Reciprocal throughput
		p0	p1	p01	p2	p3	p4		
FLD	r	1							
FLD	m32/64				1			1	
FLD	m80	2			2				
FBLD	m80	38			2				
FST(P)	r	1							
FST(P)	m32/m64					1	1	1	
FSTP	m80	2				2	2		
FBSTP	m80	165				2	2		
FXCH	r							0	1/3 f)
FILD	m	3			1			5	
FIST(P)	m	2				1	1	5	
FLDZ		1							
FLD1 FLDPI FLDL2E etc.		2							
FCMOVcc	r	2						2	
FNSTSW	AX	3						7	
FNSTSW	m16	1				1	1		
FLDCW	m16	1		1	1			10	
FNSTCW	m16	1				1	1		
FADD(P) FSUB(R)(P)	r	1						3	1
FADD(P) FSUB(R)(P)	m	1			1			3-4	1
FMUL(P)	r	1						5	2 g)
FMUL(P)	m	1			1			5-6	2 g)
FDIV(R)(P)	r	1						38 h)	37
FDIV(R)(P)	m	1			1			38 h)	37
FABS		1							
FCHS		3						2	
FCOM(P) FUCOM	r	1						1	
FCOM(P) FUCOM	m	1			1			1	
FCOMPP FUCOMPP		1		1				1	
FCOMI(P) FUCOMI(P)	r	1						1	
FCOMI(P) FUCOMI(P)	m	1			1			1	
FIADD FISUB(R)	m	6			1				
FIMUL	m	6			1				
FIDIV(R)	m	6			1				
FICOM(P)	m	6			1				
FTST		1						1	
FXAM		1						2	
FPREM		23							
FPREM1		33							
FRNDINT		30							

Pentium II and III

FSCALE		56						
FXTRACT		15						
FSQRT		1					69	e,i)
FSIN FCOS		17-97				27-103	e)	
FSINCOS		18-110				29-130	e)	
F2XM1		17-48				66	e)	
FYL2X		36-54				103	e)	
FYL2XP1		31-53				98-107	e)	
FPTAN		21-102				13-143	e)	
FPATAN		25-86				44-143	e)	
FNOP		1						
FINCSTP FDECSTP		1						
FFREE	r	1						
FFREEP	r	2						
FNCLEX				3				
FNINIT		13						
FNSAVE		141						
FRSTOR		72						
WAIT				2				

**Notes:**

- e) Not pipelined
- f) FXCH generates 1  $\mu$ op that is resolved by register renaming without going to any port.
- g) FMUL uses the same circuitry as integer multiplication. Therefore, the combined throughput of mixed floating point and integer multiplications is 1 FMUL + 1 IMUL per 3 clock cycles.
- h) FDIV latency depends on precision specified in control word: 64 bits precision gives latency 38, 53 bits precision gives latency 32, 24 bits precision gives latency 18. Division by a power of 2 takes 9 clocks. Reciprocal throughput is  $1/(latency-1)$ .
- i) Faster for lower precision.

**Integer MMX instructions (Pentium II and Pentium III)**

Instruction	Operands	$\mu$ ops						Latency	Reciprocal throughput
		p0	p1	p01	p2	p3	p4		
MOVD MOVQ	r,r			1				1	0,5
MOVD MOVQ	mm,m32/64				1				1
MOVD MOVQ	m32/64,mm					1	1		1
PADD PSUB PCMP	mm,mm			1				1	0,5
PADD PSUB PCMP	mm,m64			1	1				1
PMUL PMADD	mm,mm	1						3	1
PMUL PMADD	mm,m64	1			1			3	1
PAND(N) POR PXOR	mm,mm			1				1	0,5
PAND(N) POR PXOR	mm,m64			1	1				1
PSRA PSRL PSLL	mm,mm/i		1					1	1
PSRA PSRL PSLL	mm,m64		1		1				1
PACK PUNPCK	mm,mm		1					1	1
PACK PUNPCK	mm,m64		1		1				1
EMMS		11						6 k)	
MASKMOVQ d)	mm,mm			1		1	1	2-8	2 - 30

Pentium II and III

PMOVMASKB d)	r32,mm		1					1	1
MOVNTQ d)	m64,mm					1	1		1 - 30
PSHUFW d)	mm,mm,i		1					1	1
PSHUFW d)	mm,m64,i		1		1			2	1
PEXTRW d)	r32,mm,i		1	1				2	1
PINSRW d)	mm,r32,i		1					1	1
PINSRW d)	mm,m16,i		1		1			2	1
PAVGB PAVGW d)	mm,mm			1				1	0,5
PAVGB PAVGW d)	mm,m64			1	1			2	1
PMIN/MAXUB/SW d)	mm,mm			1				1	0,5
PMIN/MAXUB/SW d)	mm,m64			1	1			2	1
PMULHUW d)	mm,mm	1						3	1
PMULHUW d)	mm,m64	1			1			4	1
PSADBW d)	mm,mm	2		1				5	2
PSADBW d)	mm,m64	2		1	1			6	2

**Notes:**

- d) P3 only.
- k) The delay can be hidden by inserting other instructions between EMMS and any subsequent floating point instruction.

**Floating point XMM instructions (Pentium III)**

Instruction	Operands	μops						Latency	Reciprocal throughput
		p0	p1	p01	p2	p3	p4		
MOVAPS	xmm,xmm			2				1	1
MOVAPS	xmm,m128				2			2	2
MOVAPS	m128,xmm					2	2	3	2
MOVUPS	xmm,m128				4			2	4
MOVUPS	m128,xmm		1			4	4	3	4
MOVSS	xmm,xmm			1				1	1
MOVSS	xmm,m32			1	1			1	1
MOVSS	m32,xmm					1	1	1	1
MOVHPS MOVLPS	xmm,m64			1				1	1
MOVHPS MOVLPS	m64,xmm					1	1	1	1
MOVLHPS MOVHLPS	xmm,xmm			1				1	1
MOVMASKPS	r32,xmm	1						1	1
MOVNTPS	m128,xmm					2	2		2 - 15
CVTPI2PS	xmm,mm		2					3	1
CVTPI2PS	xmm,m64		2		1			4	2
CVT(T)PS2PI	mm,xmm		2					3	1
CVTPS2PI	mm,m128		1		2			4	1
CVTSI2SS	xmm,r32		2		1			4	2
CVTSI2SS	xmm,m32		2		2			5	2
CVT(T)SS2SI	r32,xmm		1		1			3	1
CVTSS2SI	r32,m128		1		2			4	2
ADDPS SUBPS	xmm,xmm		2					3	2
ADDPS SUBPS	xmm,m128		2		2			3	2
ADDSS SUBSS	xmm,xmm		1					3	1
ADDSS SUBSS	xmm,m32		1		1			3	1

## Pentium II and III

MULPS	xmm,xmm	2					4	2
MULPS	xmm,m128	2			2		4	2
MULSS	xmm,xmm	1					4	1
MULSS	xmm,m32	1			1		4	1
DIVPS	xmm,xmm	2					48	34
DIVPS	xmm,m128	2			2		48	34
DIVSS	xmm,xmm	1					18	17
DIVSS	xmm,m32	1			1		18	17
AND(N)PS ORPS XORPS	xmm,xmm		2				2	2
AND(N)PS ORPS XORPS	xmm,m128		2		2		2	2
MAXPS MINPS	xmm,xmm		2				3	2
MAXPS MINPS	xmm,m128		2		2		3	2
MAXSS MINSS	xmm,xmm		1				3	1
MAXSS MINSS	xmm,m32		1		1		3	1
CMPccPS	xmm,xmm		2				3	2
CMPccPS	xmm,m128		2		2		3	2
CMPccSS	xmm,xmm		1				3	1
CMPccSS	xmm,m32		1		1		3	1
COMISS UCOMISS	xmm,xmm		1				1	1
COMISS UCOMISS	xmm,m32		1		1		1	1
SQRTPS	xmm,xmm	2					56	56
SQRTPS	xmm,m128	2			2		57	56
SQRTSS	xmm,xmm	2					30	28
SQRTSS	xmm,m32	2			1		31	28
RSQRTPS	xmm,xmm	2					2	2
RSQRTPS	xmm,m128	2			2		3	2
RSQRTSS	xmm,xmm	1					1	1
RSQRTSS	xmm,m32	1			1		2	1
RCPPS	xmm,xmm	2					2	2
RCPPS	xmm,m128	2			2		3	2
RCPSS	xmm,xmm	1					1	1
RCPSS	xmm,m32	1			1		2	1
SHUFPS	xmm,xmm,i		2	1			2	2
SHUFPS	xmm,m128,i		2		2		2	2
UNPCKHPS UNPCKLPS	xmm,xmm		2	2			3	2
UNPCKHPS UNPCKLPS	xmm,m128		2		2		3	2
LDMXCSR	m32	11					15	15
STMXCSR	m32	6					7	9
FXSAVE	m4096	116					62	
FXRSTOR	m4096	89					68	

## Intel Pentium M, Core Solo and Core Duo

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops fused domain:</b>	The number of $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused $\mu$ ops count as one.
<b><math>\mu</math>ops unfused domain:</b>	The number of $\mu$ ops for each execution port. Fused $\mu$ ops count as two.
<b>p0:</b>	Port 0: ALU, etc.
<b>p1:</b>	Port 1: ALU, jumps
<b>p01:</b>	Instructions that can go to either port 0 or 1, whichever is vacant first.
<b>p2:</b>	Port 2: load data, etc.
<b>p3:</b>	Port 3: address generation for store
<b>p4:</b>	Port 4: store data
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. (This is not the same as the time spent in the execution unit. Values may be inaccurate in situations where they cannot be measured exactly, especially with memory operands). The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays by 50-150 clocks, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.
<b>Reciprocal throughput:</b>	The average number of clock cycles per instruction for a series of independent instructions of the same kind.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain						Latency	Reciprocal throughput
			p0	p1	p01	p2	p3	p4		
<b>Move instructions</b>										
MOV	r,r/i	1			1					0,5
MOV	r,m	1				1				1
MOV	m,r	1					1	1		1
MOV	m,i	2					1	1		1
MOV	r,sr	1			1					
MOV	m,sr	2			1		1	1		
MOV	sr,r	8	8						5	
MOV	sr,m	8	7			1			8	
MOVNTI	m,r32	2					1	1		2
MOVSX MOVZX	r,r	1			1				1	0,5
MOVSX MOVZX	r,m	1				1				1
CMOVcc	r,r	2	1		1				2	1,5
CMOVcc	r,m	2	1		1	1				
XCHG	r,r	3			3				2	1,5

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XCHG	r,m	7			4	1	1	1	high b)	
XLAT		2			1	1				1
PUSH	r	1					1	1	1	1
PUSH	i	2					1	1	1	1
PUSH	m	2				1	1	1	2	1
PUSH	sr	2			1		1	1		
PUSHF(D)		16	3		11		1	1		6
PUSHA(D)		18			2		8	8	8	8
POP	r	1				1				
POP	(E)SP	3			2	1				
POP	m	2				1	1	1	2	1
POP	sr	10			9	1				
POPF(D)		17	10		6	1				16
POPA(D)		10			2	8			7	7
LAHF SAHF		1			1				1	1
SALC		2	1	1						1
LEA	r,m	1	1						1	1
BSWAP	r	2	1		1					
LDS LES LFS LGS LSS	m	11			8	3				
PREFETCHNTA	m	1				1				1
PREFETCHT0/1/2	m	1				1				1
SFENCE/LFENCE/MFENCE		2					1	1		6
IN			18						>300	
OUT			18						>300	
<b>Arithmetic instructions</b>										
ADD SUB	r,r/i	1			1				1	0,5
ADD SUB	r,m	1			1	1			2	1
ADD SUB	m,r/i	3			1	1	1	1		1
ADC SBB	r,r/i	2		1	1				2	2
ADC SBB	r,m	2		1	1	1				
ADC SBB	m,r/i	7			4	1	1	1		
CMP	r,r/i	1			1				1	0,5
CMP	m,r	1			1	1			1	1
CMP	m,i	2			1	1				1
INC DEC NEG NOT	r	1			1				1	0,5
INC DEC NEG NOT	m	3			1	1	1	1		
AAA AAS DAA DAS		1		1						
AAD		3	1		2				2	
AAM		4	1	1	2				15	
MUL IMUL	r8	1	1						4	1
MUL IMUL	r16/r32	3	3						5	1
IMUL	r,r	1	1						4	1
IMUL	r,r,i	1	1						4	1
MUL IMUL	m8	1	1			1			4	1
MUL IMUL	m16/m32	3	3			1			5	1
IMUL	r,m	1	1			1			4	1
IMUL	r,m,i	2	1			1			4	1
DIV IDIV	r8	5	4		1				15-16 c)	12
DIV IDIV	r16	4	3		1				15-24 c)	12-20 c)
DIV IDIV	r32	4	3		1				15-39 c)	12-20 c)
DIV IDIV	m8	6	4		1	1			15-16 c)	12
DIV IDIV	m16	5	3		1	1			15-24 c)	12-20 c)

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DIV IDIV	m32	5	3		1	1			15-39 c)	12-20 c)
CBW CWDE		1		1					1	1
CWD CDQ		1		1					1	1
<b>Logic instructions</b>										
AND OR XOR	r,r/i	1			1				1	0,5
AND OR XOR	r,m	1			1	1			2	1
AND OR XOR	m,r/i	3			1	1	1	1		1
TEST	r,r/i	1			1				1	0,5
TEST	m,r	1			1	1			1	1
TEST	m,i	2			1	1				1
SHR SHL SAR ROR ROL	r,i/CL	1	1						1	1
SHR SHL SAR ROR ROL	m,i/CL	3	1			1	1	1		
RCR RCL	r,1	2	1		1				2	2
RCR	r8,i/CL	9	5		4				11	
RCL	r8,i/CL	8	4		4				10	
RCR RCL	r16/32,i/CL	6	3		3				9	9
RCR RCL	m,1	7	2		2	1	1	1		
RCR	m8,i/CL	12	6		3	1	1	1		
RCL	m8,i/CL	11	5		3	1	1	1		
RCR RCL	m16/32,i/CL	10	5		2	1	1	1		
SHLD SHRD	r,r,i/CL	2	2						2	2
SHLD SHRD	m,r,i/CL	4	1		1	1	1	1		
BT	r,r/i	1		1					1	1
BT	m,r	8			7	1				
BT	m,i	2		1		1				
BTR BTS BTC	r,r/i	1		1						
BTR BTS BTC	m,r	10			7	1	1	1	6	
BTR BTS BTC	m,i	3		1		1	1	1		
BSF BSR	r,r	2		1	1					
BSF BSR	r,m	2		1	1	1				
SETcc	r	1		1						
SETcc	m	2		1			1	1		
CLC STC CMC		1		1						1
CLD STD		4			4					7
<b>Control transfer instructions</b>										
JMP	short/near	1		1						1
JMP	far	22	21			1				28
JMP	r	1		1						1
JMP	m(near)	2		1		1				2
JMP	m(far)	25	23			2				31
conditional jump	short/near	1		1						1
J(E)CXZ	short	2		1	1					1
LOOP	short	11	2	1	8					6
LOOP(N)E	short	11	2	1	8					6
CALL	near	4		1	1		1	1		2
CALL	far	32	27			1	2	2		27
CALL	r	4		1	2		1	1		9
CALL	m(near)	4		1		1	1	1		2
CALL	m(far)	35	29			2	2	2		30
RETN		2		1	2	1				2

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RETN	i	3		1	1	1				2
RETF		27	24			3				30
RETF	i	27	24			3				30
BOUND	r,m	15	7		6	2				8
INTO		5			5					4
<b>String instructions</b>										
LODS		2				2				4
REP LODS		6n			10+6n					0,5
STOS		3				1	1	1		1
REP STOS		5n			ca. 5r	a)				0,7
MOVS		6			1	3	1	1		0,7
REP MOVS		6n			ca. 6r	a)				0,5
SCAS		3			1	2				1,3
REP(N)E SCAS		7n			12+7n					0,6
CMPS		6			4	2				0,7
REP(N)E CMPS		9n			12+9n					0,5
<b>Other</b>										
NOP (90)		1				1				0,5
Long NOP (0F 1F)		1				1				1
PAUSE		2				2				
CLI			9							
STI			17							
ENTER	i,0	12			10		1	1		
ENTER	a,b		ca.	18	+4b		b-1	2b		
LEAVE		3			2	1				
CPUID		38-59	38-59						ca. 130	
RDTSC		13	13							42

**Notes:**

- a) Faster under certain conditions: see manual 3: "The microarchitecture of Intel, AMD and VIA CPUs".
- b) Has an implicit LOCK prefix.
- c) High values are typical, low values are for round divisors. Core Solo/Duo is more efficient than Pentium M in cases with round values that allow an early-out algorithm.

**Floating point x87 instructions**

Instruction	Operands	µops fused domain	µops unfused domain						Latency	Reciprocal throughput
			p0	p1	p01	p2	p3	p4		
<b>Move instructions</b>										
FLD	r	1	1						1	
FLD	m32/64	1				1			1	
FLD	m80	4	2			2				
FBLD	m80	40	38			2				
FST(P)	r	1	1							
FST(P)	m32/m64	1					1	1	1	
FSTP	m80	6	2				2	2		3
FBSTP	m80	169	165				2	2		167
FXCH	r	1							0	0.33 f)



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FILD	m	4	3			1			5	2
FIST(P)	m	4	2				1	1	5	2
FISTTP g)	m	4	2				1	1	5	2
FLDZ		1	1							
FLD1 FLDPI FLDL2E etc.		2	2							
FCMOVcc	r	2	2						2	
FNSTSW	AX	3	3						7	3
FNSTSW	m16	2	1				1	1		
FLDCW	m16	3	1		1	1				19
FNSTCW	m16	3	1				1	1		3
FINCSTP FDECSTP		1	1						1	
FFREE	r	1	1							1
FFREEP	r	2	2							2
FNSAVE		142	142							131
FRSTOR		72	72							91
<b>Arithmetic instructions</b>										
FADD(P) FSUB(R)(P)	r	1			1				3	1
FADD(P) FSUB(R)(P)	m	1			1	1			3	1
FMUL(P)	r	1	1						5	2
FMUL(P)	m	1	1			1			5	2
FDIV(R)(P)	r	1	1						9-38 c)	8-37 c)
FDIV(R)(P)	m	1	1			1			9-38 c)	8-37 c)
FABS		1	1						1	1
FCHS		1	1						1	1
FCOM(P) FUCOM	r	1			1				1	1
FCOM(P) FUCOM	m	1			1	1			1	1
FCOMPP FUCOMPP		2			1	1			1	1
FCOMI(P) FUCOMI(P)	r	1			1				1	1
FIADD FISUB(R)	m	6	3		1	1	1		3	3
FIMUL	m	6	5				1		5	3
FIDIV(R)	m	6	5				1		9-38 c)	8-37 c)
FICOM(P)	m	6	3		2	1				4
FTST		1			1					1
FXAM		1			1					1
FPREM FPREM1		26	26						37	
FRNDINT		15	15						19	
<b>Math</b>										
FSCALE		28	28						43	
FXTRACT		15				15			9	
FSQRT		1	1						9 h)	8
FSIN FCOS		80-100	80-100						80-110	
FSINCOS		90-110	90-110						100-130	
F2XM1		~ 20	~20						~45	
FYL2X		~ 40	~40						~60	
FYL2XP1		~ 55	~55						~65	
FPTAN		~ 100	~100						~140	
FPATAN		~ 85	~85						~140	
<b>Other</b>										
FNOP		1	1							1
WAIT		2			1	1				1

Pentium M

FNCLEX		3	3						13
FNINIT		14	14						27

**Notes:**

- c) High values are typical, low values are for low precision or round divisors.
- f) FXCH generates 1  $\mu$ op that is resolved by register renaming without going to any port.
- g) SSE3 instruction only available on Core Solo and Core Duo.

**Integer MMX and XMM instructions**

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain						Latency	Reciprocal throughput
			p0	p1	p01	p2	p3	p4		
<b>Move instructions</b>										
MOVD	r32,mm	1			1				1	0,5
MOVD	mm,r32	1			1				1	0,5
MOVD	mm,m32	1				1				1
MOVD	m32,mm	1					1	1		1
MOVD	r32,xmm	1		1					1	1
MOVD	xmm,r32	2			2					1
MOVD	xmm,m32	2			1	1				1
MOVD	m32, xmm	1					1	1		1
MOVQ	mm,mm	1			1					0,5
MOVQ	mm,m64	1				1				1
MOVQ	m64,mm	1					1	1		1
MOVQ	xmm,xmm	2			2				1	1
MOVQ	xmm,m64	2			1	1				1
MOVQ	m64, xmm	1					1	1		1
MOVDQA	xmm, xmm	2			2				1	1
MOVDQA	xmm, m128	2				2				2
MOVDQA	m128, xmm	2					2	2		2
MOVDQU	xmm, m128	4			2	2				2-10
MOVDQU	m128, xmm	8			5-6		2-3	2-3		4-20
LDDQU g)	xmm, m128	4								2
MOVDQ2Q	mm, xmm	1		1					1	1
MOVQ2DQ	xmm,mm	2		1	1				1	1
MOVNTQ	m64,mm	1					1	1		2
MOVNTDQ	m128,xmm	4					2	2		3
PACKSSWB/DW										
PACKUSWB	mm,mm	1	1						1	1
PACKSSWB/DW										
PACKUSWB	mm,m64	1	1			1			1	1
PACKSSWB/DW										
PACKUSWB	xmm,xmm	3	2	1					2	2
PACKSSWB/DW										
PACKUSWB	xmm,m128	4	1	1		2			2	2
PUNPCKH/LBW/WD/DQ	mm,mm	1	1						1	1
PUNPCKH/LBW/WD/DQ	mm,m64	1	1			1				1
PUNPCKH/LBW/WD/DQ	xmm,xmm	2	2						2	2
PUNPCKH/LBW/WD/DQ	xmm,m128	3	1			2				2
PUNPCKHQDQ	xmm,xmm	2		1	1				1	1
PUNPCKHQDQ	xmm, m128	3		1		2				1

Pentium M

PUNPCKLQDQ	xmm,xmm	1		1				1	1
PUNPCKLQDQ	xmm, m128	1			1				1
PSHUFW	mm,mm,i	1	1					1	1
PSHUFW	mm,m64,i	2	1		1				1
PSHUFD	xmm,xmm,i	3	2	1				2	2
PSHUFD	xmm,m128,i	4	1	1	2				2
PSHUFL/HW	xmm,xmm,i	2	1	1					1
PSHUFL/HW	xmm, m128,i	3		1	2				1
MASKMOVQ	mm,mm	3			1	1	1		
MASKMOVDQU	xmm,xmm	8		1		2	2		
PMOVMSKB	r32,mm	1	1					1	1
PMOVMSKB	r32,xmm	1	1	j)				1	1
PEXTRW	r32,mm,i	2	1	1				2	1
PEXTRW	r32,xmm,i	4	2	2				3	2
PINSRW	mm,r32,i	1	1					1	1
PINSRW	xmm,r32,i	2	2					1	2
<b>Arithmetic instructions</b>									
PADD/SUB(U)(S)B/W/D	mm,mm	1			1			1	0,5
PADD/SUB(U)(S)B/W/D	mm,m64	1			1	1			1
PADD/SUB(U)(S)B/W/D	xmm,xmm	2			2			1	1
PADD/SUB(U)(S)B/W/D	xmm,m128	4			2	2			2
PADDQ PSUBQ	mm,mm	2			2			2	1
PADDQ PSUBQ	mm,m64	2			2	1			1
PADDQ PSUBQ	xmm,xmm	4			4			2	2
PADDQ PSUBQ	xmm,m128	6			4	2			2
PCMPEQ/GTB/W/D	mm,mm	1			1			1	0,5
PCMPEQ/GTB/W/D	mm,m64	1			1	1			1
PCMPEQ/GTB/W/D	xmm,xmm	2			2			1	1
PCMPEQ/GTB/W/D	xmm,m128	2			2	2			2
PMULL/HW PMULHUW	mm,mm	1			1			3	1
PMULL/HW PMULHUW	mm,m64	1			1	1		3	1
PMULL/HW PMULHUW	xmm,xmm	2			2			3	2
PMULL/HW PMULHUW	xmm,m128	4			2	2		3	2
PMULUDQ	mm,mm	1	1					4	1
PMULUDQ	mm,m64	1	1			1		4	1
PMULUDQ	xmm,xmm	2	2					4	2
PMULUDQ	xmm,m128	4	2			2		4	2
PMADDWD	mm,mm	1			1			3	1
PMADDWD	mm,m64	1			1	1		3	1
PMADDWD	xmm,xmm	2			2			3	2
PMADDWD	xmm,m128	4			2	2		3	2
PAVGB/W	mm,mm	1			1			1	0,5
PAVGB/W	mm,m64	1			1	1			1
PAVGB/W	xmm,xmm	2			2			1	1
PAVGB/W	xmm,m128	4			2	2			2
PMIN/MAXUB/SW	mm,mm	1			1			1	0,5
PMIN/MAXUB/SW	mm,m64	1			1	1			1
PMIN/MAXUB/SW	xmm,xmm	2			2			1	1
PMIN/MAXUB/SW	xmm,m128	4			2	2			2
PSADBW	mm,mm	2			2			4	1
PSADBW	mm,m64	2			2	1		4	1
PSADBW	xmm,xmm	4			4			4	2

Pentium M

PSADBW	xmm,m128	6			4	2			4	2
<b>Logic instructions</b>										
PAND(N) POR PXOR	mm,mm	1			1				1	0,5
PAND(N) POR PXOR	mm,m64	1			1	1			1	1
PAND(N) POR PXOR	xmm,xmm	2			2				1	1
PAND(N) POR PXOR	xmm,m128	4			2	2				2
PSLL/RL/RAW/D/Q	mm,mm/i	1	1						1	1
PSLL/RL/RAW/D/Q	mm,m64	1	1			1				1
PSLL/RL/RAW/D/Q	xmm,i	2	2						2	2
PSLL/RL/RAW/D/Q	xmm,xmm	3	2	1					2	2
PSLL/RL/RAW/D/Q	xmm,m128	3		1		2				2
PSLL/RLDQ	xmm,i	4	3	1					3	3
<b>Other</b>										
EMMS		11			11				6 k)	6

**Notes:**

- g) SSE3 instruction only available on Core Solo and Core Duo.
- j) Also uses some execution units under port 1.
- k) You may hide the delay by inserting other instructions between EMMS and any subsequent floating point instruction.

**Floating point XMM instructions**

Instruction	Operands	µops fused domain	µops unfused domain						Latency	Reciprocal throughput
			p0	p1	p01	p2	p3	p4		
<b>Move instructions</b>										
MOVAPS/D	xmm,xmm	2			2				1	1
MOVAPS/D	xmm,m128	2				2			2	2
MOVAPS/D	m128,xmm	2					2	2	3	2
MOVUPS/D	xmm,m128	4				4			2	2
MOVUPS/D	m128,xmm	8			4		2	2	3	4
MOVSS/D	xmm,xmm	1		1					1	1
MOVSS/D	xmm,m32/64	2		1		1			1	1
MOVSS/D	m32/64,xmm	1					1	1	1	1
MOVHPS/D MOVLPS/D	xmm,m64	1		1		1			1	1
MOVHPS/D MOVLPS/D	m64,xmm	1					1	1	1	1
MOVLHPS MOVHLPS	xmm,xmm	1		1					1	1
MOVMSKPS/D	r32,xmm	1	1	j)					2	1
MOVNTPS/D	m128,xmm	2					2	2		3
SHUFPS/D	xmm,xmm,i	3	2	1					2	2
SHUFPS/D	xmm,m128,i	4	1	1		2				2
MOVDDUP g)	xmm,xmm	2							1	1
MOVSH/LDUP g)	xmm,xmm	2							2	2
MOVSH/LDUP g)	xmm,m128	4								
UNPCKH/LPS	xmm,xmm	4	2	2					3-4	5
UNPCKH/LPS	xmm,m128	4		2		2				5
UNPCKH/LPD	xmm,xmm	2		1	1				1	1
UNPCKH/LPD	xmm,m128	3		1	1	1				1

Pentium M

<b>Conversion</b>									
CVT <sub>PS2</sub> PD	xmm,xmm	4	2	2				3	3
CVT <sub>PS2</sub> PD	xmm,m64	4	1	2		1			3
CVT <sub>PD2</sub> PS	xmm,xmm	4	3	1				4	3
CVT <sub>PD2</sub> PS	xmm,m128	6	3	1		2			3
CVT <sub>SD2</sub> SS	xmm,xmm	2			2			4	2
CVT <sub>SD2</sub> SS	xmm,m64	3			2	1			2
CVT <sub>SS2</sub> SD	xmm,xmm	2	2					2	2
CVT <sub>SS2</sub> SD	xmm,m64	3	2			1			2
CVT <sub>DQ2</sub> PS	xmm,xmm	2			2			3	2
CVT <sub>DQ2</sub> PS	xmm,m128	4			2	2			2
CVT(T) <sub>PS2</sub> DQ	xmm,xmm	2			2			3	2
CVT(T) <sub>PS2</sub> DQ	xmm,m128	4			2	2			2
CVT <sub>DQ2</sub> PD	xmm,xmm	4			4			4	2
CVT <sub>DQ2</sub> PD	xmm,m64	5			4	1			2
CVT(T) <sub>PD2</sub> DQ	xmm,xmm	4			4			4	3
CVT(T) <sub>PD2</sub> DQ	xmm,m128	6			4	2			3
CVT <sub>PI2</sub> PS	xmm,mm	1		1				3	1
CVT <sub>PI2</sub> PS	xmm,m64	2		1		1			1
CVT(T) <sub>PS2</sub> PI	mm,xmm	1		1				3	1
CVT(T) <sub>PS2</sub> PI	mm,m128	2		1		1			1
CVT <sub>PI2</sub> PD	xmm,mm	4	2	2				5	2
CVT <sub>PI2</sub> PD	xmm,m64	5	2	2		1			2
CVT(T) <sub>PD2</sub> PI	mm,xmm	3			3			4	2
CVT(T) <sub>PD2</sub> PI	mm,m128	5			3	2			2
CVT <sub>SI2</sub> SS	xmm,r32	2	1	1				4	1
CVT(T) <sub>SS2</sub> SI	r32,xmm	2		1	1			4	1
CVT(T) <sub>SS2</sub> SI	r32,m32	3		1	1	1			1
CVT <sub>SI2</sub> SD	xmm,r32	2	1	1				4	1
CVT <sub>SI2</sub> SD	xmm,m32	3	1	1		1			1
CVT(T) <sub>SD2</sub> SI	r32,xmm	2		1	1			4	1
CVT(T) <sub>SD2</sub> SI	r32,m64	3		1	1	1			1
<b>Arithmetic</b>									
ADD <sub>SS/D</sub> SUB <sub>SS/D</sub>	xmm,xmm	1			1			3	1
ADD <sub>SS/D</sub> SUB <sub>SS/D</sub>	xmm,m32/64	2			1	1		3	1
ADD <sub>PS/D</sub> SUB <sub>PS/D</sub>	xmm,xmm	2			2			3	2
ADD <sub>PS/D</sub> SUB <sub>PS/D</sub>	xmm,m128	4			2	2		3	2
ADD <sub>SUBPS/D</sub> g)	xmm,xmm	2			2			3	2
HADD <sub>PS</sub> H <sub>SUBPS</sub> g)	xmm,xmm	6?			?			7	4
HADD <sub>PD</sub> H <sub>SUBPD</sub> g)	xmm,xmm	3			3			4	2
MUL <sub>SS</sub>	xmm,xmm	1	1					4	1
MUL <sub>SD</sub>	xmm,xmm	1	1					5	2
MUL <sub>SS</sub>	xmm,m32	2	1			1		4	1
MUL <sub>SD</sub>	xmm,m64	2	1			1		5	2
MUL <sub>PS</sub>	xmm,xmm	2	2					4	2
MUL <sub>PD</sub>	xmm,xmm	2	2					5	4
MUL <sub>PS</sub>	xmm,m128	4	2			2		4	2
MUL <sub>PD</sub>	xmm,m128	4	2			2		5	4
DIV <sub>SS</sub>	xmm,xmm	1	1					9-18 c)	8-17 c)
DIV <sub>SD</sub>	xmm,xmm	1	1					9-32 c)	8-31 c)
DIV <sub>SS</sub>	xmm,m32	2	1			1		9-18 c)	8-17 c)
DIV <sub>SD</sub>	xmm,m64	2	1			1		9-32 c)	8-31 c)

## Pentium M

DIVPS	xmm,xmm	2	2					16-34 c)	16-34 c)
DIVPD	xmm,xmm	2	2					16-62 c)	16-62 c)
DIVPS	xmm,m128	4	2			2		16-34 c)	16-34 c)
DIVPD	xmm,m128	4	2			2		16-62 c)	16-62 c)
CMPccSS/D	xmm,xmm	1			1			3	1
CMPccSS/D	xmm,m32/64	2			1	1			1
CMPccPS/D	xmm,xmm	2			2			3	2
CMPccPS/D	xmm,m128	4			2	2			2
COMISS/D UCOMISS/D	xmm,xmm	1		1					1
COMISS/D UCOMISS/D	xmm,m32/64	2		1		1			1
MAXSS/D MINSS/D	xmm,xmm	1			1			3	1
MAXSS/D MINSS/D	xmm,m32/64	2			1	1		3	1
MAXPS/D MINPS/D	xmm,xmm	2			2			3	2
MAXPS/D MINPS/D	xmm,m128	4			2	2		3	2
RCPSS	xmm,xmm	1		1				3	1
RCPSS	xmm,m32	2		1		1			1
RCPPS	xmm,xmm	2		2				3	2
RCPPS	xmm,m128	4		2		2			2
<b>Math</b>									
SQRTSS	xmm,xmm	2	2					6-30	4-28
SQRTSS	xmm,m32	3	2			1			4-28
SQRTSD	xmm,xmm	1	1					5-58	4-57
SQRTSD	xmm,m64	2	1			1			4-57
SQRTPS	xmm,xmm	2	2					8-56	16-55
SQRTPD	xmm,xmm	2	2					16-114	16-114
SQRTPS	xmm,m128	4	2			2			16-55
SQRTPD	xmm,m128	4	2			2			16-114
RSQRTSS	xmm,xmm	1		1				3	1
RSQRTSS	xmm,m32	2		1		1			1
RSQRTPS	xmm,xmm	2		3				3	2
RSQRTPS	xmm,m128	4		2		2			2
<b>Logic</b>									
AND/ANDN/OR/XORPS/D	xmm,xmm	2			2			1	1
AND/ANDN/OR/XORPS/D	xmm,m128	4			2	2			1
<b>Other</b>									
LDMXCSR	m32	9	9						20
STMXCSR	m32	6	6						12
FXSAVE	m4096	118	32				43	43	63
FXRSTOR	m4096	87	43			44			72

**Notes:**

- c) High values are typical, low values are for round divisors.  
g) SSE3 instruction only available on Core Solo and Core Duo.  
j) Also uses some execution units under port 1.

## Intel Core 2 (Merom, 65nm)

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

- Operands:** i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
- $\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused  $\mu$ ops count as one.
- $\mu$ ops unfused domain:** The number of  $\mu$ ops for each execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if the sum of the numbers listed under p015 + p2 + p3 + p4 exceeds the number listed under  $\mu$ ops fused domain. An x under p0, p1 or p5 means that at least one of the  $\mu$ ops listed under p015 can optionally go to this port. For example, a 1 under p015 and an x under p0 and p5 means one  $\mu$ op which can go to either port 0 or port 5, whichever is vacant first. A value listed under p015 but nothing under p0, p1 and p5 means that it is not known which of the three ports these  $\mu$ ops go to.
- p015:** The total number of  $\mu$ ops going to port 0, 1 and 5.
- p0:** The number of  $\mu$ ops going to port 0 (execution units).
- p1:** The number of  $\mu$ ops going to port 1 (execution units).
- p5:** The number of  $\mu$ ops going to port 5 (execution units).
- p2:** The number of  $\mu$ ops going to port 2 (memory read).
- p3:** The number of  $\mu$ ops going to port 3 (memory write address).
- p4:** The number of  $\mu$ ops going to port 4 (memory write data).
- Unit:** Tells which execution unit cluster is used. An additional delay of 1 clock cycle is generated if a register written by a  $\mu$ op in the integer unit (int) is read by a  $\mu$ op in the floating point unit (float) or vice versa. flt→int means that an instruction with multiple  $\mu$ ops receive the input in the float unit and delivers the output in the int unit. Delays for moving data between different units are included under latency when they are unavoidable. For example, movd eax,xmm0 has an extra 1 clock delay for moving from the XMM-integer unit to the general purpose integer unit. This is included under latency because it occurs regardless of which instruction comes next. Nothing listed under unit means that additional delays are either unlikely to occur or unavoidable and therefore included in the latency figure.
- Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.
- Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain								Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4				
<b>Move instructions</b>													
MOV	r,r/i	1	1	x	x	x					int	1	0,33

## Merom

MOV a)	r,m	1					1			int	2	1
MOV a)	m,r	1						1	1	int	3	1
MOV	m,i	1						1	1	int	3	1
MOV	r,sr	1					1			int		1
MOV	m,sr	2					1	1	1	int		1
MOV	sr,r	8	4	x	x	x	4			int		16
MOV	sr,m	8	3	x		x	5			int		16
MOVNTI	m,r	2						1	1	int		2
MOVSX MOVZX												
MOVSXD	r,r	1	1	x	x	x				int	1	0,33
MOVSX MOVZX	r,m	1					1			int		1
CMOVcc	r,r	2	2	x	x	x				int	2	1
CMOVcc	r,m	2	2	x	x	x	1			int		
XCHG	r,r	3	3	x	x	x				int	2	2
XCHG	r,m	7	x				1	1	1	int	high b)	
XLAT		2	1				1			int	4	1
PUSH	r	1						1	1	int	3	1
PUSH	i	1						1	1	int		1
PUSH	m	2					1	1	1	int		1
PUSH	sr	2	1					1	1	int		1
PUSHF(D/Q)		17	15	x	x	x		1	1	int		7
PUSHA(D) i)		18	9					1	8	int		8
POP	r	1					1			int	2	1
POP	(E/R)SP	4	3				1			int		
POP	m	2					1	1	1	int		1,5
POP	sr	10	9				1			int		17
POPF(D/Q)		24	23	x	x	x	1			int	20	
POPA(D) i)		10	2				8			int		7
LAHF SAHF		1	1	x	x	x				int	1	0,33
SALC i)		2	2	x	x	x				int	4	1
LEA a)	r,m	1	1	1						int	1	1
BSWAP	r	2	2	1		1				int	4	1
LDS LES LFS LGS LSS	m	11	11				1			int		17
PREFETCHNTA	m	1					1			int		1
PREFETCHT0/1/2	m	1					1			int		1
LFENCE		2						1	1	int		8
MFENCE		2						1	1	int		9
SFENCE		2						1	1	int		9
CLFLUSH	m8	4	2	x	x	x		1	1	int	240	117
IN										int		
OUT										int		
<b>Arithmetic instructions</b>												
ADD SUB	r,r/i	1	1	x	x	x				int	1	0,33
ADD SUB	r,m	1	1	x	x	x	1			int		1
ADD SUB	m,r/i	2	1	x	x	x	1	1	1	int	6	1
ADC SBB	r,r/i	2	2	x	x	x				int	2	2
ADC SBB	r,m	2	2	x	x	x	1			int	2	2
ADC SBB	m,r/i	4	3	x	x	x	1	1	1	int	7	
CMP	r,r/i	1	1	x	x	x				int	1	0,33
CMP	m,r/i	1	1	x	x	x	1			int	1	1
INC DEC NEG NOT	r	1	1	x	x	x				int	1	0,33
INC DEC NEG NOT	m	3	1	x	x	x	1	1	1	int	6	1



## Merom

AAA AAS DAA DAS i)		1	1		1						int		1
AAD i)		3	3	x	x	x					int		1
AAM i)		4	4								int	17	
MUL IMUL	r8	1	1		1						int	3	1
MUL IMUL	r16	3	3	x	x	x					int	5	1,5
MUL IMUL	r32	3	3	x	x	x					int	5	1,5
MUL IMUL	r64	3	3	x	x	x					int	7	4
IMUL	r16,r16	1	1		1						int	3	1
IMUL	r32,r32	1	1		1						int	3	1
IMUL	r64,r64	1	1	1							int	5	2
IMUL	r16,r16,i	1	1		1						int	3	1
IMUL	r32,r32,i	1	1		1						int	3	1
IMUL	r64,r64,i	1	1	1							int	5	2
MUL IMUL	m8	1	1		1		1				int	3	1
MUL IMUL	m16	3	3	x	x	x	1				int	5	1,5
MUL IMUL	m32	3	3	x	x	x	1				int	5	1,5
MUL IMUL	m64	3	2	2			1				int	7	4
IMUL	r16,m16	1	1		1		1				int	3	1
IMUL	r32,m32	1	1		1		1				int	3	1
IMUL	r64,m64	1	1	1			1				int	5	2
IMUL	r16,m16,i	1	1		1		1				int		2
IMUL	r32,m32,i	1	1		1		1				int		1
IMUL	r64,m64,i	1	1	1			1				int		2
DIV IDIV	r8	3	3								int	18	12
DIV IDIV	r16	5	5								int	18-26	12-20 c)
DIV IDIV	r32	4	4								int	18-42	12-36 c)
DIV	r64	32	32								int	29-61	18-37 c)
IDIV	r64	56	56								int	39-72	28-40 c)
DIV IDIV	m8	4	3				1				int	18	12
DIV IDIV	m16	6	5				1				int	18-26	12-20 c)
DIV IDIV	m32	5	4				1				int	18-42	12-36 c)
DIV	m64	32	31				1				int	29-61	18-37 c)
IDIV	m64	56	55				1				int	39-72	28-40 c)
CBW CWDE CDQE		1	1	x	x	x					int	1	
CWD CDQ CQO		1	1	x		x					int	1	
<b>Logic instructions</b>													
AND OR XOR	r,r/i	1	1	x	x	x					int	1	0,33
AND OR XOR	r,m	1	1	x	x	x	1				int		1
AND OR XOR	m,r/i	2	1	x	x	x	1	1	1		int	6	1
TEST	r,r/i	1	1	x	x	x					int	1	0,33
TEST	m,r/i	1	1	x	x	x	1				int		1
SHR SHL SAR	r,i/cl	1	1	x		x					int	1	0,5
SHR SHL SAR	m,i/cl	3	2	x		x	1	1	1		int	6	1
ROR ROL	r,i/cl	1	1	x		x					int	1	1
ROR ROL	m,i/cl	3	2	x		x	1	1	1		int	6	1
RCR RCL	r,1	2	2	x	x	x					int	2	2
RCR	r8,i/cl	9	9	x	x	x					int	12	
RCL	r8,i/cl	8	8	x	x	x					int	11	
RCR RCL	r16/32/64,i/cl	6	6	x	x	x					int	11	
RCR RCL	m,1	4	3	x	x	x	1	1	1		int	7	
RCR	m8,i/cl	12	9	x	x	x	1	1	1		int	14	
RCL	m8,i/cl	11	8	x	x	x	1	1	1		int	13	

Merom

RCL RCR	m16/32/64,i/cl	10	7	x	x	x	1	1	1	int	13	
SHLD SHRD	r,r,i/cl	2	2	x	x	x				int	2	1
SHLD SHRD	m,r,i/cl	3	2	x	x	x	1	1	1	int	7	
BT	r,r/i	1	1	x	x	x				int	1	1
BT	m,r	10	9	x	x	x	1			int		5
BT	m,i	2	1	x	x	x	1			int		1
BTR BTS BTC	r,r/i	1	1	x	x	x				int	1	
BTR BTS BTC	m,r	11	8	x	x	x	1	1	1	int	5	
BTR BTS BTC	m,i	3	1	x	x	x	1	1	1	int	6	
BSF BSR	r,r	2	2	x	1	x				int	2	1
BSF BSR	r,m	2	2	x	1	x	1			int		2
SETcc	r	1	1	x	x	x				int	1	1
SETcc	m	2	1	x	x	x		1	1	int		1
CLC STC CMC		1	1	x	x	x				int	1	0,33
CLD		7	7	x	x	x				int		4
STD		6	6	x	x	x				int		14
<b>Control transfer instructions</b>												
JMP	short/near	1	1				1			int	0	1-2
JMP i)	far	30	30							int		76
JMP	r	1	1				1			int	0	1-2
JMP	m(near)	1	1				1	1		int	0	1-2
JMP	m(far)	31	29					2		int		68
Conditional jump	short/near	1	1				1			int	0	1
Fused compare/test and branch e,i)		1	1				1			int	0	1
J(E/R)CXZ	short	2	2	x	x	1				int		1-2
LOOP	short	11	11	x	x	x				int		5
LOOP(N)E	short	11	11	x	x	x				int		5
CALL	near	3	2	x	x	x		1	1	int		2
CALL i)	far	43	43							int		75
CALL	r	3	2					1	1	int		2
CALL	m(near)	4	3					1	1	int		2
CALL	m(far)	44	42					2		int		75
RETN		1	1				1	1		int		2
RETN	i	3	x				1	1		int		2
RETF		32	30					2		int		78
RETF	i	32	30					2		int		78
BOUND i)	r,m	15	13					2		int		8
INTO i)		5	5							int		3
<b>String instructions</b>												
LODS		3	2					1		int		1
REP LODS		$4+7n - 14+6n$								int	$1+5n - 21+3n$	
STOS		4	2						1	int		1
REP STOS		$8+5n - 20+1.2n$								int	$7+2n - 0.55n$	
MOVS		8	5							int		
REP MOVS		$7+7n - 13+n$		1			5			int		
SCAS		4	3					1		int		1
REP(N)E SCAS		$7+8n - 17+7n$								int	$3+8n - 23+6n$	
CMPS		7	5					2		int		3
REP(N)E CMPS		$7+10n - 7+9n$								int	$2+7n - 22+5n$	

Merom

Other												
NOP (90)		1	1	x	x	x					int	0,33
Long NOP (0F 1F)		1	1	x	x	x					int	1
PAUSE		3	3	x	x	x					int	8
ENTER	i,0	12	10						1	1	int	8
ENTER	a,b										int	
LEAVE		3	2					1			int	
CPUID		46-100									int	180-215
RDTSC		29									int	64
RDPMSR		23									int	54

Notes:

- a) Applies to all addressing modes
- b) Has an implicit LOCK prefix.
- c) Low values are for small results, high values for high results.
- e) See manual 3: "The microarchitecture of Intel, AMD and VIA CPUs" for restrictions on macro-op fusion.
- i) Not available in 64 bit mode.

Floating point x87 instructions

Instruction	Operands	μops fused domain	μops unfused domain								Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4				
<b>Move instructions</b>													
FLD	r	1	1	1							float	1	1
FLD	m32/64	1	1					1			float	3	1
FLD	m80	4	2	2				2			float	4	3
FBLD	m80	40	38					2			float	45	20
FST(P)	r	1	1	1							float	1	1
FST(P)	m32/m64	1							1	1	float	3	1
FSTP	m80	7	3	x	x	x		2	2		float	4	5
FBSTP	m80	170	166	x	x	x		2	2		float	164	166
FXCH	r	1	0 f)								float	0	1
FILD	m	1	1	1				1			float	6	1
FIST	m	2	1		1				1	1	float	6	1
FISTP	m	3	1		1				1	1	float	6	1
FISTTP g)	m	3	1		1				1	1	float	6	1
FLDZ		1	1	1							float		1
FLD1		2	2	1	1						float		2
FLDPI FLDL2E etc.		2	2		2						float		2
FCMOVcc	r	2	2	2							float	2	2
FNSTSW	AX	1	1	1							float		1
FNSTSW	m16	2	1	1					1	1	float		2
FLDCW	m16	2	1					1			float		10
FNSTCW	m16	3	1						1	1	float		8
FINCSTP FDECSTP		1	1	1							float	1	1
FFREE(P)	r	2	2	2							float		2
FNSAVE	m	142									float	184	192
FRSTOR	m	78									float	169	177
<b>Arithmetic instructions</b>													

Merom

FADD(P) FSUB(R)(P)	r	1	1		1					float	3	1
FADD(P) FSUB(R)(P)	m	1	1		1		1			float		1
FMUL(P)	r	1	1	1						float	5	2
FMUL(P)	m	1	1	1			1			float		2
FDIV(R)(P)	r	1	1	1						float	6-38 d)	5-37 d)
FDIV(R)(P)	m	1	1	1				1		float		5-37 d)
FABS		1	1	1						float	1	1
FCHS		1	1	1						float	1	1
FCOM(P) FUCOM	r	1	1		1					float		1
FCOM(P) FUCOM	m	1	1		1		1			float		1
FCOMPP FUCOMPP		2	2	1	1					float		
FCOMI(P) FUCOMI(P)	r	1	1		1					float		1
FIADD FISUB(R)	m	2	2	1	1		1			float		2
FIMUL	m	2	2	2			1			float		2
FIDIV(R)	m	2	2	2			1			float		5-37 d)
FICOM(P)	m	2	2	1	1		1			float		2
FTST		1	1		1					float		1
FXAM		1	1		1					float		1
FPREM FPREM1		21-27	21-27							float	16-56	
FRNDINT		7-15	7-15							float	22-29	
<b>Math</b>												
FSCALE		27	27							float	41	
FEXTRACT		82	82							float	170	
FSQRT		1	1							float	6-69	
FSIN FCOS		~96	~96							float	~96	
FSINCOS		~100	~100							float	~115	
F2XM1		~19	~19							float	~45	
FYL2X FYL2XP1		~53	~53							float	~96	
FPTAN		~98	~98							float	~136	
FPATAN		~70	~70							float	~119	
<b>Other</b>												
FNOP		1	1	1						float		1
WAIT		2	2							float		1
FNCLEX		4	4							float		15
FNINIT		15	15							float		63

**Notes:**

- d) Round divisors or low precision give low values.
- f) Resolved by register renaming. Generates no  $\mu$ ops in the unfused domain.
- g) SSE3 instruction set.

**Integer MMX and XMM instructions**

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain							Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												
MOVD k)	r32/64,(x)mm	1	1	x	x	x				int	2	0,33
MOVD k)	m32/64,(x)mm	1						1	1	int	3	1
MOVD k)	(x)mm,r32/64	1	1	x		x				int	2	0,5
MOVD k)	(x)mm,m32/64	1					1			int	2	1

## Merom

MOVQ	(x)mm, (x)mm	1	1	x	x	x				int	1	0,33
MOVQ	(x)mm,m64	1					1			int	2	1
MOVQ	m64, (x)mm	1						1	1		3	1
MOVDQA	xmm, xmm	1	1	x	x	x				int	1	0,33
MOVDQA	xmm, m128	1					1			int	2	1
MOVDQA	m128, xmm	1						1	1		3	1
MOVDQU	m128, xmm	9	4	x	x	x	1	2	2		3-8	4
MOVDQU	xmm, m128	4	2	x		x	2			int	2-8	2
LDDQU g)	xmm, m128	4	2	x		x	2			int	2-8	2
MOVDQ2Q	mm, xmm	1	1	x	x	x				int	1	0,33
MOVQ2DQ	xmm,mm	1	1	x	x	x				int	1	0,33
MOVNTQ	m64,mm	1						1	1			2
MOVNTDQ	m128,xmm	1						1	1			2
PACKSSWB/DW	mm,mm	1	1	1						int	1	1
PACKUSWB	mm,m64	1	1	1			1			int		1
PACKSSWB/DW	xmm,xmm	3	3							flt→int	3	2
PACKUSWB	xmm,m128	4	3				1			int		2
PUNPCKH/LBW/WD/DQ	mm,mm	1	1	1						int	1	1
PUNPCKH/LBW/WD/DQ	mm,m64	1	1	1			1			int		1
PUNPCKH/LBW/WD/DQ	xmm,xmm	3	3							flt→int	3	2
PUNPCKH/LBW/WD/DQ	xmm,m128	4	3				1			int		2
PUNPCKH/LQDQ	xmm,xmm	1	1							int	1	1
PUNPCKH/LQDQ	xmm, m128	2	1				1			int		1
PSHUFB h)	mm,mm	1	1			1				int	1	1
PSHUFB h)	mm,m64	2	1			1	1			int		1
PSHUFB h)	xmm,xmm	4	4							int	3	2
PSHUFB h)	xmm,m128	5	4				1			int		2
PSHUFW	mm,mm,i	1	1			1				int	1	1
PSHUFW	mm,m64,i	2	1			1	1			int		1
PSHUFD	xmm,xmm,i	2	2	x	x	1				flt→int	3	1
PSHUFD	xmm,m128,i	3	2	x	x	1	1			int		1
PSHUFL/HW	xmm,xmm,i	1	1			1				int	1	1
PSHUFL/HW	xmm, m128,i	2	1			1	1			int		1
PALIGNR h)	mm,mm,i	2	2	x	x	x				int	2	1
PALIGNR h)	mm,m64,i	2	2	x	x	x	1			int		1
PALIGNR h)	xmm,xmm,i	2	2	x	x	x				int	2	1
PALIGNR h)	xmm,m128,i	2	2	x	x	x	1			int		1
MASKMOVQ	mm,mm	4								int		2-5
MASKMOVDQU	xmm,xmm	10								int		6-10
PMOVMSKB	r32,(x)mm	1	1	1						int	2	1
PEXTRW	r32,mm,i	2	2							int	3	1
PEXTRW	r32,xmm,i	3	3							int	5	1
PINSRW	mm,r32,i	1	1			1				int	2	1
PINSRW	mm,m16,i	2	1			1	1			int		1
PINSRW	xmm,r32,i	3	3	x	x	x				int	6	1,5
PINSRW	xmm,m16,i	4	3	x	x	x	1			int		1,5
<b>Arithmetic instructions</b>												
PADD/SUB(U)(S)B/W/D	(x)mm, (x)mm	1	1	x		x				int	1	0,5
PADD/SUB(U)(S)B/W/D	(x)mm,m	1	1	x		x	1			int		1
PADDQ PSUBQ	(x)mm, (x)mm	2	2	x		x				int	2	1
PADDQ PSUBQ	(x)mm,m	2	2	x		x	1			int		1

## Merom

PHADD(S)W PHSUB(S)W h)	mm,mm	5	5						int	5	4
PHADD(S)W PHSUB(S)W h)	mm,m64	6	5				1		int		4
PHADD(S)W PHSUB(S)W h)	xmm,xmm	7	7						int	6	4
PHADD(S)W PHSUB(S)W h)	xmm,m128	8	7				1		int		4
PHADDD PHSUBD h)	mm,mm	3	3						int	3	2
PHADDD PHSUBD h)	mm,m64	4	3				1		int		2
PHADDD PHSUBD h)	xmm,xmm	5	5						int	5	3
PHADDD PHSUBD h)	xmm,m128	6	5				1		int		3
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	1	x		x			int	1	0,5
PCMPEQ/GTB/W/D	(x)mm,m	1	1	x		x	1		int		1
PMULL/HW PMULHUW	(x)mm,(x)mm	1	1		1				int	3	1
PMULL/HW PMULHUW	(x)mm,m	1	1		1		1		int		1
PMULHSW h)	(x)mm,(x)mm	1	1		1				int	3	1
PMULHSW h)	(x)mm,m	1	1		1		1		int		1
PMULUDQ	(x)mm,(x)mm	1	1		1				int	3	1
PMULUDQ	(x)mm,m	1	1		1		1		int		1
PMADDWD	(x)mm,(x)mm	1	1		1				int	3	1
PMADDWD	(x)mm,m	1	1		1		1		int		1
PMADDUBSW h)	(x)mm,(x)mm	1	1		1				int	3	1
PMADDUBSW h)	(x)mm,m	1	1		1		1		int		1
PAVGB/W	(x)mm,(x)mm	1	1	x		x			int	1	0,5
PAVGB/W	(x)mm,m	1	1	x		x	1		int		1
PMIN/MAXUB/SW	(x)mm,(x)mm	1	1	x		x			int	1	0,5
PMIN/MAXUB/SW	(x)mm,m	1	1	x		x	1		int		1
PABSB PABSW PABSD h)	(x)mm,(x)mm	1	1	x		x			int	1	0,5
PABSB PABSW PABSD h)	(x)mm,m	1	1	x		x	1		int		1
PSIGNB PSIGNW	(x)mm,(x)mm	1	1	x		x			int	1	0,5
PSIGND h)	(x)mm,m	1	1	x		x	1		int		1
PSADBW	(x)mm,(x)mm	1	1		1				int	3	1
PSADBW	(x)mm,m	1	1		1		1		int		1
<b>Logic instructions</b>											
PAND(N) POR PXOR	(x)mm,(x)mm	1	1	x	x	x			int	1	0,33
PAND(N) POR PXOR	(x)mm,m	1	1	x	x	x	1		int		1
PSLL/RL/RAW/D/Q	mm,mm/i	1	1	1					int	1	1
PSLL/RL/RAW/D/Q	mm,m64	1	1	1			1		int		1
PSLL/RL/RAW/D/Q	xmm,i	1	1	1					int	1	1
PSLL/RL/RAW/D/Q	xmm,xmm	2	2	x	x				int	2	1
PSLL/RL/RAW/D/Q	xmm,m128	3	2	x	x		1		int		1
PSLL/RDQ	xmm,i	2	2	x	x				int	2	1
<b>Other</b>											
EMMS		11	11	x	x	x			float		6

Notes:

- g) SSE3 instruction set.  
h) Supplementary SSE3 instruction set.  
k) MASM uses the name MOVQ rather than MOVQ for this instruction even when moving 64 bits.

## Floating point XMM instructions

Instruction	Operands	μops fused domain	μops unfused domain							Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												
MOVAPS/D	xmm,xmm	1	1	x	x	x				int	1	0,33
MOVAPS/D	xmm,m128	1					1			int	2	1
MOVAPS/D	m128,xmm	1						1	1		3	1
MOVUPS/D	xmm,m128	4	2	1		1	2			int	2-4	2
MOVUPS/D	m128,xmm	9	4	x	x	x	1	2	2		3-4	4
MOVSS/D	xmm,xmm	1	1	x	x	x				int	1	0,33
MOVSS/D	xmm,m32/64	1					1			int	2	1
MOVSS/D	m32/64,xmm	1						1	1		3	1
MOVHPS/D MOVLPS/D	xmm,m64	2	1			1	1			int	3	1
MOVHPS/D	m64,xmm	2	1	1				1	1		5	1
MOVLPS/D	m64,xmm	1						1	1		3	1
MOVLHPS MOVHLPS	xmm,xmm	1	1	1						float	1	1
MOVMSKPS/D	r32,xmm	1	1	1						float	1	1
MOVNTPS/D	m128,xmm	1						1	1			2-3
SHUFPS	xmm,xmm,i	3	3		3					flt→int	3	2
SHUFPS	xmm,m128,i	4	3		3		1			flt→int		2
SHUFPD	xmm,xmm,i	1	1	1						float	1	1
SHUFPD	xmm,m128,i	2	1	1			1			float		1
MOVDDUP g)	xmm,xmm	1	1	1						int	1	1
MOVDDUP g)	xmm,m64	2	1	1			1			int		1
MOVSH/LDUP g)	xmm,xmm	1	1			1				int	1	1
MOVSH/LDUP g)	xmm,m128	2	1			1	1			int		1
UNPCKH/LPS	xmm,xmm	3	3		3					flt→int	3	2
UNPCKH/LPS	xmm,m128	4	3		3		1			int		2
UNPCKH/LPD	xmm,xmm	1	1	1						float	1	1
UNPCKH/LPD	xmm,m128	2	1	1			1			float		1
<b>Conversion</b>												
CVTPD2PS	xmm,xmm	2	2							float	4	1
CVTPD2PS	xmm,m128	2	2				1			float		1
CVTSD2SS	xmm,xmm	2	2							float	4	1
CVTSD2SS	xmm,m64	2	2				1			float		1
CVTPS2PD	xmm,xmm	2	2	2						float	2	2
CVTPS2PD	xmm,m64	2	2	2			1			float		2
CVTSS2SD	xmm,xmm	2	2							float	2	2
CVTSS2SD	xmm,m32	2	2	2			1			float		2
CVTDQ2PS	xmm,xmm	1	1		1					float	3	1
CVTDQ2PS	xmm,m128	1	1		1		1			float		1
CVT(T) PS2DQ	xmm,xmm	1	1		1					float	3	1
CVT(T) PS2DQ	xmm,m128	1	1		1		1			float		1
CVTDQ2PD	xmm,xmm	2	2	1	1					float	4	1
CVTDQ2PD	xmm,m64	3	2				1			float		1
CVT(T)PD2DQ	xmm,xmm	2	2							float	4	1
CVT(T)PD2DQ	xmm,m128	2	2				1			float		1

## Merom

CVTPI2PS	xmm,mm	1	1	1			float	3	3
CVTPI2PS	xmm,m64	1	1	1	1		float		3
CVT(T)PS2PI	mm,xmm	1	1	1			float	3	1
CVT(T)PS2PI	mm,m128	1	1	1	1		float		1
CVTPI2PD	xmm,mm	2	2	1	1		float	4	1
CVTPI2PD	xmm,m64	2	2	1	1	1	float		1
CVT(T) PD2PI	mm,xmm	2	2	1	1		float	4	1
CVT(T) PD2PI	mm,m128	2	2	1	1	1	float		1
CVTSI2SS	xmm,r32	1	1	1			float	4	3
CVTSI2SS	xmm,m32	1	1	1	1		float		3
CVT(T)SS2SI	r32,xmm	1	1	1			float	3	1
CVT(T)SS2SI	r32,m32	1	1	1	1		float		1
CVTSI2SD	xmm,r32	2	2	1	1		float	4	3
CVTSI2SD	xmm,m32	2	1	1	1	1	float		3
CVT(T)SD2SI	r32,xmm	1	1	1			float	3	1
CVT(T)SD2SI	r32,m64	1	1	1	1		float		1
<b>Arithmetic</b>									
ADDSS/D SUBSS/D	xmm,xmm	1	1	1			float	3	1
ADDSS/D SUBSS/D	xmm,m32/64	1	1	1	1		float		1
ADDPSS/D SUBPSS/D	xmm,xmm	1	1	1			float	3	1
ADDPSS/D SUBPSS/D	xmm,m128	1	1	1	1		float		1
ADDSUBPSS/D g)	xmm,xmm	1	1	1			float	3	1
ADDSUBPSS/D g)	xmm,m128	1	1	1	1		float		1
HADDPSS HSUBPSS g)	xmm,xmm	6	6				float	9	3
HADDPSS HSUBPSS g)	xmm,m128	7	6			1	float		3
HADDPD HSUBPD g)	xmm,xmm	3	3				float	5	2
HADDPD HSUBPD g)	xmm,m128	4	3			1	float		2
MULSS	xmm,xmm	1	1	1			float	4	1
MULSS	xmm,m32	1	1	1	1		float		1
MULSD	xmm,xmm	1	1	1			float	5	1
MULSD	xmm,m64	1	1	1	1		float		1
MULPSS	xmm,xmm	1	1	1			float	4	1
MULPSS	xmm,m128	1	1	1	1		float		1
MULPD	xmm,xmm	1	1	1			float	5	1
MULPD	xmm,m128	1	1	1	1		float		1
DIVSS	xmm,xmm	1	1	1			float	6-18 d)	5-17 d)
DIVSS	xmm,m32	1	1	1	1		float		5-17 d)
DIVSD	xmm,xmm	1	1	1			float	6-32 d)	5-31 d)
DIVSD	xmm,m64	1	1	1	1		float		5-31 d)
DIVPSS	xmm,xmm	1	1	1			float	6-18 d)	5-17 d)
DIVPSS	xmm,m128	1	1	1	1		float		5-17 d)
DIVPD	xmm,xmm	1	1	1			float	6-32 d)	5-31 d)
DIVPD	xmm,m128	1	1	1	1		float		5-31 d)
RCPSS/PS	xmm,xmm	1	1	1			float	3	2
RCPSS/PS	xmm,m	1	1	1	1		float		2
CMPccSS/D	xmm,xmm	1	1	1			float	3	1
CMPccSS/D	xmm,m32/64	1	1	1	1		float		1
CMPccPSS/D	xmm,xmm	1	1	1			float	3	1
CMPccPSS/D	xmm,m128	1	1	1	1		float		1
COMISS/D UCOMISS/D	xmm,xmm	1	1	1			float	3	1
COMISS/D UCOMISS/D	xmm,m32/64	1	1	1	1		float		1
MAXSS/D MINSS/D	xmm,xmm	1	1	1			float	3	1



Merom

MAXSS/D MINSS/D	xmm,m32/64	1	1		1		1			float		1
MAXPS/D MINPS/D	xmm,xmm	1	1		1					float	3	1
MAXPS/D MINPS/D	xmm,m128	1	1		1		1			float		1
<b>Math</b>												
SQRTSS/PS	xmm,xmm	1	1	1						float	6-29	6-29
SQRTSS/PS	xmm,m	2	1	1			1			float		6-29
SQRTSD/PD	xmm,xmm	1	1	1						float	6-58	6-58
SQRTSD/PD	xmm,m	2	1	1			1			float		6-58
RSQRTSS/PS	xmm,xmm	1	1		1					float	3	2
RSQRTSS/PS	xmm,m	1	1		1		1			float		2
<b>Logic</b>												
AND/ANDN/OR/XORPS/D	xmm,xmm	1	1	x	x	x				int	1	0,33
AND/ANDN/OR/XORPS/D	xmm,m128	1	1	x	x	x	1			int		1
<b>Other</b>												
LDMXCSR	m32	14	13				1					42
STMXCSR	m32	6	4					1	1			19
FXSAVE	m4096	141									145	145
FXRSTOR	m4096	119									164	164

**Notes:**

- d) Round divisors give low values.
- g) SSE3 instruction set.

## Intel Core 2 (Wolfdale, 45nm)

### List of instruction timings and $\mu$ op breakdown

*Explanation of column headings:*

- Operands:** i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
- $\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused  $\mu$ ops count as one.
- $\mu$ ops unfused domain:** The number of  $\mu$ ops for each execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if the sum of the numbers listed under p015 + p2 + p3 + p4 exceeds the number listed under  $\mu$ ops fused domain. An x under p0, p1 or p5 means that at least one of the  $\mu$ ops listed under p015 can optionally go to this port. For example, a 1 under p015 and an x under p0 and p5 means one  $\mu$ op which can go to either port 0 or port 5, whichever is vacant first. A value listed under p015 but nothing under p0, p1 and p5 means that it is not known which of the three ports these  $\mu$ ops go to.
- p015:** The total number of  $\mu$ ops going to port 0, 1 and 5.
- p0:** The number of  $\mu$ ops going to port 0 (execution units).
- p1:** The number of  $\mu$ ops going to port 1 (execution units).
- p5:** The number of  $\mu$ ops going to port 5 (execution units).
- p2:** The number of  $\mu$ ops going to port 2 (memory read).
- p3:** The number of  $\mu$ ops going to port 3 (memory write address).
- p4:** The number of  $\mu$ ops going to port 4 (memory write data).
- Unit:** Tells which execution unit cluster is used. An additional delay of 1 clock cycle is generated if a register written by a  $\mu$ op in the integer unit (int) is read by a  $\mu$ op in the floating point unit (float) or vice versa. flt→int means that an instruction with multiple  $\mu$ ops receive the input in the float unit and delivers the output in the int unit. Delays for moving data between different units are included under latency when they are unavoidable. For example, movd eax,xmm0 has an extra 1 clock delay for moving from the XMM-integer unit to the general purpose integer unit. This is included under latency because it occurs regardless of which instruction comes next. Nothing listed under unit means that additional delays are either unlikely to occur or unavoidable and therefore included in the latency figure.
- Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.
- Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain							Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												

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MOV	r,r/i	1	1	x	x	x				1	0,33
MOV a)	r,m	1					1			2	1
MOV a)	m,r	1						1	1	3	1
MOV	m,i	1						1	1	3	1
MOV	r,sr	1					1				1
MOV	m,sr	2					1	1	1		1
MOV	sr,r	8	4	x	x	x	4				16
MOV	sr,m	8	3	x		x	5				16
MOVNTI	m,r	2						1	1		2
MOVSX MOVZX											
MOVSXD	r,r	1	1	x	x	x				1	0,33
MOVSX MOVZX	r16/32,m	1					1				1
MOVSX MOVSD	r64,m	2	1	x	x	x	1				1
CMOVcc	r,r	2	2	x	x	x				2	1
CMOVcc	r,m	2	2	x	x	x	1				
XCHG	r,r	3	3	x	x	x				2	2
XCHG	r,m	7	x				1	1	1	high b)	
XLAT		2	1				1			4	1
PUSH	r	1						1	1	3	1
PUSH	i	1						1	1		1
PUSH	m	2					1	1	1		1
PUSH	sr	2	1					1	1		1
PUSHF(D/Q)		17	15	x	x	x		1	1		7
PUSHA(D) i)		18	9					1	8		8
POP	r	1					1			2	1
POP	(E/R)SP	4	3				1				
POP	m	2					1	1	1		1,5
POP	sr	10	9				1				17
POPF(D/Q)		24	23	x	x	x	1			20	
POPA(D) i)		10	2				8				7
LAHF SAHF		1	1	x	x	x				1	0,33
SALC i)		2	2	x	x	x				4	1
LEA a)	r,m	1	1	1						1	1
BSWAP	r	2	2	1		1				4	1
LDS LES LFS LGS LSS	m	11	11				1				17
PREFETCHNTA	m	1					1				1
PREFETCHT0/1/2	m	1					1				1
LFENCE		2						1	1		8
MFENCE		2						1	1		6
SFENCE		2						1	1		9
CLFLUSH	m8	4	2	1		1		1	1	120	90
IN											
OUT											
<b>Arithmetic instructions</b>											
ADD SUB	r,r/i	1	1	x	x	x				1	0,33
ADD SUB	r,m	1	1	x	x	x	1				1
ADD SUB	m,r/i	2	1	x	x	x	1	1	1	6	1
ADC SBB	r,r/i	2	2	x	x	x				2	2
ADC SBB	r,m	2	2	x	x	x	1			2	2
ADC SBB	m,r/i	4	3	x	x	x	1	1	1	7	
CMP	r,r/i	1	1	x	x	x				1	0,33
CMP	m,r/i	1	1	x	x	x	1			1	1

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INC DEC NEG NOT	r	1	1	x	x	x				1	0,33
INC DEC NEG NOT	m	3	1	x	x	x	1	1	1	6	1
AAAAS DAA DAS i)		1	1		1						1
AAD i)		3	3	x	x	x					1
AAM i)		5	5	x	x	x				17	
MUL IMUL	r8	1	1		1					3	1
MUL IMUL	r16	3	3	x	x	x				5	1,5
MUL IMUL	r32	3	3	x	x	x				5	1,5
MUL IMUL	r64	3	3	x	x	x				7	4
IMUL	r16,r16	1	1		1					3	1
IMUL	r32,r32	1	1		1					3	1
IMUL	r64,r64	1	1	1						5	2
IMUL	r16,r16,i	1	1		1					3	1
IMUL	r32,r32,i	1	1		1					3	1
IMUL	r64,r64,i	1	1	1						5	2
MUL IMUL	m8	1	1		1		1			3	1
MUL IMUL	m16	3	3	x	x	x	1			5	1,5
MUL IMUL	m32	3	3	x	x	x	1			5	1,5
MUL IMUL	m64	3	2	2			1			7	4
IMUL	r16,m16	1	1		1		1			3	1
IMUL	r32,m32	1	1		1		1			3	1
IMUL	r64,m64	1	1	1			1			5	2
IMUL	r16,m16,i	1	1		1		1				2
IMUL	r32,m32,i	1	1		1		1				1
IMUL	r64,m64,i	1	1	1			1				2
DIV IDIV	r8	4	4	1	2	1				9-18 c)	
DIV IDIV	r16	7	7	x	x	x				14-22 c)	
DIV IDIV	r32	7	7	2	3	2				14-23 c)	
DIV	r64	32-38	32-38	9	10	13				18-57 c)	
IDIV	r64	56-62	56-62	x	x	x				34-88 c)	
DIV IDIV	m8	4	3	1	2		1			9-18	
DIV IDIV	m16	7	7	2	3	2	1			14-22 c)	
DIV IDIV	m32	7	6	x	x	x	1			14-23 c)	
DIV	m64	32	31	x	x	x	1			34-88 c)	
IDIV	m64	56	55	x	x	x	1			39-72 c)	
CBW CWDE CDQE		1	1	x	x	x				1	
CWD CDQ CQO		1	1	x		x				1	
<b>Logic instructions</b>											
AND OR XOR	r,r/i	1	1	x	x	x				1	0,33
AND OR XOR	r,m	1	1	x	x	x	1				1
AND OR XOR	m,r/i	2	1	x	x	x	1	1	1	6	1
TEST	r,r/i	1	1	x	x	x				1	0,33
TEST	m,r/i	1	1	x	x	x	1				1
SHR SHL SAR	r,i/cl	1	1	x		x				1	0,5
SHR SHL SAR	m,i/cl	3	2	x		x	1	1	1	6	1
ROR ROL	r,i/cl	1	1	x		x				1	1
ROR ROL	m,i/cl	3	2	x		x	1	1	1	6	1
RCR RCL	r,1	2	2	x	x	x				2	2
RCR	r8,i/cl	9	9	x	x	x				12	
RCL	r8,i/cl	8	8	x	x	x				11	
RCR RCL	r,i/cl	6	6	x	x	x				11	
RCR RCL	m,1	4	3	x	x	x	1	1	1	7	

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RCR	m8,i/cl	12	9	x	x	x	1	1	1	14	
RCL	m8,i/cl	11	8	x	x	x	1	1	1	13	
RCR RCL	m,i/cl	10	7	x	x	x	1	1	1	13	
SHLD SHRD	r,r,i/cl	2	2	x	x	x				2	1
SHLD SHRD	m,r,i/cl	3	2	x	x	x	1	1	1	7	
BT	r,r/i	1	1	x	x	x				1	1
BT	m,r	9	8	x	x	x	1				4
BT	m,i	3	2	x	x	x	1				1
BTR BTS BTC	r,r/i	1	1	x	x	x				1	
BTR BTS BTC	m,r	10	7	x	x	x	1	1	1	5	
BTR BTS BTC	m,i	3	1	x	x	x	1	1	1	6	
BSF BSR	r,r	2	2	x	1	x				2	1
BSF BSR	r,m	2	2	x	1	x	1				1
SETcc	r	1	1	x	x	x				1	1
SETcc	m	2	1	x	x	x		1	1		1
CLC STC CMC		1	1	x	x	x				1	0,33
CLD		6	6	x	x	x					3
STD		6	6	x	x	x					14
<b>Control transfer instructions</b>											
JMP	short/near	1	1				1			0	1-2
JMP i)	far	30	30								76
JMP	r	1	1				1			0	1-2
JMP	m(near)	1	1				1	1		0	1-2
JMP	m(far)	31	29					2			68
Conditional jump	short/near	1	1				1			0	1
Fused compare/test and branch e,i)		1	1				1			0	1
J(E/R)CXZ	short	2	2	x	x	1					1-2
LOOP	short	11	11	x	x	x					5
LOOP(N)E	short	11	11	x	x	x					5
CALL	near	3	2	x	x	x			1	1	2
CALL i)	far	43	43								75
CALL	r	3	2						1	1	2
CALL	m(near)	4	3				1	1	1		2
CALL	m(far)	44	42					2			75
RETN		1	1				1	1			2
RETN	i	3	1				1	1			2
RETF		32	30					2			78
RETF	i	32	30					2			78
BOUND i)	r,m	15	13					2			8
INTO i)		5	5								3
<b>String instructions</b>											
LODS		3	2					1			1
REP LODS		4+7n-14+6n								1+5n-21+3n	
STOS		4	2						1	1	1
REP STOS		8+5n-20+1.2n								7+2n-0.55n	
MOVS		8	5								
		1	1	1			5				
REP MOVS		7+7n-13+n								1+3n-0.63n	
SCAS		4	3					1			1
REP(N)E SCAS		7+8n-17+7n								3+8n-23+6n	
CMPS		7	5					2			3

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REP(N)E CMPS	7+10n-7+9n							2+7n-22+5n		
<b>Other</b>										
NOP (90)		1	1	x	x	x				0,33
Long NOP (0F 1F)		1	1	x	x	x				1
PAUSE		3	3	x	x	x				8
ENTER	i,0	12	10					1	1	8
ENTER	a,b									
LEAVE		3	2				1			
CPUID		53-117								53-211
RDTSC		13								32
RDPMSR		23								54

**Notes:**

- a) Applies to all addressing modes
- b) Has an implicit LOCK prefix.
- c) Low values are for small results, high values for high results. The reciprocal throughput is only slightly less than the latency.
- e) See manual 3: "The microarchitecture of Intel, AMD and VIA CPUs" for restrictions on macro-op fusion.
- i) Not available in 64 bit mode.

**Floating point x87 instructions**

Instruction	Operands	µops fused domain	µops unfused domain								Unit	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4				
<b>Move instructions</b>													
FLD	r	1	1	1							float	1	1
FLD	m32/64	1	1					1			float	3	1
FLD	m80	4	2	2				2			float	4	3
FBLD	m80	40	38	x	x	x	2				float	45	20
FST(P)	r	1	1	1							float	1	1
FST(P)	m32/m64	1							1	1	float	3	1
FSTP	m80	7	3	x	x	x		2	2	float	4	5	
FBSTP	m80	171	167	x	x	x		2	2	float	164	166	
FXCH	r	1	0 f)								float	0	1
FILD	m	1	1		1			1			float	6	1
FIST	m	2	1		1				1	1	float	6	1
FISTP	m	3	1		1				1	1	float	6	1
FISTTP g)	m	3	1		1				1	1	float	6	1
FLDZ		1	1	1							float		1
FLD1		2	2	1	1						float		2
FLDPI FLDL2E etc.		2	2		2						float		2
FCMOVcc	r	2	2	2							float	2	2
FNSTSW	AX	1	1	1							float		1
FNSTSW	m16	2	1	1						1	float		2
FLDCW	m16	2	1					1			float		10
FNSTCW	m16	3	1			1			1	1	float		8
FINCSTP FDECSTP		1	1	1							float	1	1
FFREE(P)	r	2	2	x	x	x					float		2
FNSAVE	m	141	95	x	x	x	7	23	23	float		142	

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FRSTOR	m	78	51	x	x	x	27		float		177
<b>Arithmetic instructions</b>											
FADD(P) FSUB(R)(P)	r	1	1		1				float	3	1
FADD(P) FSUB(R)(P)	m	1	1		1		1		float		1
FMUL(P)	r	1	1	1					float	5	2
FMUL(P)	m	1	1	1			1		float		2
FDIV(R)(P)	r	1	1	1					float	6-21 d)	5-20 d)
FDIV(R)(P)	m	1	1	1			1		float	6-21 d)	5-20 d)
FABS		1	1	1					float	1	1
FCHS		1	1	1					float	1	1
FCOM(P) FUCOM	r	1	1		1				float		1
FCOM(P) FUCOM	m	1	1		1		1		float		1
FCOMPP FUCOMPP		2	2	1	1				float		
FCOMI(P) FUCOMI(P)	r	1	1		1				float		1
FIADD FISUB(R)	m	2	2		2		1		float	3	2
FIMUL	m	2	2	1	1		1		float	5	2
FIDIV(R)	m	2	2	1	1		1		float	6-21	5-20 d)
FICOM(P)	m	2	2		2		1		float		2
FTST		1	1		1				float		1
FXAM		1	1		1				float		1
FPREM		26-29		x	x	x			float	13-40	
FPREM1		28-35		x	x	x			float	18-41	
FRNDINT		17-19		x	x	x			float	10-22	
<b>Math</b>											
FSCALE		28	28	x	x	x			float	43	
FEXTRACT		53-84		x	x	x			float	~170	
FSQRT		1	1	1					float	6-20	
FSIN		18-85		x	x	x			float	32-85	
FCOS		76-100		x	x	x			float	70-100	
FSINCOS		18-105		x	x	x			float	38-107	
F2XM1		19	19	x	x	x			float	45	
FYL2X FYL2XP1		57-65		x	x	x			float	50-100	
FPTAN		19-100		x	x	x			float	40-130	
FPATAN		23-87		x	x	x			float	55-130	
<b>Other</b>											
FNOP		1	1	1					float		1
WAIT		2	2	x	x	x			float		1
FNCLEX		4	4		x	x			float		15
FNINIT		15	15	x	x	x			float		63

**Notes:**

- d) Round divisors or low precision give low values.
- f) Resolved by register renaming. Generates no  $\mu$ ops in the unused domain.
- g) SSE3 instruction set.

**Integer MMX and XMM instructions**

Instruction	Operands	$\mu$ ops fused	$\mu$ ops unused domain	Unit	Latency	Reciprocal
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Wolfdale

		do- main	p015	p0	p1	p5	p2	p3	p4			through- put
<b>Move instructions</b>												
MOVD k)	r,(x)mm	1	1	x	x	x				int	2	0,33
MOVD k)	m,(x)mm	1						1	1		3	1
MOVD k)	(x)mm,r	1	1	x		x				int	2	0,5
MOVD k)	(x)mm,m	1					1			int	2	1
MOVQ	v,v	1	1	x	x	x				int	1	0,33
MOVQ	(x)mm,m64	1					1			int	2	1
MOVQ	m64, (x)mm	1						1	1		3	1
MOVDQA	xmm, xmm	1	1	x	x	x				int	1	0,33
MOVDQA	xmm, m128	1					1			int	2	1
MOVDQA	m128, xmm	1						1	1		3	1
MOVDQU	m128, xmm	9	4	x	x	x	1	2	2		3-8	4
MOVDQU	xmm, m128	4	2	x		x	2			int	2-8	2
LDDQU g)	xmm, m128	4	2	x		x	2			int	2-8	2
MOVDQ2Q	mm, xmm	1	1	x	x	x				int	1	0,33
MOVQ2DQ	xmm,mm	1	1	x	x	x				int	1	0,33
MOVNTQ	m64,mm	1						1	1			2
MOVNTDQ	m128,xmm	1						1	1			2
MOVNTDQA j)	xmm, m128	1					1				2	1
PACKSSWB/DW												
PACKUSWB	mm,mm	1	1	1						int	1	1
PACKSSWB/DW												
PACKUSWB	mm,m64	1	1	1			1			int		1
PACKSSWB/DW												
PACKUSWB	xmm,xmm	1	1			1				int	1	1
PACKSSWB/DW												
PACKUSWB	xmm,m128	1	1			1	1			int		1
PACKUSDW j)	xmm,xmm	1	1			1				int	1	1
PACKUSDW j)	xmm,m	1	1			1	1			int		1
PUNPCKH/LBW/WD/DQ	mm,mm	1	1	1						int	1	1
PUNPCKH/LBW/WD/DQ	mm,m64	1	1	1			1			int		1
PUNPCKH/LBW/WD/DQ	xmm,xmm	1	1			1				int	1	1
PUNPCKH/LBW/WD/DQ	xmm,m128	1	1			1	1			int		1
PUNPCKH/LQDQ	xmm,xmm	1	1			1				int	1	1
PUNPCKH/LQDQ	xmm, m128	2	1			1	1			int		1
PMOVSX/ZXBW j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXBW j)	xmm,m64	1	1			1	1			int		1
PMOVSX/ZXBD j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXBD j)	xmm,m32	1	1			1	1			int		1
PMOVSX/ZXBQ j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXBQ j)	xmm,m16	1	1			1	1			int		1
PMOVSX/ZXWD j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXWD j)	xmm,m64	1	1			1	1			int		1
PMOVSX/ZXWQ j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXWQ j)	xmm,m32	1	1			1	1			int		1
PMOVSX/ZXDQ j)	xmm,xmm	1	1			1				int	1	1
PMOVSX/ZXDQ j)	xmm,m64	1	1			1	1			int		1
PSHUFB h)	mm,mm	1	1			1				int	1	1
PSHUFB h)	mm,m64	2	1			1	1			int		1
PSHUFB h)	xmm,xmm	1	1			1				int	1	1
PSHUFB h)	xmm,m128	1	1			1	1			int		1



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PSHUFW	mm,mm,i	1	1			1				int	1	1
PSHUFW	mm,m64,i	2	1			1	1			int		1
PSHUFD	xmm,xmm,i	1	1			1				int	1	1
PSHUFD	xmm,m128,i	2	1			1	1			int		1
PSHUFL/HW	xmm,xmm,i	1	1			1				int	1	1
PSHUFL/HW	x, m128,i	2	1			1	1			int		1
PALIGNR h)	mm,mm,i	2	2			2				int	2	1
PALIGNR h)	mm,m64,i	3	3			3	1			int		1
PALIGNR h)	xmm,xmm,i	1	1			1				int	1	1
PALIGNR h)	xmm,m128,i	1	1			1	1			int		1
PBLENDVB j)	x,x,xmm0	2	2			2				int	2	2
PBLENDVB j)	x,m,xmm0	2	2			2	1			int		2
PBLENDW j)	xmm,xmm,i	1	1			1				int	1	1
PBLENDW j)	xmm,m,i	1	1			1	1			int		1
MASKMOVQ	mm,mm	4	1	1			1	1	1	int		2-5
MASKMOVDQU	xmm,xmm	10	4	1		3	2	2	3	int		6-10
PMOVMASKB	r32,(x)mm	1	1	1						int	2	1
PEXTRB j)	r32,xmm,i	2	2	x	x	x				int	3	1
PEXTRB j)	m8,xmm,i	2	2	x	x	x				int	3	1
PEXTRW	r32,(x)mm,i	2	2	x	x	x	1			int	3	1
PEXTRW j)	m16,(x)mm,i	2	2	?	?	1		1	1	int		1
PEXTRD j)	r32,xmm,i	2	2	x	x	x				int	3	1
PEXTRD j)	m32,xmm,i	2	1			1		1	1	int		1
PEXTRQ j,m)	r64,xmm,i	2	2	x	x	x				int	3	1
PEXTRQ j,m)	m64,xmm,i	2	1			1		1	1	int		1
PINSRB j)	xmm,r32,i	1	1			1				int	1	1
PINSRB j)	xmm,m8,i	2	1			1	1			int		1
PINSRW	(x)mm,r32,i	1	1			1				int	2	1
PINSRW	(x)mm,m16,i	2	1			1	1			int		1
PINSRD j)	xmm,r32,i	1	1			1				int	1	1
PINSRD j)	xmm,m32,i	2	1			1	1			int		1
PINSRQ j,m)	xmm,r64,i	1	1			1				int	1	1
PINSRQ j,m)	xmm,m64,i	2	1			1	1			int		1
<b>Arithmetic instructions</b>												
PADD/SUB(U)(S)B/W/D	v,v	1	1	x		x				int	1	0,5
PADD/SUB(U)(S)B/W/D	(x)mm,m	1	1	x		x	1			int		1
PADDQ PSUBQ	v,v	2	2	x		x				int	2	1
PADDQ PSUBQ	(x)mm,m	2	2	x		x	1			int		1
PHADD(S)W												
PHSUB(S)W h)	v,v	3	3	1		2				int	3	2
PHADD(S)W												
PHSUB(S)W h)	(x)mm,m64	4	3	1		2	1			int		2
PHADDD PHSUBD h)	v,v	3	3	1		2				int	3	2
PHADDD PHSUBD h)	(x)mm,m64	4	3	1		2	1			int		2
PCMPEQ/GTB/W/D	v,v	1	1	x		x				int	1	0,5
PCMPEQ/GTB/W/D	(x)mm,m	1	1	x		x	1			int		1
PCMPEQQ j)	xmm,xmm	1	1			1				int	1	1
PCMPEQQ j)	xmm,m128	1	1			1	1			int		1
PMULL/HW PMULHUW	v,v	1	1		1					int	3	1
PMULL/HW PMULHUW	(x)mm,m	1	1		1		1			int		1
PMULHRW h)	v,v	1	1		1					int	3	1
PMULHRW h)	(x)mm,m	1	1		1		1			int		1

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PMULLD j)	xmm,xmm	4	4		2	2			int	5	2
PMULLD j)	xmm,m128	6	5	1	2	2	1		int	5	4
PMULDQ j)	xmm,xmm	1	1		1				int	3	1
PMULDQ j)	xmm,m128	1	1		1		1		int		1
PMULUDQ	v,v	1	1		1				int	3	1
PMULUDQ	(x)mm,m	1	1		1		1		int		1
PMADDWD	v,v	1	1		1				int	3	1
PMADDWD	(x)mm,m	1	1		1		1		int		1
PMADDUBSW h)	v,v	1	1		1				int	3	1
PMADDUBSW h)	(x)mm,m	1	1		1		1		int		1
PAVGB/W	v,v	1	1	x		x			int	1	0,5
PAVGB/W	(x)mm,m	1	1	x		x	1		int		1
PMIN/MAXSB j)	xmm,xmm	1	1	1					int	1	1
PMIN/MAXSB j)	xmm,m128	1	1	1			1		int		1
PMIN/MAXUB	v,v	1	1	x		x			int	1	0,5
PMIN/MAXUB	(x)mm,m	1	1	x		x	1		int		1
PMIN/MAXSW	v,v	1	1	x		x			int	1	0,5
PMIN/MAXSW	(x)mm,m	1	1	x		x	1		int		1
PMIN/MAXUW j)	xmm,xmm	1	1	1					int	1	1
PMIN/MAXUW j)	xmm,m	1	1				1		int		1
PMIN/MAXSD j)	xmm,xmm	1	1	1					int	1	1
PMIN/MAXSD j)	xmm,m128	1	1	1			1		int		1
PMIN/MAXUD j)	xmm,xmm	1	1	1					int	1	1
PMIN/MAXUD j)	xmm,m128	1	1	1			1		int		1
PHMINPOSUW j)	xmm,xmm	4	4			4			int	4	4
PHMINPOSUW j)	xmm,m128	4	4			4	1		int		4
PASB PABSW PABSD h)	v,v	1	1	x		x			int	1	0,5
PASB PABSW PABSD h)	(x)mm,m	1	1	x		x	1		int		1
PSIGNB PSIGNW											
PSIGND h)	v,v	1	1	x		x			int	1	0,5
PSIGNB PSIGNW											
PSIGND h)	(x)mm,m	1	1	x		x	1		int		1
PSADBW	v,v	1	1		1				int	3	1
PSADBW	(x)mm,m	1	1		1		1		int		1
MPSADBW j)	xmm,xmm,i	3	3		1	2			int	5	2
MPSADBW j)	xmm,m,i	4	3		1	2	1		int		2
<b>Logic instructions</b>											
PAND(N) POR PXOR	v,v	1	1	x	x	x			int	1	0,33
PAND(N) POR PXOR	(x)mm,m	1	1	x	x	x	1		int		1
PTEST j)	xmm,xmm	2	2	1	x	x			int	1	1
PTEST j)	xmm,m128	2	2	1	x	x	1		int		1
PSLL/RL/RAW/D/Q	mm,mm/i	1	1	1					int	1	1
PSLL/RL/RAW/D/Q	mm,m64	1	1	1			1		int		1
PSLL/RL/RAW/D/Q	xmm,i	1	1	1					int	1	1
PSLL/RL/RAW/D/Q	xmm,xmm	2	2	x		x			int	2	1
PSLL/RL/RAW/D/Q	xmm,m128	3	2	x		x	1		int		1
PSLL/RLDQ	xmm,i	1	1	x		x			int	1	1
<b>Other</b>											
EMMS		11	11	x	x	x			float		6

Notes:

- g) SSE3 instruction set.
- h) Supplementary SSE3 instruction set.
- j) SSE4.1 instruction set
- k) MASM uses the name MOVD rather than MOVQ for this instruction even when moving 64 bits
- m) Only available in 64 bit mode

### Floating point XMM instructions

Instruction	Operands	μops fused do-main	μops unfused domain								Unit	Laten-cy	Reci-procal through-put
			p015	p0	p1	p5	p2	p3	p4				
<b>Move instructions</b>													
MOVAPS/D	xmm,xmm	1	1	x	x	x					int	1	0,33
MOVAPS/D	xmm,m128	1					1				int	2	1
MOVAPS/D	m128,xmm	1						1	1			3	1
MOVUPS/D	xmm,m128	4	2	1		1	2				int	2-4	2
MOVUPS/D	m128,xmm	9	4	x	x	x	1	2	2			3-4	4
MOVSS/D	xmm,xmm	1	1	x	x	x					int	1	0,33
MOVSS/D	x,m32/64	1					1				int	2	1
MOVSS/D	m32/64,x	1						1	1			3	1
MOVHPS/D MOVLPS/D	xmm,m64	2	1			1	1				int	3	1
MOVHPS/D	m64,xmm	2	1	1				1	1			5	1
MOVLPS/D	m64,xmm	1						1	1			3	1
MOVLHPS MOVHLPS	xmm,xmm	1	1	1							float	1	1
MOVMSKPS/D	r32,xmm	1	1	1							float	1	1
MOVNTPS/D	m128,xmm	1						1	1				2-3
SHUFPS	xmm,xmm,i	1	1			1					int	1	1
SHUFPS	xmm,m128,i	2	1			1	1				int		1
SHUFPD	xmm,xmm,i	1	1	1							float	1	1
SHUFPD	xmm,m128,i	2	1	1			1				float		1
BLENDPS/PD j)	xmm,xmm,i	1	1			1					int	1	1
BLENDPS/PD j)	xmm,m128,i	1	1			1	1				int		1
BLENDVPS/PD j)	x,x,xmm0	2	2			2					int	2	2
BLENDVPS/PD j)	x,m,xmm0	2	2			2	1				int		2
MOVDDUP g)	xmm,xmm	1	1	1							int	1	1
MOVDDUP g)	xmm,m64	2	1	1			1				int		1
MOVSH/LDUP g)	xmm,xmm	1	1			1					int	1	1
MOVSH/LDUP g)	xmm,m128	2	1			1	1				int		1
UNPCKH/LPS	xmm,xmm	1	1			1					int	1	1
UNPCKH/LPS	xmm,m128	1	1			1	1				int		1
UNPCKH/LPD	xmm,xmm	1	1	1							float	1	1
UNPCKH/LPD	xmm,m128	2	1	1			1				float		1
EXTRACTPS j)	r32,xmm,i	2	2	x	x	x					int	4	1
EXTRACTPS j)	m32,xmm,i	2	1			1		1	1		int		1
INSERTPS j)	xmm,xmm,i	1	1			1					int	1	1
INSERTPS j)	xmm,m32,i	2	1			1	1				int		1
<b>Conversion</b>													
CVTPD2PS	xmm,xmm	2	2	1	1						float	4	1
CVTPD2PS	xmm,m128	2	2	1	1		1				float		1
CVTSD2SS	xmm,xmm	2	2	1	1						float	4	1
CVTSD2SS	xmm,m64	2	2	1	1		1				float		1

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CVTPS2PD	xmm,xmm	2	2	2					float	2	2
CVTPS2PD	xmm,m64	2	2	2			1		float		2
CVTSS2SD	xmm,xmm	2	2	2					float	2	2
CVTSS2SD	xmm,m32	2	2	2			1		float		2
CVTDQ2PS	xmm,xmm	1	1		1				float	3	1
CVTDQ2PS	xmm,m128	1	1		1		1		float		1
CVT(T) PS2DQ	xmm,xmm	1	1		1				float	3	1
CVT(T) PS2DQ	xmm,m128	1	1		1		1		float		1
CVTDQ2PD	xmm,xmm	2	2	1	1				float	4	1
CVTDQ2PD	xmm,m64	2	2	1	1		1		float		1
CVT(T)PD2DQ	xmm,xmm	2	2	1	1				float	4	1
CVT(T)PD2DQ	xmm,m128	2	2	1	1		1		float		1
CVTPI2PS	xmm,mm	1	1		1				float	3	3
CVTPI2PS	xmm,m64	1	1		1		1		float		3
CVT(T)PS2PI	mm,xmm	1	1		1				float	3	1
CVT(T)PS2PI	mm,m128	1	1		1		1		float		1
CVTPI2PD	xmm,mm	2	2	1	1				float	4	1
CVTPI2PD	xmm,m64	2	2	1	1		1		float		1
CVT(T) PD2PI	mm,xmm	2	2	1	1				float	4	1
CVT(T) PD2PI	mm,m128	2	2	1	1		1		float		1
CVTSI2SS	xmm,r32	1	1		1				float	4	3
CVTSI2SS	xmm,m32	1	1		1		1		float		3
CVT(T)SS2SI	r32,xmm	1	1		1				float	3	1
CVT(T)SS2SI	r32,m32	1	1		1		1		float		1
CVTSI2SD	xmm,r32	2	2	1	1				float	4	3
CVTSI2SD	xmm,m32	2	1		1		1		float		3
CVT(T)SD2SI	r32,xmm	1	1		1				float	3	1
CVT(T)SD2SI	r32,m64	1	1		1		1		float		1
<b>Arithmetic</b>											
ADDSS/D SUBSS/D	xmm,xmm	1	1		1				float	3	1
ADDSS/D SUBSS/D	x,m32/64	1	1		1		1		float		1
ADDPS/D SUBPS/D	xmm,xmm	1	1		1				float	3	1
ADDPS/D SUBPS/D	xmm,m128	1	1		1		1		float		1
ADDSUBPS/D g)	xmm,xmm	1	1		1				float	3	1
ADDSUBPS/D g)	xmm,m128	1	1		1		1		float		1
HADDPS HSUBPS g)	xmm,xmm	3	3		1	2			float	7	3
HADDPS HSUBPS g)	xmm,m128	4	3		1	2	1		float		3
HADDPD HSUBPD g)	xmm,xmm	3	3	x	x	x			float	6	1,5
HADDPD HSUBPD g)	xmm,m128	4	3	x	x	x	1		float		1,5
MULSS	xmm,xmm	1	1	1					float	4	1
MULSS	xmm,m32	1	1	1			1		float		1
MULSD	xmm,xmm	1	1	1					float	5	1
MULSD	xmm,m64	1	1	1			1		float		1
MULPS	xmm,xmm	1	1	1					float	4	1
MULPS	xmm,m128	1	1	1			1		float		1
MULPD	xmm,xmm	1	1	1					float	5	1
MULPD	xmm,m128	1	1	1			1		float		1
DIVSS	xmm,xmm	1	1	1					float	6-13 d)	5-12 d)
DIVSS	xmm,m32	1	1	1			1		float		5-12 d)
DIVSD	xmm,xmm	1	1	1					float	6-21 d)	5-20 d)
DIVSD	xmm,m64	1	1	1			1		float		5-20 d)
DIVPS	xmm,xmm	1	1	1					float	6-13 d)	5-12 d)

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DIVPS	xmm,m128	1	1	1			1			float		5-12 d)
DIVPD	xmm,xmm	1	1	1						float	6-21 d)	5-20 d)
DIVPD	xmm,m128	1	1	1			1			float		5-20 d)
RCPSS/PS	xmm,xmm	1	1		1					float	3	2
RCPSS/PS	xmm,m	1	1		1		1			float		2
CMPccSS/D	xmm,xmm	1	1		1					float	3	1
CMPccSS/D	x,m32/64	1	1		1		1			float		1
CMPccPS/D	xmm,xmm	1	1		1					float	3	1
CMPccPS/D	xmm,m128	1	1		1		1			float		1
COMISS/D UCOMISS/D	xmm,xmm	1	1		1					float	3	1
COMISS/D UCOMISS/D	x,m32/64	1	1		1		1			float		1
MAXSS/D MINSS/D	xmm,xmm	1	1		1					float	3	1
MAXSS/D MINSS/D	x,m32/64	1	1		1		1			float		1
MAXPS/D MINPS/D	xmm,xmm	1	1		1					float	3	1
MAXPS/D MINPS/D	xmm,m128	1	1		1		1			float		1
ROUNDSS/D j)	xmm,xmm,i	1	1		1					float	3	1
ROUNDSS/D j)	xmm,m128,i	1	1		1		1			float		1
ROUNDPS/D j)	xmm,xmm,i	1	1		1					float	3	1
ROUNDPS/D j)	xmm,m128,i	1	1		1		1			float		1
DPPS j)	xmm,xmm,i	4	4	2	2					float	11	3
DPPS j)	xmm,m128,i	4	4	2	2		1			float		3
DPPD j)	xmm,xmm,i	4	4	x	x	x				float	9	3
DPPD j)	xmm,m128,i	4	4	x	x	x	1			float		3
<b>Math</b>												
SQRTSS/PS	xmm,xmm	1	1	1						float	6-13	5-12
SQRTSS/PS	xmm,m	2	1	1			1			float		5-12
SQRTSD/PD	xmm,xmm	1	1	1						float	6-20	5-19
SQRTSD/PD	xmm,m	2	1	1			1			float		5-19
RSQRTSS/PS	xmm,xmm	1	1		1					float	3	2
RSQRTSS/PS	xmm,m	1	1		1		1			float		2
<b>Logic</b>												
AND/ANDN/OR/XORPS/D	xmm,xmm	1	1	x	x	x				int	1	0,33
AND/ANDN/OR/XORPS/D	xmm,m128	1	1	x	x	x	1			int		1
<b>Other</b>												
LDMXCSR	m32	13	12	x	x	x	1					38
STMXCSR	m32	10	8	x	x	x		1	1			20
FXSAVE	m4096	151	67	x	x	x	8	38	38			145
FXRSTOR	m4096	121	74	x	x	x	47					150

**Notes:**

- d) Round divisors give low values.
- g) SSE3 instruction set.

**Intel Nehalem****List of instruction timings and  $\mu$ op breakdown***Explanation of column headings:*

<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops fused domain:</b>	The number of $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused $\mu$ ops count as one.
<b><math>\mu</math>ops unfused domain:</b>	The number of $\mu$ ops for each execution port. Fused $\mu$ ops count as two. Fused macro-ops count as one. The instruction has $\mu$ op fusion if the sum of the numbers listed under p015 + p2 + p3 + p4 exceeds the number listed under $\mu$ ops fused domain. An x under p0, p1 or p5 means that at least one of the $\mu$ ops listed under p015 can optionally go to this port. For example, a 1 under p015 and an x under p0 and p5 means one $\mu$ op which can go to either port 0 or port 5, whichever is vacant first. A value listed under p015 but nothing under p0, p1 and p5 means that it is not known which of the three ports these $\mu$ ops go to.
<b>p015:</b>	The total number of $\mu$ ops going to port 0, 1 and 5.
<b>p0:</b>	The number of $\mu$ ops going to port 0 (execution units).
<b>p1:</b>	The number of $\mu$ ops going to port 1 (execution units).
<b>p5:</b>	The number of $\mu$ ops going to port 5 (execution units).
<b>p2:</b>	The number of $\mu$ ops going to port 2 (memory read).
<b>p3:</b>	The number of $\mu$ ops going to port 3 (memory write address).
<b>p4:</b>	The number of $\mu$ ops going to port 4 (memory write data).
<b>Domain:</b>	<p>Tells which execution unit domain is used: "int" = integer unit (general purpose registers), "ivec" = integer vector unit (SIMD), "fp" = floating point unit (XMM and x87 floating point). An additional "bypass delay" is generated if a register written by a <math>\mu</math>op in one domain is read by a <math>\mu</math>op in another domain. The bypass delay is 1 clock cycle between the "int" and "ivec" units, and 2 clock cycles between the "int" and "fp", and between the "ivec" and "fp" units.</p> <p>The bypass delay is indicated under latency only where it is unavoidable because either the source operand or the destination operand is in an unnatural domain such as a general purpose register (e.g. eax) in the "ivec" domain. For example, the PEXTRW instruction executes in the "int" domain. The source operand is an xmm register and the destination operand is a general purpose register. The latency for this instruction is indicated as 2+1, where 2 is the latency of the instruction itself and 1 is the bypass delay, assuming that the xmm operand is most likely to come from the "ivec" domain. If the xmm operand comes from the "fp" domain then the bypass delay will be 2 rather than one. The flags register can also have a bypass delay. For example, the COMISS instruction (floating point compare) executes in the "fp" domain and returns the result in the integer flags. Almost all instructions that read these flags execute in the "int" domain. Here the latency is indicated as 1+2, where 1 is the latency of the instruction itself and 2 is the bypass delay from the "fp" domain to the "int" domain.</p> <p>The bypass delay from the memory read unit to any other unit and from any unit to the memory write unit are included in the latency figures in the table. Where the domain is not listed, the bypass delays are either unlikely to occur or unavoidable and therefore included in the latency figure.</p>

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**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

**Integer instructions**

Instruction	Operands	μops fused domain	μops unfused domain							Do-main	Laten-cy	Reci-procal through-put
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												
MOV	r,r/i	1	1	x	x	x				int	1	0.33
MOV a)	r,m	1					1			int	2	1
MOV a)	m,r	1						1	1	int	3	1
MOV	m,i	1						1	1	int	3	1
MOV	r,sr	1					1			int		1
MOV	m,sr	2					1	1	1	int		1
MOV	sr,r	6	3	x	x	x	3			int		13
MOV	sr,m	6	2	x		x	4			int		14
MOVNTI	m,r	2						1	1	int	~270	1
MOVSX MOVZX												
MOVSXD	r,r	1	1	x	x	x				int	1	0.33
MOVSX MOVZX												
MOVSXD	r,m	1					1			int		1
CMOVcc	r,r	2	2	x	x	x				int	2	1
CMOVcc	r,m	2	2	x	x	x	1			int		
XCHG	r,r	3	3	x	x	x				int	2	2
XCHG	r,m	7	x				1	1	1	int	20 b)	
XLAT		2	1				1			int	5	1
PUSH	r	1						1	1	int	3	1
PUSH	i	1						1	1	int		1
PUSH	m	2					1	1	1	int		1
PUSH	sr	2	1					1	1	int		1
PUSHF(D/Q)		3	2	x	x	x		1	1	int		1
PUSHA(D) i)		18	2	x	1	x		8	8	int		8
POP	r	1					1			int	2	1
POP	(E/R)SP	3	2	x	1	x	1			int		5
POP	m	2					1	1	1	int		1
POP	sr	7	2				5			int		15
POPF(D/Q)		8	7	x	x	x	1			int		14
POPA(D) i)		10	2				8			int		8
LAHF SAHF		1	1	x	x	x				int	1	0.33
SALC i)		2	2	x	x	x				int	4	1
LEA a)	r,m	1	1		1					int	1	1
BSWAP	r32	1	1		1					int	1	1
BSWAP	r64	1	1		1					int	3	1
LDS LES LFS LGS LSS	m	9	3	x	x	x	6			int		15
PREFETCHNTA	m	1					1			int		1

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PREFETCH0/1/2	m	1					1			int		1
LFENCE		2						1	1	int		9
MFENCE		3	1	x	x	x		1	1	int		23
SFENCE		2						1	1	int		5
<b>Arithmetic instructions</b>												
ADD SUB	r,r/i	1	1	x	x	x				int	1	0.33
ADD SUB	r,m	1	1	x	x	x	1			int		1
ADD SUB	m,r/i	2	1	x	x	x	1	1	1	int	6	1
ADC SBB	r,r/i	2	2	x	x	x				int	2	2
ADC SBB	r,m	2	2	x	x	x	1			int	2	2
ADC SBB	m,r/i	4	3	x	x	x	1	1	1	int	7	
CMP	r,r/i	1	1	x	x	x				int	1	0.33
CMP	m,r/i	1	1	x	x	x	1			int	1	1
INC DEC NEG NOT	r	1	1	x	x	x				int	1	0.33
INC DEC NEG NOT	m	3	1	x	x	x	1	1	1	int	6	1
AAA AAS DAA DAS i)		1	1		1					int	3	1
AAD i)		3	3	x	x	x				int	15	2
AAM i)		5	5	x	x	x				int	20	7
MUL IMUL	r8	1	1		1					int	3	1
MUL IMUL	r16	3	3	x	x	x				int	5	2
MUL IMUL	r32	3	3	x	x	x				int	5	2
MUL IMUL	r64	3	3	x	x	x				int	3	2
IMUL	r16,r16	1	1		1					int	3	1
IMUL	r32,r32	1	1		1					int	3	1
IMUL	r64,r64	1	1	1						int	3	1
IMUL	r16,r16,i	1	1		1					int	3	1
IMUL	r32,r32,i	1	1		1					int	3	1
IMUL	r64,r64,i	1	1	1						int	3	2
MUL IMUL	m8	1	1		1		1			int	3	1
MUL IMUL	m16	3	3	x	x	x	1			int	5	2
MUL IMUL	m32	3	3	x	x	x	1			int	5	2
MUL IMUL	m64	3	2	2			1			int	3	2
IMUL	r16,m16	1	1		1		1			int	3	1
IMUL	r32,m32	1	1		1		1			int	3	1
IMUL	r64,m64	1	1	1			1			int	3	1
IMUL	r16,m16,i	1	1		1		1			int		1
IMUL	r32,m32,i	1	1		1		1			int		1
IMUL	r64,m64,i	1	1	1			1			int		1
DIV c)	r8	4	4	1	2	1				int	11-21	7-11
DIV c)	r16	6	6	x	4	x				int	17-22	7-12
DIV c)	r32	6	6	x	3	x				int	17-28	7-17
DIV c)	r64	~40	x	x	x	x				int	28-90	19-69
IDIV c)	r8	4	4	1	2	1				int	10-22	7-11
IDIV c)	r16	8	8	x	5	x				int	18-23	7-12
IDIV c)	r32	7	7	x	3	x				int	17-28	7-17
IDIV c)	r64	~60	x	x	x	x				int	37-100	26-86
CBW CWDE CDQE		1	1	x	x	x				int	1	1
CWD CDQ CQO		1	1	x		x				int	1	1
POPCNT ℓ)	r,r	1	1		1					int	3	1
POPCNT ℓ)	r,m	1	1		1		1			int		1
CRC32 ℓ)	r,r	1	1		1					int	3	1
CRC32 ℓ)	r,m	1	1		1		1			int		1



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<b>Logic instructions</b>												
AND OR XOR	r,r/i	1	1	x	x	x				int	1	0.33
AND OR XOR	r,m	1	1	x	x	x	1			int		1
AND OR XOR	m,r/i	2	1	x	x	x	1	1	1	int	6	1
TEST	r,r/i	1	1	x	x	x				int	1	0.33
TEST	m,r/i	1	1	x	x	x	1			int		1
SHR SHL SAR	r,i/cl	1	1	x		x				int	1	0.5
SHR SHL SAR	m,i/cl	3	2	x		x	1	1	1	int	6	1
ROR ROL	r,i/cl	1	1	x		x				int	1	1
ROR ROL	m,i/cl	3	2	x		x	1	1	1	int	6	1
RCR RCL	r,1	2	2	x	x	x				int	2	2
RCR	r8,i/cl	9	9	x	x	x				int		13
RCL	r8,i/cl	8	8	x	x	x				int		11
RCR RCL	r16/32/64,i/cl	6	6	x	x	x				int	12-13	12-13
RCR RCL	m,1	4	3	x	x	x	1	1	1	int	7	
RCR	m8,i/cl	12	9	x	x	x	1	1	1	int		16
RCL	m8,i/cl	11	8	x	x	x	1	1	1	int		14
RCR RCL	m16/32/64,i/cl	10	7	x	x	x	1	1	1	int		15
SHLD	r,r,i/cl	2	2	x	x	x				int	3	1
SHLD	m,r,i/cl	3	2	x	x	x	1	1	1	int	8	
SHRD	r,r,i/cl	2	2	x	x	x				int	4	1
SHRD	m,r,i/cl	3	2	x	x	x	1	1	1	int	9	
BT	r,r/i	1	1	x		x				int	1	1
BT	m,r	9	8	x		x	1			int		5
BT	m,i	2	2	x		x	1			int		1
BTR BTS BTC	r,r/i	1	1	x		x				int	1	1
BTR BTS BTC	m,r	10	7	x	x	x	1	1	1	int	6	
BTR BTS BTC	m,i	3	3	x		x	1	1	1	int	6	
BSF BSR	r,r	1	1		1					int	3	1
BSF BSR	r,m	2	1		1		1			int	3	1
SETcc	r	1	1	x		x				int	1	1
SETcc	m	2	1	x	x	x		1	1	int		1
CLC STC CMC		1	1	x	x	x				int	1	0.33
CLD		2	2	x	x	x				int		4
STD		2	2	x	x	x				int		5
<b>Control transfer instructions</b>												
JMP	short/near	1	1			1				int	0	2
JMP i)	far	31	31							int		67
JMP	r	1	1			1				int	0	2
JMP	m(near)	1	1			1	1			int	0	2
JMP	m(far)	31	31				11			int		73
Conditional jump	short/near	1	1			1				int	0	2
Fused compare/test and branch e)		1	1			1				int	0	2
J(E/R)CXZ	short	2	2	x	x	1				int		2
LOOP	short	6	6	x	x	x				int		4
LOOP(N)E	short	11	11	x	x	x				int		7
CALL	near	2	2	?	?	1		1	1	int		2
CALL i)	far	46	46				9			int		74
CALL	r	3	2	?	?	1		1	1	int		2
CALL	m(near)	4	3	?	?	1	1	1	1	int		2
CALL	m(far)	47	47				1			int		79

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RETN		1	1			1	1				int		2
RETN	i	3	2			1	1				int		2
RETF		39	39								int		120
RETF	i	40	40								int		124
BOUND i)	r,m	15	13					2			int		7
INTO i)		4	4								int		5
<b>String instructions</b>													
LODS		2	1	x	x	x	1				int		1
REP LODS		11+4n									int	40+12n	
STOS		3	1	x	x	x			1	1	int		1
REP STOS	small n	60+n									int	12+n	
REP STOS	large n	2.5/16 bytes									int	1 clk / 16 bytes	
MOVS		5	2	x	x	x	1	1	1		int		4
REP MOVS	small n	13+6n									int	12+n	
REP MOVS	large n	2/16 bytes									int	1 clk / 16 bytes	
SCAS		3	2	x	x	x	1				int		1
REP SCAS		37+6n									int	40+2n	
CMPS		5	3	x	x	x	2				int		4
REP CMPS		65+8n									int	42+2n	
<b>Other</b>													
NOP (90)		1	1	x	x	x					int		0.33
Long NOP (0F 1F)		1	1	x	x	x					int		1
PAUSE		5	5	x	x	x					int		9
ENTER	a,0	11	9	x	x	x	1	1	1		int		8
ENTER	a,b	34+7b									int	79+5b	
LEAVE		3	3					1			int		5
CPUID		25-100									int	~200	~200
RDTSC		22									int		24
RDPMSR		28									int		40-60

**Notes:**

- a) Applies to all addressing modes
- b) Has an implicit LOCK prefix.
- c) Low values are for small results, high values for high results.
- e) See manual 3: "The microarchitecture of Intel, AMD and VIA CPUs" for restrictions on macro-op fusion.
- i) Not available in 64 bit mode.
- ℓ) SSE4.2 instruction set.

**Floating point x87 instructions**

Instruction	Operands	μops fused domain	μops unfused domain								Do-main	Laten-cy	Reci-procal through-put
			p015	p0	p1	p5	p2	p3	p4				
<b>Move instructions</b>													
FLD	r	1	1	1							float	1	1
FLD	m32/64	1	1					1			float	3	1
FLD	m80	4	2	1	1			2			float	4	2
FBLD	m80	41	38	x	x	x		3			float	45	20
FST(P)	r	1	1	1							float	1	1
FST(P)	m32/m64	1							1	1	float	4	1

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FSTP	m80	7	3	x	x	x		2	2	float	5	5
FBSTP	m80	208	204	x	x	x		2	2	float	242	245
FXCH	r	1	0 f)							float	0	1
FILD	m	1	1		1		1			float	6	1
FIST(P)	m	3	1		1			1	1	float	7	1
FISTTP g)	m	3	1		1			1	1	float	7	1
FLDZ		1	1	1						float		1
FLD1		2	2	1	1					float		2
FLDPI FLDL2E etc.		2	2		2					float		2
FCMOVcc	r	2	2	2						float	2+2	2
FNSTSW	AX	2	2							float		1
FNSTSW	m16	3	2					1	1	float		2
FLDCW	m16	2	1				1			float	7	31
FNSTCW	m16	2	1	1				1	1	float	5	1
FINCSTP FDECSTP		1	1	1						float	1	1
FFREE(P)	r	2	2	x	x	x				float		4
FNSAVE	m	143	89	x	x	x	8	23	23	float	178	178
FRSTOR	m	79	52	x	x	x	27			float	156	156
<b>Arithmetic instructions</b>												
FADD(P) FSUB(R)(P)	r	1	1		1					float	3	1
FADD(P) FSUB(R)(P)	m	1	1		1		1			float		1
FMUL(P)	r	1	1	1						float	5	1
FMUL(P)	m	1	1	1			1			float		1
FDIV(R)(P)	r	1	1	1						float	7-27 d)	7-27 d)
FDIV(R)(P)	m	1	1	1			1			float	7-27 d)	7-27 d)
FABS		1	1	1						float	1	1
FCHS		1	1	1						float	1	1
FCOM(P) FUCOM	r	1	1		1					float		1
FCOM(P) FUCOM	m	1	1		1		1			float		1
FCOMPP FUCOMPP		2	2	1	1					float		1
FCOMI(P) FUCOMI(P)	r	1	1		1					float		1
FIADD FISUB(R)	m	2	2		2		1			float	3	2
FIMUL	m	2	2	1	1		1			float	5	2
FIDIV(R)	m	2	2	1	1		1			float	7-27 d)	7-27 d)
FICOM(P)	m	2	2		2		1			float		1
FTST		1	1		1					float		1
FXAM		1	1		1					float		1
FPREM		25	25	x	x	x				float	14	
FPREM1		35	35	x	x	x				float	19	
FRNDINT		17	17	x	x	x				float	22	
<b>Math</b>												
FSCALE		24	24	x	x	x				float	12	
FXTRACT		17	17	x	x	x				float	13	
FSQRT		1	1	1						float	~27	
FSIN		~100	~100	x	x	x				float	40-100	
FCOS		~100	~100	x	x	x				float	40-100	
FSINCOS		~100	~100	x	x	x				float	~110	
F2XM1		19	19	x	x	x				float	58	
FYL2X FYL2XP1		~55	~55	x	x	x				float	~80	
FPTAN		~100	~100	x	x	x				float	~115	
FPATAN		~82	~82	x	x	x				float	~120	

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<b>Other</b>												
FNOP		1	1	1							float	1
WAIT		2	2	x	x	x					float	1
FNCLEX		3	3		x	x					float	17
FNINIT		~190	~190	x	x	x					float	77

**Notes:**

- d) Round divisors or low precision give low values.
- f) Resolved by register renaming. Generates no  $\mu$ ops in the unfused domain.
- g) SSE3 instruction set.

**Integer MMX and XMM instructions**

Instruction	Operands	$\mu$ ops fused do-main	$\mu$ ops unfused domain							Do-main	Latency	Reciprocal throughput
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												
MOVD k)	r32/64,(x)mm	1	1	x	x	x				int	1+1	0.33
MOVD k)	m32/64,(x)mm	1						1	1		3	1
MOVD k)	(x)mm,r32/64	1	1	x	x	x				ivec	1+1	0.33
MOVD k)	(x)mm,m32/64	1					1				2	1
MOVQ	(x)mm, (x)mm	1	1	x	x	x				ivec	1	0.33
MOVQ	(x)mm,m64	1					1				2	1
MOVQ	m64, (x)mm	1						1	1		3	1
MOVDQA	xmm, xmm	1	1	x	x	x				ivec	1	0.33
MOVDQA	xmm, m128	1					1				2	1
MOVDQA	m128, xmm	1						1	1		3	1
MOVDQU	xmm, m128	1	1				1				2	1
MOVDQU	m128, xmm	1	1					1	1		3	1
LDDQU g)	xmm, m128	1	1				1				2	1
MOVDQ2Q	mm, xmm	1	1	x	x	x				ivec	1	0.33
MOVQ2DQ	xmm,mm	1	1	x	x	x				ivec	1	0.33
MOVNTQ	m64,mm	1						1	1		~270	2
MOVNTDQ	m128,xmm	1						1	1		~270	2
MOVNTDQA j)	xmm, m128	1					1				2	1
PACKSSWB/DW												
PACKUSWB	mm,mm	1	1		1					ivec	1	1
PACKSSWB/DW												
PACKUSWB	mm,m64	1	1		1		1					2
PACKSSWB/DW												
PACKUSWB	xmm,xmm	1	1	x		x				ivec	1	0.5
PACKSSWB/DW												
PACKUSWB	xmm,m128	1	1	x		x	1					2
PACKUSDW j)	xmm,xmm	1	1	x		x				ivec	1	2
PACKUSDW j)	xmm,m	1	1	x		x	1					2
PUNPCKH/LBW/WD/DQ	(x)mm, (x)mm	1	1	x		x				ivec	1	0.5
PUNPCKH/LBW/WD/DQ	(x)mm,m	1	1	x		x	1					2
PUNPCKH/LQDQ	xmm,xmm	1	1	x		x				ivec	1	0.5
PUNPCKH/LQDQ	xmm, m128	2	1	x		x	1					1
PMOVSX/ZXBW j)	xmm,xmm	1	1	x		x				ivec	1	1
PMOVSX/ZXBW j)	xmm,m64	1	1	x		x	1					2
PMOVSX/ZXBD j)	xmm,xmm	1	1	x		x				ivec	1	1
PMOVSX/ZXBD j)	xmm,m32	1	1	x		x	1					2

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PMOVSX/ZXBQ j)	xmm,xmm	1	1	x	x				ivec	1	1
PMOVSX/ZXBQ j)	xmm,m16	1	1	x	x	1					2
PMOVSX/ZXWD j)	xmm,xmm	1	1	x	x				ivec	1	1
PMOVSX/ZXWD j)	xmm,m64	1	1	x	x	1					2
PMOVSX/ZXWQ j)	xmm,xmm	1	1	x	x				ivec	1	1
PMOVSX/ZXWQ j)	xmm,m32	1	1	x	x	1					2
PMOVSX/ZXDQ j)	xmm,xmm	1	1	x	x				ivec	1	1
PMOVSX/ZXDQ j)	xmm,m64	1	1	x	x	1					2
PSHUFB h)	(x)mm, (x)mm	1	1	x	x				ivec	1	0.5
PSHUFB h)	(x)mm,m	2	1	x	x	1					1
PSHUFW	mm,mm,i	1	1	x	x				ivec	1	0.5
PSHUFW	mm,m64,i	2	1	x	x	1					1
PSHUFD	xmm,xmm,i	1	1	x	x				ivec	1	0.5
PSHUFD	xmm,m128,i	2	1	x	x	1					1
PSHUFL/HW	xmm,xmm,i	1	1	x	x				ivec	1	0.5
PSHUFL/HW	xmm, m128,i	2	1	x	x	1					1
PALIGNR h)	(x)mm,(x)mm,i	1	1	x	x				ivec	1	1
PALIGNR h)	(x)mm,m,i	2	1	x	x	1					1
PBLENDVB j)	x,x,xmm0	2	2	1	1				ivec	2	1
PBLENDVB j)	xmm,m,xmm0	3	2	1	1	1					1
PBLENDW j)	xmm,xmm,i	1	1	x	x				ivec	1	0.5
PBLENDW j)	xmm,m,i	2	1	x	x	1					1
MASKMOVQ	mm,mm	4	1	1		1	1	1	ivec		2
MASKMOVDQU	xmm,xmm	10	4	x	x	2	2	x	ivec		7
PMOVMASKB	r32,(x)mm	1	1	1					float	2+2	1
PEXTRB j)	r32,xmm,i	2	2	x	x	x			ivec	2+1	1
PEXTRB j)	m8,xmm,i	2	2	x	x						1
PEXTRW	r32,(x)mm,i	2	2	x	x	x			ivec	2+1	1
PEXTRW j)	m16,(x)mm,i	2	2	x	x		1	1			1
PEXTRD j)	r32,xmm,i	2	2	x	x	x			ivec	2+1	1
PEXTRD j)	m32,xmm,i	2	1	x	x		1	1			1
PEXTRQ j,m)	r64,xmm,i	2	2	x	x	x			ivec	2+1	1
PEXTRQ j,m)	m64,xmm,i	2	1	x	x		1	1			1
PINSRB j)	xmm,r32,i	1	1	x	x				ivec	1+1	1
PINSRB j)	xmm,m8,i	2	1	x	x	1					1
PINSRW	(x)mm,r32,i	1	1	x	x				ivec	1+1	1
PINSRW	(x)mm,m16,i	2	1	x	x	1					1
PINSRD j)	xmm,r32,i	1	1	x	x				ivec	1+1	1
PINSRD j)	xmm,m32,i	2	1	x	x	1					1
PINSRQ j,m)	xmm,r64,i	1	1	x	x				ivec	1+1	1
PINSRQ j,m)	xmm,m64,i	2	1	x	x	1					1
<b>Arithmetic instructions</b>											
PADD/SUB(U)(S)B/W/D/Q	(x)mm, (x)mm	1	1	x	x				ivec	1	0.5
PADD/SUB(U)(S)B/W/D/Q	(x)mm,m	1	1	x	x	1					2
PHADD/SUB(S)W/D h)	(x)mm, (x)mm	3	3	x	x				ivec	3	1,5
PHADD/SUB(S)W/D h)	(x)mm,m64	4	3	x	x	1					3
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	1	x	x				ivec	1	0.5
PCMPEQ/GTB/W/D	(x)mm,m	1	1	x	x	1					2
PCMPEQQ j)	xmm,xmm	1	1	x	x				ivec	1	0.5
PCMPEQQ j)	xmm,m128	1	1	x	x	1					2

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PCMPGTQ †)	xmm,xmm	1	1	1				ivec	3	1
PCMPGTQ †)	xmm,m128	1	1	1	1					1
PMULL/HW PMULHUW	(x)mm,(x)mm	1	1	1				ivec	3	1
PMULL/HW PMULHUW	(x)mm,m	1	1	1	1					1
PMULHRSW h)	(x)mm,(x)mm	1	1	1				ivec	3	1
PMULHRSW h)	(x)mm,m	1	1	1	1					1
PMULLD j)	xmm,xmm	2	2	2				ivec	6	2
PMULLD j)	xmm,m128	3	2	2	1					
PMULDQ j)	xmm,xmm	1	1	1				ivec	3	1
PMULDQ j)	xmm,m128	1	1	1	1					1
PMULUDQ	(x)mm,(x)mm	1	1	1				ivec	3	1
PMULUDQ	(x)mm,m	1	1	1	1					1
PMADDWD	(x)mm,(x)mm	1	1	1				ivec	3	1
PMADDWD	(x)mm,m	1	1	1	1					1
PMADDUBSW h)	(x)mm,(x)mm	1	1	1				ivec	3	1
PMADDUBSW h)	(x)mm,m	1	1	1	1					1
PAVGB/W	(x)mm,(x)mm	1	1	x		x		ivec	1	0.5
PAVGB/W	(x)mm,m	1	1	x	x	1				1
PMIN/MAXSB j)	xmm,xmm	1	1	x	x			ivec	1	1
PMIN/MAXSB j)	xmm,m128	1	1	x	x	1				2
PMIN/MAXUB	(x)mm,(x)mm	1	1	x	x			ivec	1	0.5
PMIN/MAXUB	(x)mm,m	1	1	x	x	1				2
PMIN/MAXSW	(x)mm,(x)mm	1	1	x	x			ivec	1	0.5
PMIN/MAXSW	(x)mm,m	1	1	x	x	1				2
PMIN/MAXUW j)	xmm,xmm	1	1	x	x			ivec	1	1
PMIN/MAXUW j)	xmm,m	1	1	x	x	1				2
PMIN/MAXU/SD j)	xmm,xmm	1	1	x	x			ivec	1	1
PMIN/MAXU/SD j)	xmm,m128	1	1	x	x	1				2
PHMINPOSUW j)	xmm,xmm	1	1		1			ivec	3	1
PHMINPOSUW j)	xmm,m128	1	1		1	1				3
PABSB PABSW PABSD h)	(x)mm,(x)mm	1	1	x	x			ivec	1	0.5
PABSB PABSW PABSD h)	(x)mm,m	1	1	x	x	1				1
PSIGNB PSIGNW PSIGND h)	(x)mm,(x)mm	1	1	x	x			ivec	1	0.5
PSIGNB PSIGNW PSIGND h)	(x)mm,m	1	1	x	x	1				2
PSADBW	(x)mm,(x)mm	1	1		1			ivec	3	1
PSADBW	(x)mm,m	1	1		1	1				3
MPSADBW j)	xmm,xmm,i	3	3	x	x	x		ivec	5	1
MPSADBW j)	xmm,m,i	4	3	x	x	x	1			2
PCLMULQDQ n)	xmm,xmm,i								12	8
AESDEC, AESDECLAST, AESENC, AESENCLAST n)									~5	~2
AESIMC n)	xmm,xmm								~5	~2
AESKEYGENASSIST n)	xmm,xmm,i								~5	~2
<b>Logic instructions</b>										
PAND(N) POR PXOR	(x)mm,(x)mm	1	1	x	x	x		ivec	1	0.33
PAND(N) POR PXOR	(x)mm,m	1	1	x	x	x	1			1

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PTEST j)	xmm,xmm	2	2	x	x	x				ivec	3	1
PTEST j)	xmm,m128	2	2	x	x	x	1					1
PSLL/RL/RAW/D/Q	mm,mm/i	1	1		1					ivec	1	1
PSLL/RL/RAW/D/Q	mm,m64	1	1		1		1					2
PSLL/RL/RAW/D/Q	xmm,i	1	1		1					ivec	1	1
PSLL/RL/RAW/D/Q	xmm,xmm	2	2	x	1	x				ivec	2	2
PSLL/RL/RAW/D/Q	xmm,m128	3	2	x	1	x	1					1
PSLL/RLDQ	xmm,i	1	1	x		x				ivec	1	1
<b>String instructions</b>												
PCMPSTRM ℓ)	xmm,xmm,i	8	8	x	x	x				ivec	14	5
PCMPSTRM ℓ)	xmm,m128,i	9	8	x	x	x	1			ivec	14	6
PCMPSTRM ℓ)	xmm,xmm,i	9	9	x	x	x				ivec	7	6
PCMPSTRM ℓ)	xmm,m128,i	10	10	x	x	x	1			ivec	7	6
PCMPSTRM ℓ)	xmm,xmm,i	3	3	x	x	x				ivec	8	2
PCMPSTRM ℓ)	xmm,m128,i	4	4	x	x	x	1			ivec	8	2
PCMPSTRM ℓ)	xmm,xmm,i	4	4	x	x	x				ivec	7	2
PCMPSTRM ℓ)	xmm,m128,i	6	5	x	x	x	1			ivec	7	5
<b>Other</b>												
EMMS		11	11	x	x	x				float		6

**Notes:**

- g) SSE3 instruction set.
- h) Supplementary SSE3 instruction set.
- j) SSE4.1 instruction set
- k) MASM uses the name MOVD rather than MOVQ for this instruction even when moving 64 bits
- ℓ) SSE4.2 instruction set
- m) Only available in 64 bit mode
- n) Only available on newer models

**Floating point XMM instructions**

Instruction	Operands	μops fused domain	μops unfused domain							Do-main	Laten-cy	Reci-procal through-put
			p015	p0	p1	p5	p2	p3	p4			
<b>Move instructions</b>												
MOVAPS/D	xmm,xmm	1	1			1				float	1	1
MOVAPS/D	xmm,m128	1					1				2	1
MOVAPS/D	m128,xmm	1						1	1		3	1
MOVUPS/D	xmm,m128	1					1				2	1-4
MOVUPS/D	m128,xmm	1						1	1		3	1-3
MOVSS/D	xmm,xmm	1	1			1					1	1
MOVSS/D	xmm,m32/64	1					1				2	1
MOVSS/D	m32/64,xmm	1						1	1		3	1
MOVHPS/D MOVLPS/D	xmm,m64	2	1			1	1				3	2
MOVH/LPS/D	m64,xmm	2	1			1		1	1		5	1
MOVLHPS MOVHLPS	xmm,xmm	1	1			1				float	1	1
MOVMSKPS/D	r32,xmm	1	1	1						float	1+2	1
MOVNTPS/D	m128,xmm	1						1	1		~270	2
SHUFPS/D	xmm,xmm,i	1	1			1				float	1	1
SHUFPS/D	xmm,m128,i	2	1			1	1			float		1
BLENDPS/PD j)	xmm,xmm,i	1	1			1				float	1	1

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BLENDPS/PD j)	xmm,m128,i	2	1			1	1			float		1
BLENDVPS/PD j)	x,x,xmm0	2	2			2				float	2	2
BLENDVPS/PD j)	xmm,m,xmm0	3	2			2	1			float		2
MOVDDUP g)	xmm,xmm	1	1			1				float	1	1
MOVDDUP g)	xmm,m64	1					1				2	1
MOVSH/LDUP g)	xmm,xmm	1	1			1				float	1	1
MOVSH/LDUP g)	xmm,m128	1					1					1
UNPCKH/LPS/D	xmm,xmm	1	1			1				float	1	1
UNPCKH/LPS/D	xmm,m128	1	1			1	1			float		1
EXTRACTPS j)	r32,xmm,i	1	1			1				float	1+2	1
EXTRACTPS j)	m32,xmm,i	2	1			1		1	1			1
INSERTPS j)	xmm,xmm,i	1	1			1				float	1	1
INSERTPS j)	xmm,m32,i	3	2			2	1			float		2
<b>Conversion</b>												
CVTPD2PS	xmm,xmm	2	2			1	1			float	4	1
CVTPD2PS	xmm,m128	2	2			1		1		float		1
CVTSD2SS	xmm,xmm	2	2			1	1			float	4	1
CVTSD2SS	xmm,m64	2	2	?	?	?	1			float		1
CVTPS2PD	xmm,xmm	2	2	1		1				float	2	1
CVTPS2PD	xmm,m64	2	2	1		1	1			float		1
CVTSS2SD	xmm,xmm	1	1	1						float	1	1
CVTSS2SD	xmm,m32	1	1	1				1		float		2
CVTDQ2PS	xmm,xmm	1	1			1				float	3+2	1
CVTDQ2PS	xmm,m128	1	1			1		1		float		1
CVT(T) PS2DQ	xmm,xmm	1	1			1				float	3+2	1
CVT(T) PS2DQ	xmm,m128	1	1			1		1		float		1
CVTDQ2PD	xmm,xmm	2	2			1	1			float	4+2	1
CVTDQ2PD	xmm,m64	2	2			1	1	1		float		1
CVT(T)PD2DQ	xmm,xmm	2	2			1	1			float	4+2	1
CVT(T)PD2DQ	xmm,m128	2	2			1	1	1		float		1
CVTPI2PS	xmm,mm	1	1			1				float	3+2	3
CVTPI2PS	xmm,m64	1	1			1		1		float		3
CVT(T)PS2PI	mm,xmm	1	1			1				float	3+2	1
CVT(T)PS2PI	mm,m128	1	1			1		1		float		1
CVTPI2PD	xmm,mm	2	2			1	1			ivec/float	6	1
CVTPI2PD	xmm,m64	2	2			1	1	1				1
CVT(T) PD2PI	mm,xmm	2	2	x		1	x			float/ivec	6	1
CVT(T) PD2PI	mm,m128	2	2	x		1	x	1				1
CVTSI2SS	xmm,r32	1	1			1				float	3+2	3
CVTSI2SS	xmm,m32	1	1			1		1		float		3
CVT(T)SS2SI	r32,xmm	1	1			1				float	3+2	1
CVT(T)SS2SI	r32,m32	1	1			1		1		float		1
CVTSI2SD	xmm,r32	2	2	1		1				float	4+2	3
CVTSI2SD	xmm,m32	2	1			1		1		float		3
CVT(T)SD2SI	r32,xmm	1	1			1				float	3+2	1
CVT(T)SD2SI	r32,m64	1	1			1		1		float		1
<b>Arithmetic</b>												
ADDSS/D SUBSS/D	xmm,xmm	1	1			1				float	3	1
ADDSS/D SUBSS/D	xmm,m32/64	1	1			1		1		float		1
ADDPS/D SUBPS/D	xmm,xmm	1	1			1				float	3	1
ADDPS/D SUBPS/D	xmm,m128	1	1			1		1		float		1



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ADDSUBPS/D g)	xmm,xmm	1	1		1					float	3	1
ADDSUBPS/D g)	xmm,m128	1	1		1		1			float		1
HADDPS HSUBPS g)	xmm,xmm	3	3		1	2				float	5	2
HADDPS HSUBPS g)	xmm,m128	4	3		1	2	1			float		2
HADDPD HSUBPD g)	xmm,xmm	3	3		1	2				float	3	2
HADDPD HSUBPD g)	xmm,m128	4	3		1	2	1			float		2
MULSS MULPS	xmm,xmm	1	1	1						float	4	1
MULSS MULPS	xmm,m	1	1	1			1			float		1
MULSD MULPD	xmm,xmm	1	1	1						float	5	1
MULSD MULPD	xmm,m	1	1	1			1			float		1
DIVSS DIVPS	xmm,xmm	1	1	1						float	7-14	7-14
DIVSS DIVPS	xmm,m	1	1	1			1			float		7-14
DIVSD DIVPD	xmm,xmm	1	1	1						float	7-22	7-22
DIVSD DIVPD	xmm,m	1	1	1			1			float		7-22
RCPSS/PS	xmm,xmm	1	1		1					float	3	2
RCPSS/PS	xmm,m	1	1		1		1			float		2
CMPccSS/D CMPccPS/D	xmm,xmm	1	1		1					float	3	1
CMPccSS/D CMPccPS/D	xmm,m	2	1		1		1			float		1
COMISS/D UCOMISS/D	xmm,xmm	1	1		1					float	1+2	1
COMISS/D UCOMISS/D	xmm,m32/64	1	1		1		1			float		1
MAXSS/D MINSS/D	xmm,xmm	1	1		1					float	3	1
MAXSS/D MINSS/D	xmm,m32/64	1	1		1		1			float		1
MAXPS/D MINPS/D	xmm,xmm	1	1		1					float	3	1
MAXPS/D MINPS/D	xmm,m128	1	1		1		1			float		1
ROUNDSS/D												
ROUNDPS/D j)	xmm,xmm,i	1	1		1					float	3	1
ROUNDSS/D												
ROUNDPS/D j)	xmm,m128,i	2	1		1		1			float		1
DPPS j)	xmm,xmm,i	4	4	1	2	1				float	11	2
DPPS j)	xmm,m128,i	6	5	x	x	x	1			float		
DPPD j)	xmm,xmm,i	3	3	x	x	x				float	9	1
DPPD j)	xmm,m128,i	4	3	x	x	x	1			float		3
<b>Math</b>												
SQRTSS/PS	xmm,xmm	1	1	1						float	7-18	7-18
SQRTSS/PS	xmm,m	2	1	1			1			float		7-18
SQRTSD/PD	xmm,xmm	1	1	1						float	7-32	7-32
SQRTSD/PD	xmm,m	2	1	1			1			float		7-32
RSQRTSS/PS	xmm,xmm	1	1		1					float	3	2
RSQRTSS/PS	xmm,m	1	1		1		1			float		2
<b>Logic</b>												
AND/ANDN/OR/XORPS/D	xmm,xmm	1	1				1			float	1	1
AND/ANDN/OR/XORPS/D	xmm,m128	1	1				1	1		float		1
<b>Other</b>												
LDMXCSR	m32	6	6	x	x	x	1					5
STMXCSR	m32	2	1				1	1	1			1
FXSAVE	m4096	141	141	x	x	x	5	38	38		90	90
FXRSTOR	m4096	112	90	x	x	x	42					100

Notes:

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**g)**

SSE3 instruction set.

## Intel Sandy Bridge

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.

**$\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused  $\mu$ ops count as one.

**$\mu$ ops unfused domain:** The number of  $\mu$ ops for each execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if the sum of the numbers listed under p015 + p23 + p4 exceeds the number listed under  $\mu$ ops fused domain. A number indicated as 1+ under a read or write port means a 256-bit read or write operation using two clock cycles for handling 128 bits each cycle. The port cannot receive another read or write  $\mu$ op in the second clock cycle, but a read port can receive an address-calculation  $\mu$ op in the second clock cycle. An x under p0, p1 or p5 means that at least one of the  $\mu$ ops listed under p015 can optionally go to this port. For example, a 1 under p015 and an x under p0 and p5 means one  $\mu$ op which can go to either port 0 or port 5, whichever is vacant first. A value listed under p015 but nothing under p0, p1 and p5 means that it is not known which of the three ports these  $\mu$ ops go to.

**p015:** The total number of  $\mu$ ops going to port 0, 1 and 5.

**p0:** The number of  $\mu$ ops going to port 0 (execution units).

**p1:** The number of  $\mu$ ops going to port 1 (execution units).

**p5:** The number of  $\mu$ ops going to port 5 (execution units).

**p23:** The number of  $\mu$ ops going to port 2 or 3 (memory read or address calculation).

**p4:** The number of  $\mu$ ops going to port 4 (memory write data).

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Where hyperthreading is enabled, the use of the same execution units in the other thread leads to inferior performance. Denormal numbers, NAN's and infinity do not increase the latency. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

The latencies and throughputs listed below for addition and multiplication using full size YMM registers are obtained only after a warm-up period of a thousand instructions or more. The latencies may be one or two clock cycles longer and the reciprocal throughputs double the values for shorter sequences of code. There is no warm-up effect when vectors are 128 bits wide or less.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											
MOV	r,r/i	1	1	x	x	x			1		

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MOV	r,m	1					1		2	0.5	all addressing modes
MOV	m,r	1					1	1	3	1	
MOV	m,i	1					1	1		1	
MOVNTI	m,r	2					1	1	~350	1	
MOVSX MOVZX	r,r	1	1	x	x	x			1		
MOVSXD											
MOVSX MOVZX	r,m	1					1			0.5	
MOVSXD											
CMOVcc	r,r	2	2	x	x	x			2	1	
CMOVcc	r,m	2	2	x	x	x	1			1	
XCHG	r,r	3	3	x	x	x			2	1	
XCHG	r,m	8	x				2	1	25		implicit lock
XLAT		3	2				1		7	1	
PUSH	r	1					1	1	3	1	
PUSH	i	1					1	1		1	
PUSH	m	2					2	1		1	
PUSHF(D/Q)		3	2	x	x	x	1	1		1	
PUSHA(D)		16	0				8	8		8	not 64 bit
POP	r	1					1		2	0.5	
POP	(E/R)SP	1	0				1			0.5	
POP	m	2					2	1		1	
POPF(D/Q)		9	8	x	x	x	1			18	
POPA(D)		18	10				8			9	not 64 bit
LAHF SAHF		1	1						1	1	
SALC		3	3						1	1	not 64 bit
LEA	r,m	1	1	x	x				1	0.5	simple
LEA	r,m	1	1		1				3	1	complex or rip relative
BSWAP	r32	1	1		1				1	1	
BSWAP	r64	2	2		2				2	1	
PREFETCHNTA	m	1					1			0.5	
PREFETCH0/1/2	m	1					1			0.5	
LFENCE		2					1	1		4	
MFENCE		3	1				1	1		33	
SFENCE		2					1	1		6	
<b>Arithmetic instructions</b>											
ADD SUB	r,r/i	1	1	x	x	x			1		
ADD SUB	r,m	1	1	x	x	x	1			0.5	
ADD SUB	m,r/i	2	1	x	x	x	2	1	6	1	
SUB	r,same	1	0						0	0.25	
ADC SBB	r,r/i	2	2	x	x	x			2	1	
ADC SBB	r,m	2	2	x	x	x	1		2	1	
ADC SBB	m,r/i	4	3	x	x	x	2	1	7	1,5	
CMP	r,r/i	1	1	x	x	x			1		
CMP	m,r/i	1	1	x	x	x	1		1	0.5	
INC DEC NEG NOT	r	1	1	x	x	x			1		
INC DEC NEG NOT	m	3	1	x	x	x	2	1	6	2	

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AAA AAS		2	2						4		not 64 bit
DAA DAS		3	3						4		not 64 bit
AAD		3	3						2		not 64 bit
AAM		8	8						20	11	not 64 bit
MUL IMUL	r8	1	1		1				3	1	
MUL IMUL	r16	4	4						4	2	
MUL IMUL	r32	3	3						4	2	
MUL IMUL	r64	2	2						3	1	
IMUL	r,r	1	1		1				3	1	
IMUL	r16,r16,i	2	2						4	1	
IMUL	r32,r32,i	1	1		1				3	1	
IMUL	r64,r64,i	1	1		1				3	1	
MUL IMUL	m8	1	1		1		1		3	1	
MUL IMUL	m16	4	3				1			2	
MUL IMUL	m32	3	2				1			2	
MUL IMUL	m64	2	1				1			2	
IMUL	r,m	1	1		1		1			1	
IMUL	r16,m16,i	2	2				1			1	
IMUL	r32,m32,i	1	1		1		1			1	
IMUL	r64,m64,i	1	1		1		1			1	
DIV	r8	10	10						20-24	11-14	
DIV	r16	11	11						21-25	11-14	
DIV	r32	10	10						20-28	11-18	
DIV	r64	34-56	x						30-94	22-76	
IDIV	r8	10	10						21-24	11-14	
IDIV	r16	10	10						21-25	11-14	
IDIV	r32	9	9						20-27	11-18	
IDIV	r64	59-138	x						40-103	25-84	
CBW		1	1						1	0.5	
CWDE		1	1				1		1	1	
CDQE		1	1						1	0.5	
CWD		2	2						1	1	
CDQ		1	1						1	1	
CQO		1	1						1	0.5	
POPCNT	r,r	1	1		1				3	1	SSE4.2
POPCNT	r,m	1	1		1		1			1	SSE4.2
CRC32	r,r	1	1		1				3	1	SSE4.2
CRC32	r,m	1	1		1		1			1	SSE4.2
<b>Logic instructions</b>											
AND OR XOR	r,r/i	1	1	x	x	x			1		
AND OR XOR	r,m	1	1	x	x	x	1			0.5	
AND OR XOR	m,r/i	2	1	x	x	x	2	1	6	1	
XOR	r,same	1	0						0	0.25	
TEST	r,r/i	1	1	x	x	x			1		
TEST	m,r/i	1	1	x	x	x	1			0.5	
SHR SHL SAR	r,i	1	1	x		x			1	0.5	
SHR SHL SAR	m,i	3	1				2	1		2	
SHR SHL SAR	r,cl	3	3						2	2	
SHR SHL SAR	m,cl	5	3				2	1		4	
ROR ROL	r,i	1	1						1	1	

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ROR ROL	m,i	4	3				2	1		2	
ROR ROL	r,cl	3	3						2	2	
ROR ROL	m,cl	5	3				2	1		4	
RCR	r8,1	high							high	high	
RCR	r16/32/64,1	3	3						2	2	
RCR	r,i	8	8						5	5	
RCR	m,i	11	7				x	x		6	
RCR	r,cl	8	8						5	5	
RCR	m,cl	11	7				x	x		6	
RCL	r,1	3	3						2	2	
RCL	r,i	8	8						6	6	
RCL	m,i	11	7				x	x		6	
RCL	r,cl	8	8						6	6	
RCL	m,cl	11	7				x	x		6	
SHRD SHLD	r,r,i	1	1							0.5	
SHRD SHLD	m,r,i	3					2	1		2	
SHRD SHLD	r,r,cl	4	4						2	2	
SHRD SHLD	m,r,cl	5	3				2	1		4	
BT	r,r/i	1	1						1	0.5	
BT	m,r	10	8				x			5	
BT	m,i	2	1				1			0.5	
BTR BTS BTC	r,r/i	1	1						1	0.5	
BTR BTS BTC	m,r	11	7				x	x		5	
BTR BTS BTC	m,i	3	1				2	1		2	
BSF BSR	r,r	1	1						3	1	
BSF BSR	r,m	1	1		1		1			1	
SETcc	r	1	1	x		x			1	0.5	
SETcc	m	2	1	x		x	1	1		1	
CLC		1	0							0.25	
STC CMC		1	1	x	x	x			1		
CLD STD		3	3							4	
<b>Control transfer instructions</b>											
JMP	short/near	1	1			1			0	2	
JMP	r	1	1			1			0	2	
JMP	m	1	1			1	1		0	2	
Conditional jump	short/near	1	1			1			0	1-2	fast if not jumping
Fused arithmetic and branch		1	1			1			0	1-2	
J(E/R)CXZ	short	2	2	x	x	1				2-4	
LOOP	short	7	7							5	
LOOP(N)E	short	11	11							5	
CALL	near	3	2			1	1	1		2	
CALL	r	2	1			1	1	1		2	
CALL	m	3	2			1	2	1		2	
RET		2	2			1	1			2	
RET	i	3	2			1	1			2	
BOUND	r,m	15	13							7	not 64 bit
INTO		4	4							6	not 64 bit
<b>String instructions</b>											
LODS		3	2				1			1	

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REP LODS		5n+12						~2n		
STOS		3	1				1	1	1	
REP STOS		2n						n		worst case
REP STOS		1.5/16B						1/16B		best case
MOVS		5							4	
REP MOVVS		2n						1.5 n		worst case
REP MOVVS		3/16B						1/16B		best case
SCAS		3							1	
REP SCAS		6n+47						2n+45		
CMPS		5							4	
REP CMPS		8n+80						2n+80		
<b>Other</b>										
NOP (90)		1	0						0.25	
Long NOP (0F 1F)		1	0						0.25	decode only 1 per clk
PAUSE		7	7						11	
ENTER	a,0	12	10				2	1	8	
ENTER	a,b	49+6b							84+3b	
LEAVE		3	3				1		7	
CPUID		31-75							100-250	
RDTSC		21							28	
RDTSCP		23							36	
RDPMC		35							42	

Floating point x87 instructions

Instruction	Operands	μops fused domain	μops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											
FLD	r	1	1	1					1	1	
FLD	m32/64	1	1				1		3	1	
FLD	m80	4	2	1	1		2		4	2	
FBLD	m80	43	40				3		45	21	
FST(P)	r	1	1	1					1	1	
FST(P)	m32/m64	1					1	1	4	1	
FSTP	m80	7	3				2	2	5	5	
FBSTP	m80	246								252	
FXCH	r	1	0						0	0.5	
FILD	m	1	1		1		1		6	1	
FIST(P)	m	3	1		1		1	1	7	2	
FISTTP	m	3	1		1		1	1	7	2	SSE3
FLDZ		1	1	1						2	
FLD1		2	2	1	1					2	
FLDPI FLDL2E etc.		2	2		2					2	
FCMOVcc	r	3	3						3	2	

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FNSTSW	AX	2	2					2	1
FNSTSW	m16	2	1			1	1		1
FLDCW	m16	3	2			1		8	
FNSTCW	m16	2	1	1		1	1	5	1
FINCSTP FDECSTP		1	1	1				1	1
FFREE(P)	r	1	1						1
FNSAVE	m	143							166
FRSTOR	m	90							165
<b>Arithmetic instructions</b>									
FADD(P) FSUB(R)(P)	r	1	1		1			3	1
FADD(P) FSUB(R)(P)	m	2	2		1		1		1
FMUL(P)	r	1	1	1				5	1
FMUL(P)	m	1	1	1			1		1
FDIV(R)(P)	r	1	1	1				10-24	10-24
FDIV(R)(P)	m	1	1	1			1		10-24
FABS		1	1	1				1	1
FCHS		1	1	1				1	1
FCOM(P) FUCOM	r	1	1		1			3	1
FCOM(P) FUCOM	m	1	1		1		1		1
FCOMPP FUCOMPP		2	2	1	1				1
FCOMI(P) FUCOMI(P)	r	3	3	1	1	1		4	1
FIADD FISUB(R)	m	2	2				1		1
FIMUL	m	2	2	1	1		1		1
FIDIV(R)	m	2	2	1	1		1		
FICOM(P)	m	2	2		2		1		2
FTST		1	1		1				1
FXAM		2	2		1				2
FPREM		28	28					21	21
FPREM1		41-87						26-50	26-50
FRNDINT		17	17					22	
<b>Math</b>									
FSCALE		27	27					12	
FEXTRACT		17	17					10	
FSQRT		1	1	1				10-24	
FSIN		64-100	x					47-100	
FCOS		20-110	x					47-115	
FSINCOS		20-110	x					43-123	
F2XM1		53-118	x					61-69	
FYL2X									
FYL2XP1									
FPTAN		102	102					130	
FPATAN		28-91	x					93-146	
<b>Other</b>									
FNOP		1	1	1					1
WAIT		2	2						1
FNCLEX		5	5						22
FNINIT		26	26						81

Integer MMX and XMM instructions



## Sandy Bridge

Instruction	Operands	μops fused domain	μops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											
MOVD	r32/64,(x)mm	1	1	x	x	x			1		
MOVD	m32/64,(x)mm	1					1	1	3	1	
MOVD	(x)mm,r32/64	1	1	x	x	x			1		
MOVD	(x)mm,m32/64	1					1		3	0.5	
MOVQ	(x)mm,(x)mm	1	1	x	x	x			1		
MOVQ	(x)mm,m64	1					1		3	0.5	
MOVQ	m64, (x)mm	1					1	1	3	1	
MOVDQA	x,x	1	1	x	x	x			1		
MOVDQA	x, m128	1					1		3	0.5	
MOVDQA	m128, x	1					1	1	3	1	
MOVDQU	x, m128	1	1				1		3	0.5	
MOVDQU	m128, x	1	1				1	1	3	1	
LDDQU	x, m128	1	1				1		3	0.5	SSE3
MOVDQ2Q	mm, x	2	2						1	1	
MOVQ2DQ	x,mm	1	1						1		
MOVNTQ	m64,mm	1					1	1	~300	1	
MOVNTDQ	m128,x	1					1	1	~300		
MOVNTDQA	x, m128	1					1			0.5	SSE4.1
PACKSSWB/DW											
PACKUSWB	mm,mm	1	1	1					1	1	
PACKSSWB/DW											
PACKUSWB	mm,m64	1	1	1			1				
PACKSSWB/DW											
PACKUSWB	x,x	1	1		x	x			1	0.5	
PACKSSWB/DW											
PACKUSWB	x,m128	1	1		x	x	1			0.5	
PACKUSDW	x,x	1	1		x	x			1	0.5	SSE4.1
PACKUSDW	x,m	1	1		x	x	1			0.5	SSE4.1
PUNPCKH/LBW/WD/DQ	(x)mm,(x)mm	1	1		x	x			1	0.5	
PUNPCKH/LBW/WD/DQ	(x)mm,m	1	1		x	x	1			0.5	
PUNPCKH/LQDQ	x,x	1	1		x	x			1	0.5	
PUNPCKH/LQDQ	x, m128	2	1		x	x	1			0.5	
PMOVSX/ZXBW	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXBW	x,m64	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXBD	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXBD	x,m32	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXBQ	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXBQ	x,m16	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXWD	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXWD	x,m64	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXWQ	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXWQ	x,m32	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXDQ	x,x	1	1		x	x			1	0.5	SSE4.1
PMOVSX/ZXDQ	x,m64	1	1		x	x	1			0.5	SSE4.1
PSHUFB	(x)mm,(x)mm	1	1		x	x			1	0.5	SSSE3
PSHUFB	(x)mm,m	2	1		x	x	1			0.5	SSSE3
PSHUFW	mm,mm,i	1	1		x	x			1	0.5	
PSHUFW	mm,m64,i	2	1		x	x	1			0.5	

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PSHUFD	x,x,i	1	1		x	x			1	0.5	
PSHUFD	x,m128,i	2	1		x	x	1			0.5	
PSHUFL/HW	x,x,i	1	1		x	x			1	0.5	
PSHUFL/HW	x, m128,i	2	1		x	x	1			0.5	
PALIGNR	(x)mm,(x)mm,i	1	1		x	x			1	0.5	SSSE3
PALIGNR	(x)mm,m,i	2	1		x	x	1			0.5	SSSE3
PBLENDVB	x,x,xmm0	2	2		1	1			2	1	SSE4.1
PBLENDVB	x,m,xmm0	3	2		1	1	1			1	SSE4.1
PBLENDW	x,x,i	1	1		x	x			1	0.5	SSE4.1
PBLENDW	x,m,i	2	1		x	x	1			0.5	SSE4.1
MASKMOVQ	mm,mm	4	1	1			2	1		1	
MASKMOVDQU	x,x	10	4				4	x		6	
PMOVMSKB	r32,(x)mm	1	1	1					2	1	
PEXTRB	r32,x,i	2	2	1	x	x			2	1	SSE4.1
PEXTRB	m8,x,i	2	1		x	x	1	1		1	SSE4.1
PEXTRW	r32,(x)mm,i	2	2	1	x	x			2	1	
PEXTRW	m16,(x)mm,i	2	1		x	x	1	1		2	SSE4.1
PEXTRD	r32,x,i	2	2	1	x	x			2	1	SSE4.1
PEXTRD	m32,x,i	3	2	1	x	x	1	1		1	SSE4.1
PEXTRQ	r64,x,i	2	2	1	x	x			2	1	SSE4.1,
PEXTRQ	m64,x,i	3	2	1	x	x	1	1		1	64b
PINSRB	x,r32,i	2	2		x	x			2	1	SSE4.1
PINSRB	x,m8,i	2	1		x	x	1			0.5	SSE4.1
PINSRW	(x)mm,r32,i	2	2		x	x			2	1	
PINSRW	(x)mm,m16,i	2	1		x	x	1			0.5	
PINSRD	x,r32,i	2	2		x	x			2	1	SSE4.1
PINSRD	x,m32,i	2	1		x	x	1			0.5	SSE4.1
PINSRQ	x,r64,i	2	2		x	x			2	1	SSE4.1,
PINSRQ	x,m64,i	2	1		x	x	1			0.5	64 b
<b>Arithmetic instructions</b>											
PADD/SUB(U,S)B/W/D/Q	(x)mm, (x)mm	1	1		x	x			1	0.5	
PADD/SUB(U,S)B/W/D/Q	(x)mm,m	1	1		x	x	1			0.5	
PHADD/SUB(S)W/D	(x)mm, (x)mm	3	3		x	x			2	1.5	SSSE3
PHADD/SUB(S)W/D	(x)mm,m64	4	3		x	x	1			1.5	SSSE3
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	1		x	x			1	0.5	
PCMPEQ/GTB/W/D	(x)mm,m	1	1		x	x	1			0.5	
PCMPEQQ	x,x	1	1		x	x			1	0.5	SSE4.1
PCMPEQQ	x,m128	1	1		x	x	1			0.5	SSE4.1
PCMPGTQ	x,x	1	1	1					5	1	SSE4.2
PCMPGTQ	x,m128	1	1	1			1			1	SSE4.2
PSUBxx, PCMPGTx	x,same	1	0						0	0.25	
PCMPEQx	x,same	1	1						0	0.5	
PMULL/HW PMULHUW	(x)mm,(x)mm	1	1	1					5	1	
PMULL/HW PMULHUW	(x)mm,m	1	1	1			1			1	
PMULHSW	(x)mm,(x)mm	1	1	1					5	1	SSSE3
PMULHSW	(x)mm,m	1	1	1			1			1	SSSE3
PMULLD	x,x	1	1	1					5	1	SSE4.1
PMULLD	x,m128	2	1	1			1			1	SSE4.1
PMULDQ	x,x	1	1	1					5	1	SSE4.1
PMULDQ	x,m128	1	1	1			1			1	SSE4.1
PMULUDQ	(x)mm,(x)mm	1	1	1					5	1	
PMULUDQ	(x)mm,m	1	1	1			1			1	

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PMADDWD	(x)mm,(x)mm	1	1	1				5	1	
PMADDWD	(x)mm,m	1	1	1			1		1	
PMADDUBSW	(x)mm,(x)mm	1	1	1				5	1	SSSE3
PMADDUBSW	(x)mm,m	1	1	1			1		1	SSSE3
PAVGB/W	(x)mm,(x)mm	1	1		x	x		1	0.5	
PAVGB/W	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXSB	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXSB	x,m128	1	1		x	x	1		0.5	SSE4.1
PMIN/MAXUB	(x)mm,(x)mm	1	1		x	x		1	0.5	
PMIN/MAXUB	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXSW	(x)mm,(x)mm	1	1		x	x		1	0.5	
PMIN/MAXSW	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXUW	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXUW	x,m	1	1		x	x	1		0.5	SSE4.1
PMIN/MAXU/SD	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXU/SD	x,m128	1	1		x	x	1		0.5	SSE4.1
PHMINPOSUW	x,x	1	1	1				5	1	SSE4.1
PHMINPOSUW	x,m128	1	1	1			1		1	SSE4.1
PABSB/W/D	(x)mm,(x)mm	1	1		x	x		1	0.5	SSSE3
PABSB/W/D	(x)mm,m	1	1		x	x	1		0.5	SSSE3
PSIGNB/W/D	(x)mm,(x)mm	1	1		x	x		1	0.5	SSSE3
PSIGNB/W/D	(x)mm,m	1	1		x	x	1		0.5	SSSE3
PSADBW	(x)mm,(x)mm	1	1	1				5	1	
PSADBW	(x)mm,m	1	1	1			1		1	
MPSADBW	x,x,i	3	3	1	1	1		6	1	SSE4.1
MPSADBW	x,m,i	4	3	1	1	1	1		1	SSE4.1
<b>Logic instructions</b>										
PAND(N) POR PXOR	(x)mm,(x)mm	1	1	x	x	x		1		
PAND(N) POR PXOR	(x)mm,m	1	1	x	x	x	1		0.5	
PXOR	x,same	1	0					0	0.25	
PTEST	x,x	1	2	1	x	x		1	1	SSE4.1
PTEST	x,m128	1	2	1	x	x	1		1	SSE4.1
PSLL/RL/RAW/D/Q	mm,mm/i	1	1	1				1	1	
PSLL/RL/RAW/D/Q	mm,m64	1	1	1			1		2	
PSLL/RL/RAW/D/Q	x,i	1	1	1				1	1	
PSLL/RL/RAW/D/Q	x,x	2	2	1	x	x		2	1	
PSLL/RL/RAW/D/Q	x,m128	3	2	1	x	x	1		1	
PSLL/RLDQ	x,i	1	1		x	x		1	1	
<b>String instructions</b>										
PCMPSTR	x,x,i	8	8					4	4	SSE4.2
PCMPSTR	x,m128,i	8	7				1		4	SSE4.2
PCMPSTRM	x,x,i	8	8					11-12	4	SSE4.2
PCMPSTRM	x,m128,i	8	7				1		4	SSE4.2
PCMPISTR	x,x,i	3	3					3	3	SSE4.2
PCMPISTR	x,m128,i	4	3				1		3	SSE4.2
PCMPISTRM	x,x,i	3	3					11	3	SSE4.2
PCMPISTRM	x,m128,i	4	3				1		3	SSE4.2
<b>Encryption instructions</b>										
PCLMULQDQ	x,x,i	18	18					14	8	CLMUL

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AESDEC, AESDECLAST, AESENC, AESENCLAST	x,x	2	2							8	4	AES
AESIMC	x,x	2	2								2	AES
AESKEYGENASSIST	x,x,i	11	11							8	8	AES
<b>Other</b>												
EMMS		31	31								18	

**Floating point XMM and YMM instructions**

Instruction	Operands	μops fused do- main	μops unfused domain						Latency	Reci- procal through- put	Com- ments	
			p015	p0	p1	p5	p23	p4				
<b>Move instructions</b>												
MOVAPS/D	x,x	1	1			1			1	1		
VMOVAPS/D	y,y	1	1			1			1	1		AVX
MOVAPS/D MOVUPS/D	x,m128	1						1	3	0.5		
VMOVAPS/D												
VMOVUPS/D	y,m256	1						1+	4	1		AVX
MOVAPS/D MOVUPS/D	m128,x	1						1	1	3	1	
VMOVAPS/D												
VMOVUPS/D	m256,y	1						1	1+	3	1	AVX
MOVSS/D	x,x	1	1			1			1	1		
MOVSS/D	x,m32/64	1							1	3	0.5	
MOVSS/D	m32/64,x	1							1	1	3	1
MOVHPS/D MOVLPS/D	x,m64	1	1			1		1	1	3	1	
MOVH/LPS/D	m64,x	1							1	1	3	1
MOVLHPS MOVHLPS	x,x	1	1			1				1	1	
MOVMSKPS/D	r32,x	1	1	1						2	1	
VMOVMSKPS/D	r32,y	1	1	1						2	1	
MOVNTPS/D	m128,x	1						1	1	~300	1	
VMOVNTPS/D	m256,y	1						1	4	~300	25	AVX
SHUFPS/D	x,x,i	1	1			1				1	1	
SHUFPS/D	x,m128,i	2	1			1		1			1	
VSHUFPS/D	y,y,y,i	1	1			1				1	1	AVX
VSHUFPS/D	y, y,m256,i	2	1			1		1+			1	AVX
VPERMILPS/PD	x,x,x/i	1	1			1				1	1	AVX
VPERMILPS/PD	y,y,y/i	1	1			1				1	1	AVX
VPERMILPS/PD	x,x,m	2	1			1		1			1	AVX
VPERMILPS/PD	y,y,m	2				1		1+			1	AVX
VPERMILPS/PD	x,m,i	2	1			1		1			1	AVX
VPERMILPS/PD	y,m,i	2	1			1		1+			1	AVX
VPERM2F128	y,y,y,i	1	1			1				2	1	AVX
VPERM2F128	y,y,m,i	2	1			1		1+			1	AVX
BLENDPS/PD	x,x,i	1	1	x		x				1	0.5	SSE4.1
BLENDPS/PD	x,m128,i	2	1	x		x		1			0.5	SSE4.1
VBLENDPS/PD	y,y,i	1	1	x		x				1	1	AVX
VBLENDPS/PD	y,m256,i	2	1	x		x		1+			1	AVX
BLENDVPS/PD	x,x,xmm0	2	2	x		x				2	1	SSE4.1
BLENDVPS/PD	x,m,xmm0	3	2	x		x		1			1	SSE4.1
VBLENDVPS/PD	y,y,y,y	2	2	x		x				2	1	AVX

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VBLENDVPS/PD	y,y,m,y	3	2	x	x	1+		1	AVX
MOVDDUP	x,x	1	1		1		1	1	SSE3
MOVDDUP	x,m64	1				1	3	0.5	SSE3
VMOVDDUP	y,y	1	1		1		1	1	AVX
VMOVDDUP	y,m256	1				1+	3	1	AVX
VBROADCASTSS	x,m32	1				1		1	AVX
VBROADCASTSS	y,m32	2	1		1	1		1	AVX
VBROADCASTSD	y,m64	2	1		1	1		1	AVX
VBROADCASTF128	y,m128	2	1		1	1		1	AVX
MOVSH/LDUP	x,x	1	1		1		1	1	SSE3
MOVSH/LDUP	x,m128	1				1	3	0.5	SSE3
VMOVSH/LDUP	y,y	1	1		1		1	1	AVX
VMOVSH/LDUP	y,m256	1				1+	4	1	AVX
UNPCKH/LPS/D	x,x	1	1		1		1	1	SSE3
UNPCKH/LPS/D	x,m128	1	1		1	1		1	SSE3
VUNPCKH/LPS/D	y,y,y	1	1		1		1	1	AVX
VUNPCKH/LPS/D	y,y,m256	1	1		1	1+		1	AVX
EXTRACTPS	r32,x,i	2	2	1	1		2	1	SSE4.1
EXTRACTPS	m32,x,i	3	2		1	1	1	1	SSE4.1
VEXTRACTF128	x,y,i	1	1		1		2	1	AVX
VEXTRACTF128	m128,y,i	2	1			1	1	1	AVX
INSERTPS	x,x,i	1	1		1		1	1	SSE4.1
INSERTPS	x,m32,i	2	1		1	1		1	SSE4.1
VINSERTF128	y,y,x,i	1	1		1		2	1	AVX
VINSERTF128	y,y,m128,i	2	1		1	1		1	AVX
VMASKMOVPS/D	x,x,m128	3	2			1		1	AVX
VMASKMOVPS/D	y,y,m256	3	2			1+		1	AVX
VMASKMOVPS/D	m128,x,x	4	2			1	1	1	AVX
VMASKMOVPS/D	m256,y,y	4	2			1	1+	2	AVX
<b>Conversion</b>									
CVTPD2PS	x,x	2	2		1	1	4	1	
CVTPD2PS	x,m128	2	2		1	1	1	1	
VCVTPD2PS	x,y	2	2		1	1	4	1	AVX
VCVTPD2PS	x,m256	2	2		1	1	1+	1	AVX
CVTSD2SS	x,x	2	2		1	1	3	1	
CVTSD2SS	x,m64	2	2		1	1	1	1	
CVTPS2PD	x,x	2	2	1		1	3	1	
CVTPS2PD	x,m64	2	1	1		1		1	
VCVTPS2PD	y,x	2	2	1		1	4	1	AVX
VCVTPS2PD	y,m128	3	2	1		1	1	1	AVX
CVTSS2SD	x,x	2	2	1		1	3	1	
CVTSS2SD	x,m32	2	1	1		1		1	
CVTDQ2PS	x,x	1	1		1		3	1	
CVTDQ2PS	x,m128	1	1		1	1		1	
VCVTDQ2PS	y,y	1	1		1		3	1	AVX
VCVTDQ2PS	y,m256	1	1		1	1+		1	AVX
CVT(T) PS2DQ	x,x	1	1		1		3	1	
CVT(T) PS2DQ	x,m128	1	1		1	1		1	
VCVT(T) PS2DQ	y,y	1	1		1		3	1	AVX
VCVT(T) PS2DQ	y,m256	1	1		1	1+		1	AVX
CVTDQ2PD	x,x	2	2		1	1	4	1	
CVTDQ2PD	x,m64	2	2		1	1		1	

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VCVTDQ2PD	y,x	2	2		1	1		5	1	AVX
VCVTDQ2PD	y,m128	3	2		1	1	1		1	AVX
CVT(T)PD2DQ	x,x	2	2		1	1		4	1	
CVT(T)PD2DQ	x,m128	2	2		1	1	1		1	
VCVT(T)PD2DQ	x,y	2	2		1	1		5	1	AVX
VCVT(T)PD2DQ	x,m256	2	2		1	1	1+		1	AVX
CVTPI2PS	x,mm	1	1		1			4	2	
CVTPI2PS	x,m64	1	1		1		1		2	
CVT(T)PS2PI	mm,x	2	2		1	1		4	1	
CVT(T)PS2PI	mm,m128	2	1		1		1		1	
CVTPI2PD	x,mm	2	2		1	1		4	1	
CVTPI2PD	x,m64	2	2		1	1	1		1	
CVT(T) PD2PI	mm,x	2	2					4	1	
CVT(T) PD2PI	mm,m128	2	2				1		1	
CVTSI2SS	x,r32	2	2		1	1		4	1,5	
CVTSI2SS	x,m32	1	1		1		1		1,5	
CVT(T)SS2SI	r32,x	2	2	1	1			4	1	
CVT(T)SS2SI	r32,m32	2	2		1		1		1	
CVTSI2SD	x,r32	2	2	1	1			4	1,5	
CVTSI2SD	x,m32	1	1		1		1		1,5	
CVT(T)SD2SI	r32,x	2	2	1	1			4	1	
CVT(T)SD2SI	r32,m64	2	2	1	1		1		1	
<b>Arithmetic</b>										
ADDSS/D SUBSS/D	x,x	1	1		1			3	1	
ADDSS/D SUBSS/D	x,m32/64	1	1		1		1		1	
ADDPSS/D SUBPSS/D	x,x	1	1		1			3	1	
ADDPSS/D SUBPSS/D	x,m128	1	1		1		1		1	
VADDPSS/D VSUBPSS/D	y,y,y	1	1		1			3	1	AVX
VADDPSS/D VSUBPSS/D	y,y,m256	1	1		1		1+		1	AVX
ADDSUBPSS/D	x,x	1	1		1			3	1	SSE3
ADDSUBPSS/D	x,m128	1	1		1		1		1	SSE3
VADDSUBPSS/D	y,y,y	1	1		1			3	1	AVX
VADDSUBPSS/D	y,y,m256	1	1		1		1+		1	AVX
HADDPSS/D HSUBPSS/D	x,x	3	3		1	2		5	2	SSE3
HADDPSS/D HSUBPSS/D	x,m128	4	3		1	2	1		2	SSE3
VHADDPSS/D										
VHSUBPSS/D	y,y,y	3	3		1	2		5	2	AVX
VHADDPSS/D										
VHSUBPSS/D	y,y,m256	4	3		1	2	1+		2	AVX
MULSS MULPS	x,x	1	1	1				5	1	
MULSS MULPS	x,m	1	1	1			1		1	
VMULPS	y,y,y	1	1	1				5	1	AVX
VMULPS	y,y,m256	1	1	1			1+		1	AVX
MULSD MULPD	x,x	1	1	1				5	1	
MULSD MULPD	x,m	1	1	1			1		1	
VMULPD	y,y,y	1	1	1				5	1	AVX
VMULPD	y,y,m256	1	1	1			1+		1	AVX
DIVSS DIVPS	x,x	1	1	1				10-14	10-14	
DIVSS DIVPS	x,m	1	1	1			1		10-14	
VDIVPS	y,y,y	3	3	2		1		21-29	20-28	AVX
VDIVPS	y,y,m256	4	3	2		1	1+		20-28	AVX
DIVSD DIVPD	x,x	1	1	1				10-22	10-22	

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DIVSD DIVPD	x,m	1	1	1		1		10-22	
VDIVPD	y,y,y	3	3	2		1	21-45	20-44	AVX
VDIVPD	y,y,m256	4	3	2		1		20-44	AVX
RCPSS/PS	x,x	1	1	1			5	1	
RCPSS/PS	x,m128	1	1	1				1	
VRCPPS	y,y	3	3	2		1	7	2	AVX
VRCPPS	y,m256	4	3					2	AVX
CMPccSS/D CMPccPS/D	x,x	1	1		1		3	1	
CMPccSS/D CMPccPS/D	x,m128	2	1		1	1		1	
VCMPccPS/D	y,y,y	1	1		1		3	1	AVX
VCMPccPS/D	y,y,m256	2	1		1	1+		1	AVX
COMISS/D UCOMISS/D	x,x	2	2	1	1		2	1	
COMISS/D UCOMISS/D	x,m32/64	2	2	1	1	1		1	
MAXSS/D MINSS/D	x,x	1	1		1		3	1	
MAXSS/D MINSS/D	x,m32/64	1	1		1	1		1	
MAXPS/D MINPS/D	x,x	1	1		1		3	1	
MAXPS/D MINPS/D	x,m128	1	1		1	1		1	
VMAXPS/D VMINPS/D	y,y,y	1	1		1		3	1	AVX
VMAXPS/D VMINPS/D	y,y,m256	1	1		1	1+		1	AVX
ROUNDSS/SD/PS/PD	x,x,i	1	1		1		3	1	SSE4.1
ROUNDSS/SD/PS/PD	x,m128,i	2	1		1	1		1	SSE4.1
VROUNDSS/SD/PS/PD	y,y,i	1	1		1		3	1	AVX
VROUNDSS/SD/PS/PD	y,m256,i	2	1		1	1+		1	AVX
DPPS	x,x,i	4	4	1	2	1	12	2	SSE4.1
DPPS	x,m128,i	6	5			1		4	SSE4.1
VDPPS	y,y,y,i	4	4	1	2	1	12	2	AVX
VDPPS	y,m256,i	6	5			1+		4	AVX
DPPD	x,x,i	3	3	1	1	1	9	2	SSE4.1
DPPD	x,m128,i	4	3			1		2	SSE4.1
<b>Math</b>									
SQRTSS/PS	x,x	1	1	1			10-14	10-14	
SQRTSS/PS	x,m128	1	1	1		1		10-14	
VSQRTPS	y,y	3	3					21-28	AVX
VSQRTPS	y,m256	4	3			1+		21-28	AVX
SQRTSD/PD	x,x	1	1	1			10-21	10-21	
SQRTSD/PD	x,m128	2	1	1		1		10-21	
VSQRTPD	y,y	3	3				21-43	21-43	AVX
VSQRTPD	y,m256	4	3			1+		21-43	AVX
RSQRTSS/PS	x,x	1	1	1			5	1	
RSQRTSS/PS	x,m128	1	1	1		1		1	
VRSQRTPS	y,y	3	3				7	2	AVX
VRSQRTPS	y,m256	4	3			1+		2	AVX
<b>Logic</b>									
AND/ANDN/OR/XORPS/PD	x,x	1	1			1	1	1	
AND/ANDN/OR/XORPS/PD	x,m128	1	1			1	1	1	
VAND/ANDN/OR/XORPS/PD	y,y,y	1	1			1	1	1	AVX
VAND/ANDN/OR/XORPS/PD	y,y,m256	1	1			1	1+	1	AVX

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(V)XORPS/PD	x/y,x/y,same	1	0						0	0.25	
<b>Other</b>											
VZEROUPPER		4							2	1	AVX
VZEROALL		12								11	AVX, 32 bit
VZEROALL		20								9	AVX, 64 bit
LDMXCSR	m32	3	3				1			3	
STMXCSR	m32	3	3	1		1	1	1		1	
VSTMXCSR	m32	3	3	1		1	1	1		1	AVX
FXSAVE	m4096	130								68	
FXRSTOR	m4096	116								72	
XSAVEOPT	m	100-161							60-500		



## Intel Ivy Bridge

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.

**$\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename, allocate and retirement stages in the pipeline. Fused  $\mu$ ops count as one.

**$\mu$ ops unfused domain:** The number of  $\mu$ ops for each execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if the sum of the numbers listed under p015 + p23 + p4 exceeds the number listed under  $\mu$ ops fused domain. A number indicated as 1+ under a read or write port means a 256-bit read or write operation using two clock cycles for handling 128 bits each cycle. The port cannot receive another read or write  $\mu$ op in the second clock cycle, but a read port can receive an address-calculation  $\mu$ op in the second clock cycle. An x under p0, p1 or p5 means that at least one of the  $\mu$ ops listed under p015 can optionally go to this port. For example, a 1 under p015 and an x under p0 and p5 means one  $\mu$ op which can go to either port 0 or port 5, whichever is vacant first. A value listed under p015 but nothing under p0, p1 and p5 means that it is not known which of the three ports these  $\mu$ ops go to.

**p015:** The total number of  $\mu$ ops going to port 0, 1 and 5.

**p0:** The number of  $\mu$ ops going to port 0 (execution units).

**p1:** The number of  $\mu$ ops going to port 1 (execution units).

**p5:** The number of  $\mu$ ops going to port 5 (execution units).

**p23:** The number of  $\mu$ ops going to port 2 or 3 (memory read or address calculation).

**p4:** The number of  $\mu$ ops going to port 4 (memory write data).

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Where hyperthreading is enabled, the use of the same execution units in the other thread leads to inferior performance. Denormal numbers, NAN's and infinity do not increase the latency. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

The latencies and throughputs listed below for addition and multiplication using full size YMM registers are obtained only after a warm-up period of a thousand instructions or more. The latencies may be one or two clock cycles longer and the reciprocal throughputs double the values for shorter sequences of code. There is no warm-up effect when vectors are 128 bits wide or less.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			

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Move instructions												
MOV	r,i	1	1	x	x	x				1	0.33	
MOV	r8/16,r8/16	1	1	x	x	x				1	0.33	
MOV	r32/64,r32/64	1	1	x	x	x				0-1	0.25	may be elimin.
MOV	r8/16,m8/16	1	1	x	x	x	1			2	0.5	
MOV	r32/64,m32/64	1					1			2	0.5	
MOV	r,m	1					1			2	1	64 b abs address
MOV	m,r	1					1	1		3	1	
MOV	m,i	1					1	1			1	
MOVNTI	m,r	2					1	1		~340	1	
MOVSX MOVSD	r,r	1	1	x	x	x				1	0.33	
MOVZX	r16,r8	1	1	x	x	x				1	0.33	
MOVZX	r32/64,r8	1	1	x	x	x				0-1	0.25	may be elimin.
MOVZX	r32/64,r16	1	1	x	x	x				1	0.33	
MOVSX MOVZX	r16,m8	2	1	x	x	x	1			3	0.5	
MOVSX MOVZX	r32/64,m	1					1			2	0.5	
MOVSD												
CMOVcc	r,r	2	2	x	x	x				2	0.67	
CMOVcc	r,m	2	2	x	x	x	1				~0.8	
XCHG	r,r	3	3	x	x	x				2	1	
XCHG	r,m	7	x				2	3		25		implicit lock
XLAT		3	2				1			7	1	
PUSH	r	1					1	1		3	1	
PUSH	i	1					1	1			1	
PUSH	m	2					2	1			1	
PUSH	(E/R)SP	2	1	x	x	x	1	1		3	1	
PUSHF(D/Q)		3	2	x	x	x	1	1			1	
PUSHA(D)		19	3	x	x	x	8	8			8	not 64 bit
POP	r	1					1			2	0.5	
POP	(E/R)SP	3	2	x	x	x	1				0.5	
POP	m	2					2	1			1	
POPF(D/Q)		9	8	x	x	x	1				18	
POPA(D)		18	10	x	x	x	8				9	not 64 bit
LAHF SAHF		1	1	x		x				1	1	
SALC		3	3	x	x	x				1	1	not 64 bit
LEA	r16,m	2	2	x	1	x				2-4	1	
LEA	r32/64,m	1	1	x	x					1	0.5	1-2 components
LEA	r32/64,m	1	1		1					3	1	3 components or RIP
BSWAP	r32	1	1		1					1	1	
BSWAP	r64	2	2	x	1	x				2	1	
PREFETCHNTA	m	1					1				43	
PREFETCHT0/1/2	m	1					1				43	
LFENCE		2									4	
MFENCE		3					1	1			36	
SFENCE		2					1	1			6	

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Arithmetic instructions											
ADD SUB	r,r/i	1	1	x	x	x			1	0.33	
ADD SUB	r,m	1	1	x	x	x	1			0.5	
ADD SUB	m,r/i	2	1	x	x	x	2	1	6	1	
ADC SBB	r,r/i	2	2	x	x	x			2	1	
ADC SBB	r,m	2	2	x	x	x	1		2	1	
ADC SBB	m,r/i	4	3	x	x	x	2	1	7-8	2	
CMP	r,r/i	1	1	x	x	x			1	0.33	
CMP	m,r/i	1	1	x	x	x	1		1	0.5	
INC DEC NEG NOT	r	1	1	x	x	x			1	0.33	
INC DEC NEG NOT	m	3	1	x	x	x	2	1	6	1	
AAA AAS		2	2	x	1	x			4		not 64 bit
DAA DAS		3	3						4		not 64 bit
AAD		3	3						2		not 64 bit
AAM		8	8						20	8	not 64 bit
MUL IMUL	r8	1	1		1				3	1	
MUL IMUL	r16	4	4						4	2	
MUL IMUL	r32	3	3						4	2	
MUL IMUL	r64	2	2						3	1	
IMUL	r,r	1	1		1				3	1	
IMUL	r16,r16,i	2	2						4	1	
IMUL	r32,r32,i	1	1		1				3	1	
IMUL	r64,r64,i	1	1		1				3	1	
MUL IMUL	m8	1	1		1		1		3	1	
MUL IMUL	m16	4	3				1			2	
MUL IMUL	m32	3	2				1			2	
MUL IMUL	m64	2	1				1			2	
IMUL	r,m	1	1		1		1			1	
IMUL	r16,m16,i	2	2				1			1	
IMUL	r32,m32,i	1	1		1		1			1	
IMUL	r64,m64,i	1	1		1		1			1	
DIV	r8	11	11						19-22	9	
DIV	r16	11	11						20-24	10	
DIV	r32	10	10						19-27	11	
DIV	r64	35-57	x						29-94	22-76	
IDIV	r8	11	11						20-23	8	
IDIV	r16	11	11						20-24	8	
IDIV	r32	9	9						19-26	8-11	
IDIV	r64	59-134	x						28-103	26-88	
CBW		1	1	x	x	x			1	0.33	
CWDE		1	1	x	x	x			1		
CDQE		1	1	x	x	x			1		
CWD		2	2	x	x	x			1		
CDQ		1	1	x		x			1		
CQO		1	1	x		x			1	0.5	
POPCNT	r,r	1	1		1				3	1	SSE4.2
POPCNT	r,m	1	1		1		1			1	SSE4.2
CRC32	r,r	1	1		1				3	1	SSE4.2
CRC32	r,m	1	1		1		1				SSE4.2
Logic instructions											

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AND OR XOR	r,r/i	1	1	x	x	x			1	0.33	
AND OR XOR	r,m	1	1	x	x	x	1			0.5	
AND OR XOR	m,r/i	2	1	x	x	x	2	1	6	1	
TEST	r,r/i	1	1	x	x	x			1	0.33	
TEST	m,r/i	1	1	x	x	x	1			0.5	
SHR SHL SAR	r,i	1	1	x		x			1	0.5	
SHR SHL SAR	m,i	3	1				2	1		2	
SHR SHL SAR	r,cl	2	2	1		1			1	1	
SHR SHL SAR	m,cl	5	3				2	1		4	
ROR ROL	r,1	2	2	x		x			1	1	short form
ROR ROL	r,i	1	1	x		x			1	0.5	
ROR ROL	m,i	4	3				2	1		2	
ROR ROL	r,cl	2	2	x		x			1	1	
ROR ROL	m,cl	5	3				2	1		4	
RCL RCR	r,1	3	3	x	x	x			2	2	
RCL RCR	r,i	8	8	x	x	x			5	5	
RCL RCR	m,i	11	8	x	x	x	2	1		6	
RCL RCR	r,cl	8	8	x	x	x			5	5	
RCL RCR	m,cl	11	8	x	x	x	2	1		6	
SHRD SHLD	r,r,i	1	1	x		x			1	0.5	
SHRD SHLD	m,r,i	3	3	x	x	x	2	1		2	
SHRD SHLD	r,r,cl	4	4	x	1	x			2	2	
SHRD SHLD	m,r,cl	5	4	x	1	x	2	1		4	
BT	r,r/i	1	1	x		x			1	0.5	
BT	m,r	10	9	x	x	x	1			5	
BT	m,i	2	1	x		x	1			0.5	
BTR BTS BTC	r,r/i	1	1	x		x			1	0.5	
BTR BTS BTC	m,r	11	8	x	x	x	2	1		5	
BTR BTS BTC	m,i	3	2	x		x	1	1		2	
BSF BSR	r,r	1	1		1				3	1	
BSF BSR	r,m	1	1		1		1			1	
SETcc	r	1	1	x		x			1	0.5	
SETcc	m	2	1	x		x	1	1		1	
CLC		1	0							0.25	
STC CMC		1	1	x	x	x			1	0.33	
CLD STD		3	3	x	x	x				4	
<b>Control transfer instructions</b>											
JMP	short/near	1	1			1			0	2	
JMP	r	1	1			1			0	2	
JMP	m	1	1			1	1		0	2	
Conditional jump	short/near	1	1			1			0	1-2	fast if no jump
Fused arithmetic and branch		1	1			1			0	1-2	fast if no jump
J(E/R)CXZ	short	2	2	x	x	1				1-2	
LOOP	short	7	7							4-5	
LOOP(N)E	short	11	11							6	
CALL	near	2	1			1	1	1		2	
CALL	r	2	1			1	1	1		2	
CALL	m	3	1			1	2	1		2	
RET		2	1			1	1			2	
RET	i	3	2	x	x	1	1			2	

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BOUND	r,m	15	13				2			7	not 64 bit
INTO		4	4	x	x	x				6	not 64 bit
<b>String instructions</b>											
LODS		3	2	x	x	x	1			1	
REP LODS		~5n							~2n		
STOS		3	1	x	x	x	1	1		1	
REP STOS		many							n		worst case
REP STOS		many							1/16B		best case
MOVS		5	2	x	x	x	2	1		4	
REP MOVS		2n							n		worst case
REP MOVS		4/16B							1/16B		best case
SCAS		3	2	x	x	x	1			1	
REP SCAS		~6n							~2n		
CMPS		5	3	x	x	x	2			4	
REP CMPS		~8n							~2n		
<b>Synchronization instructions</b>											
XADD	m,r	4	3	x	x	x	1	1	7		
LOCK XADD	m,r	8	5	x	x	x	2	1	22		
LOCK ADD	m,r	7	5	x	x	x	1	1	22		
CMPXCHG	m,r	5	3	x	x	x	2	1	7		
LOCK CMPXCHG	m,r	9	6	x	x	x	2	1	22		
CMPXCHG8B	m,r	14	11	x	x	x	2	1	7		
LOCK CMPXCHG8B	m,r	18	15	x	x	x	2	1	22		
CMPXCHG16B	m,r	22	19	x	x	x	2	1	16		
LOCK CMPXCHG16B	m,r	24	21	x	x	x	2	1	27		
<b>Other</b>											
NOP / Long NOP		1	0							0.25	
PAUSE		7	7							10	
ENTER	a,0	12	9	x	x	x	2	1		8	
ENTER	a,b	45+7b							84+3b		
LEAVE		3	2	x	x	x	1			6	
XGETBV		8								9	XGETBV
CPUID		37-82							100-340		
RDTSC		21								27	
RDPMSR		35								39	
RDRAND	r	13	12	x	x	x	1			104-117	RDRAND

**Floating point x87 instructions**

Instruction	Operands	μops fused domain	μops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											

Ivy Bridge

FLD	r	1	1			1			1	1	
FLD	m32/64	1					1		3	1	
FLD	m80	4	2		1	1	2		5	2	
FBLD	m80	43	40				3		45	21	
FST(P)	r	1	1			1			1	1	
FST(P)	m32/m64	1					1	1	4	1	
FSTP	m80	7	3				2	2	5	5	
FBSTP	m80	243								252	
FXCH	r	1	0						0	0.5	
FILD	m	1	1		1		1		6	1	
FIST(P)	m	3	1		1		1	1	7	1	
FISTTP	m	3	1		1		1	1	7	2	SSE3
FLDZ		1	1			1					
FLD1		2	2		1	1					
FLDPI FLDL2E etc.		2	2	1	1					2	
FCMOVcc	r	3	3	1		2			2	2	
FNSTSW	AX	2	2	1	x	x			4	1	
FNSTSW	m16	2	1				1	1		1	
FLDCW	m16	3	2			2	1			3	
FNSTCW	m16	2	1			1	1	1		1	
FINCSTP FDECSTP		1	1			1			1	1	
FFREE(P)	r	1	1			1				1	
FNSAVE	m	143								167	
FRSTOR	m	90								162	
<b>Arithmetic instructions</b>											
FADD(P) FSUB(R)(P)	r	1	1		1				3	1	
FADD(P) FSUB(R)(P)	m	2	1		1		1			1	
FMUL(P)	r	1	1	1					5	1	
FMUL(P)	m	2	1	1			1			1	
FDIV(R)(P)	r	1	1	1					10-24	8-18	
FDIV(R)(P)	m	2	1	1			1			8-18	
FABS		1	1			1			1	1	
FCHS		1	1			1			1	1	
FCOM(P) FUCOM	r	1	1		1				3	1	
FCOM(P) FUCOM	m	1	1		1		1			1	
FCOMPP FUCOMPP		2	2		1	1			4	1	
FCOMI(P) FUCOMI(P)	r	3	3	1	1	1			5	1	
FIADD FISUB(R)	m	2	2		2		1			2	
FIMUL	m	2	2	1	1		1			2	
FIDIV(R)	m	2	2	1	1		1				
FICOM(P)	m	2	2		2		1			2	
FTST		1	1		1					1	
FXAM		2	2		2					2	
FPREM		28	28						21-26	12	
FPREM1		41							27-50	19	
FRNDINT		17	17						22	11	
<b>Math</b>											
FSCALE		25	25	x	x	x			49	49	
FEXTRACT		17	17	x	x	x			10	10	
FSQRT		1	1	1					10-23	8-17	
FSIN		21-78		x	x	x			47-106	47-106	

Ivy Bridge

FCOS	23-100		x	x	x		48-115	48-115
FSINCOS	20-110		x	x	x		50-123	50-123
F2XM1	16-23		x	x	x		~68	~68
FYL2X	42	42	x	x	x		90-106	
FYL2XP1	56	56	x	x	x		82	
FPTAN	102	102	x	x	x		130	
FPATAN	28-72		x	x	x		94-150	
<b>Other</b>								
FNOP	1	1				1		1
WAIT	2	2	x	x	1			1
FNCLEX	5	5	x	x	x			22
FNINIT	26	26	x	x	x			80

Integer MMX and XMM instructions

Instruction	Operands	μops fused domain	μops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											
MOVD	r32/64,(x)mm	1	1	1					1	1	
MOVD	m32/64,(x)mm	1				1	1		3	1	
MOVD	(x)mm,r32/64	1	1			1			1	1	
MOVD	(x)mm,m32/64	1				1			3	0.5	
MOVQ	(x)mm,(x)mm	1	1	x	x	x			1	0.33	
MOVQ	(x)mm,m64	1				1			3	0.5	
MOVQ	m64,(x)mm	1				1	1		3	1	
MOVDQA MOVDQU	x,x	1	1	x	x	x			0-1	0.25	eliminat.
MOVDQA MOVDQU	x, m128	1				1			3	0.5	
MOVDQA MOVDQU	m128, x	1				1	1		3	1	
LDDQU	x, m128	1	1			1			3	0.5	SSE3
MOVDQ2Q	mm, x	2	2	x	x	1			1	1	
MOVQ2DQ	x,mm	1	1						1	0.33	
MOVNTQ	m64,mm	1				1	1		~360	1	
MOVNTDQ	m128,x	1				1	1		~360	1	
MOVNTDQA	x, m128	1				1			3	0.5	SSE4.1
PACKSSWB/DW											
PACKUSWB	mm,mm	1	1	1					1	1	
PACKSSWB/DW											
PACKUSWB	mm,m64	1	1	1		1				1	
PACKSSWB/DW											
PACKUSWB	x,x	1	1		x	x			1	0.5	
PACKSSWB/DW											
PACKUSWB	x,m128	1	1		x	x	1		1	0.5	
PACKUSDW	x,x	1	1		x	x			1	0.5	SSE4.1
PACKUSDW	x,m	1	1		x	x	1			0.5	SSE4.1
PUNPCKH/LBW/WD/DQ	(x)mm,(x)mm	1	1		x	x			1	0.5	
PUNPCKH/LBW/WD/DQ	(x)mm,m	1	1		x	x	1			0.5	
PUNPCKH/LQDQ	x,x	1	1		x	x			1	0.5	
PUNPCKH/LQDQ	x, m128	2	1		x	x	1			0.5	
PMOVSX/ZXBW	x,x	1	1		x	x			1	0.5	SSE4.1

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PMOVSX/ZXBW	x,m64	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXBD	x,x	1	1		x	x		1		0.5	SSE4.1
PMOVSX/ZXBD	x,m32	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXBQ	x,x	1	1		x	x		1		0.5	SSE4.1
PMOVSX/ZXBQ	x,m16	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXWD	x,x	1	1		x	x		1		0.5	SSE4.1
PMOVSX/ZXWD	x,m64	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXWQ	x,x	1	1		x	x		1		0.5	SSE4.1
PMOVSX/ZXWQ	x,m32	1	1		x	x	1			0.5	SSE4.1
PMOVSX/ZXDQ	x,x	1	1		x	x		1		0.5	SSE4.1
PMOVSX/ZXDQ	x,m64	1	1		x	x	1			0.5	SSE4.1
PSHUFB	(x)mm,(x)mm	1	1		x	x		1		0.5	SSSE3
PSHUFB	(x)mm,m	2	1		x	x	1			0.5	SSSE3
PSHUFW	mm,mm,i	1	1		x	x		1		0.5	
PSHUFW	mm,m64,i	2	1		x	x	1			0.5	
PSHUFD	xmm,x,i	1	1		x	x		1		0.5	
PSHUFD	x,m128,i	2	1		x	x	1			0.5	
PSHUFL/HW	x,x,i	1	1		x	x		1		0.5	
PSHUFL/HW	x, m128,i	2	1		x	x	1			0.5	
PALIGNR	(x)mm,(x)mm,i	1	1		x	x		1		0.5	SSSE3
PALIGNR	(x)mm,m,i	2	1		x	x	1			0.5	SSSE3
PBLENDVB	x,x,xmm0	2	2		1	1		2		1	SSE4.1
PBLENDVB	x,m,xmm0	3	2		1	1	1			1	SSE4.1
PBLENDW	x,x,i	1	1		x	x		1		0.5	SSE4.1
PBLENDW	x,m,i	2	1		x	x	1			0.5	SSE4.1
MASKMOVQ	mm,mm	4	1	1			2	1		1	
MASKMOVDQU	x,x	10	4	x	1	x	4	2		6	
PMOVMASKB	r32,(x)mm	1	1	1					2	1	
PEXTRB	r32,x,i	2	2	1	x	x			2	1	SSE4.1
PEXTRB	m8,x,i	2	1		x	x	1	1		1	SSE4.1
PEXTRW	r32,(x)mm,i	2	1	1	x	x			2	1	
PEXTRW	m16,(x)mm,i	2	1		x	x	1	1		1	SSE4.1
PEXTRD	r32,x,i	2	2	1	x	x			2	1	SSE4.1
PEXTRD	m32,x,i	2	1		x	x	1	1		1	SSE4.1
PEXTRQ	r64,x,i	2	2	1	x	x			2	1	SSE4.1
PEXTRQ	m64,x,i	2	1		x	x	1	1		1	
PINSRB	x,r32,i	2	2		x	x			2	1	SSE4.1
PINSRB	x,m8,i	2	1		x	x	1			0.5	SSE4.1
PINSRW	(x)mm,r32,i	2	2		x	x			2	1	
PINSRW	(x)mm,m16,i	2	1		x	x	1			0.5	
PINSRD	x,r32,i	2	1		x	x			2	1	SSE4.1
PINSRD	x,m32,i	2	1		x	x	1			0.5	SSE4.1
PINSRQ	x,r64,i	2	1		x	x			2	1	SSE4.1
PINSRQ	x,m64,i	2	1		x	x	1			0.5	SSE4.1
<b>Arithmetic instructions</b>											
PADD/SUB(U,S)B/W/D/Q	(x)mm, (x)mm	1	1		x	x			1	0.5	
PADD/SUB(U,S)B/W/D/Q	(x)mm,m	1	1		x	x	1			0.5	
PHADD/SUB(S)W/D	(x)mm, (x)mm	3	3		x	x			3	1.5	SSSE3
PHADD/SUB(S)W/D	(x)mm,m64	4	3		x	x	1			1.5	SSSE3
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	1		x	x			1	0.5	
PCMPEQ/GTB/W/D	(x)mm,m	1	1		x	x	1			0.5	
PCMPEQQ	x,x	1	1		x	x			1	0.5	SSE4.1



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PCMPEQQ	x,m128	1	1		x	x	1		0.5	SSE4.1
PCMPGTQ	x,x	1	1	1				5	1	SSE4.2
PCMPGTQ	x,m128	1	1	1			1		1	SSE4.2
PMULL/HW PMULHUW	(x)mm,(x)mm	1	1	1				5	1	
PMULL/HW PMULHUW	(x)mm,m	1	1	1			1		1	
PMULHRSW	(x)mm,(x)mm	1	1	1				5	1	SSSE3
PMULHRSW	(x)mm,m	1	1	1			1		1	SSSE3
PMULLD	x,x	1	1	1				5	1	SSE4.1
PMULLD	x,m128	2	1	1			1		1	SSE4.1
PMULDQ	x,x	1	1	1				5	1	SSE4.1
PMULDQ	x,m128	1	1	1			1		1	SSE4.1
PMULUDQ	(x)mm,(x)mm	1	1	1				5	1	
PMULUDQ	(x)mm,m	1	1	1			1		1	
PMADDWD	(x)mm,(x)mm	1	1	1				5	1	
PMADDWD	(x)mm,m	1	1	1			1		1	
PMADDUBSW	(x)mm,(x)mm	1	1	1				5	1	SSSE3
PMADDUBSW	(x)mm,m	1	1	1			1		1	SSSE3
PAVGB/W	(x)mm,(x)mm	1	1		x	x		1	0.5	
PAVGB/W	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXSB	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXSB	x,m128	1	1		x	x	1		0.5	SSE4.1
PMIN/MAXUB	(x)mm,(x)mm	1	1		x	x		1	0.5	
PMIN/MAXUB	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXSW	(x)mm,(x)mm	1	1		x	x		1	0.5	
PMIN/MAXSW	(x)mm,m	1	1		x	x	1		0.5	
PMIN/MAXUW	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXUW	x,m	1	1		x	x	1		0.5	SSE4.1
PMIN/MAXU/SD	x,x	1	1		x	x		1	0.5	SSE4.1
PMIN/MAXU/SD	x,m128	1	1		x	x	1		0.5	SSE4.1
PHMINPOSUW	x,x	1	1	1				5	1	SSE4.1
PHMINPOSUW	x,m128	1	1	1			1		1	SSE4.1
PABSB/W/D	(x)mm,(x)mm	1	1		x	x		1	0.5	SSSE3
PABSB/W/D	(x)mm,m	1	1		x	x	1		0.5	SSSE3
PSIGNB/W/D	(x)mm,(x)mm	1	1		x	x		1	0.5	SSSE3
PSIGNB/W/D	(x)mm,m	1	1		x	x	1		0.5	SSSE3
PSADBW	(x)mm,(x)mm	1	1	1				5	1	
PSADBW	(x)mm,m	1	1	1			1		1	
MPSADBW	x,x,i	3	3	1	1	1		6	1	SSE4.1
MPSADBW	x,m,i	4	3	1	1	1	1		1	SSE4.1
<b>Logic instructions</b>										
PAND(N) POR PXOR	(x)mm,(x)mm	1	1	x	x	x		1	0.33	
PAND(N) POR PXOR	(x)mm,m	1	1	x	x	x	1		0.5	
PTEST	x,x	2	2	1	x	x		1	1	SSE4.1
PTEST	x,m128	3	2	1	x	x	1		1	SSE4.1
PSLL/RL/RAW/D/Q	mm,mm/i	1	1	1				1	1	
PSLL/RL/RAW/D/Q	mm,m64	1	1	1			1		1	
PSLL/RL/RAW/D/Q	xmm,i	1	1	1				1	1	
PSLL/RL/RAW/D/Q	x,x	2	2	1	x	x		2	1	
PSLL/RL/RAW/D/Q	x,m128	3	2	1	x	x	1		1	
PSLL/RLDQ	x,i	1	1		x	x		1	0.5	
<b>String instructions</b>										

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PCMPESTRI	x,x,i	8	8	3	1	4			4	4	SSE4.2
PCMPESTRI	x,m128,i	8	7	3	1	3	1			4	SSE4.2
PCMPESTRM	x,x,i	8	8	3	1	4			12	4	SSE4.2
PCMPESTRM	x,m128,i	8	7	3	1	3	1			4	SSE4.2
PCMPISTRI	x,x,i	3	3	3					3		SSE4.2
PCMPISTRI	x,m128,i	4	3	3			1			3	SSE4.2
PCMPISTRM	x,x,i	3	3	3					11		SSE4.2
PCMPISTRM	x,m128,i	4	3	3			1			3	SSE4.2
<b>Encryption instructions</b>											
PCLMULQDQ	x,x,i	18	18	x	x	x			14	8	CLMUL
PCLMULQDQ	x,m,i	18	17	x	x	x	1			8	CLMUL
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,x	2	2	x	x	1			4	1	AES
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,m	3	2	x	x	1	1			1	AES
AESIMC	x,x	2	2			2			14	2	AES
AESIMC	x,m	3	2			2	1			2	AES
AESKEYGENASSIST	x,x,i	11	11	x	x	x			10	8	AES
AESKEYGENASSIST	x,m,i	11	10	x	x	x	1			7	AES
<b>Other</b>											
EMMS		31	31							18	

**Floating point XMM and YMM instructions**

Instruction	Operands	μops fused domain	μops unfused domain						Latency	Reciprocal throughput	Comments
			p015	p0	p1	p5	p23	p4			
<b>Move instructions</b>											
MOVAPS/D	x,x	1	1			1			0-1	≤1	elimin.
VMOVAPS/D	y,y	1	1			1			0-1	≤1	elimin.
MOVAPS/D MOVUPS/D	x,m128	1					1		3	0.5	
VMOVAPS/D	y,m256	1					1+		4	1	AVX
VMOVUPS/D	m128,x	1					1	1	3	1	
MOVAPS/D MOVUPS/D	m256,y	1					1	1+	4	2	AVX
VMOVUPS/D	x,x	1	1			1			1	1	
MOVSS/D	x,m32/64	1					1		3	0.5	
MOVSS/D	m32/64,x	1					1	1	3	1	
MOVHPS/D MOVLPS/D	x,m64	2	1			1	1	1	4	1	
MOVH/LPS/D	m64,x	2					1	1	3	1	
MOVLHPS MOVHLPS	x,x	1	1			1			1	1	
MOVMSKPS/D	r32,x	1	1	1					2	1	
VMOVMSKPS/D	r32,y	1	1	1					2	1	
MOVNTPS/D	m128,x	1					1	1	~380	1	
VMOVNTPS/D	m256,y	1					1	1+	~380	2	AVX
SHUFPS/D	x,x,i	1	1			1			1	1	

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SHUFPS/D	x,m128,i	2	1			1	1			1	
VSHUFPS/D	y,y,y,i	1	1			1		1		1	AVX
VSHUFPS/D	y, y,m256,i	2	1			1	1+			1	AVX
VPERMILPS/PD	x,x,x/i	1	1			1		1		1	AVX
VPERMILPS/PD	y,y,y/i	1	1			1		1		1	AVX
VPERMILPS/PD	x,x,m	2	1			1	1			1	AVX
VPERMILPS/PD	y,y,m	2	1			1	1+			1	AVX
VPERMILPS/PD	x,m,i	2	1			1	1			1	AVX
VPERMILPS/PD	y,m,i	2	1			1	1+			1	AVX
VPERM2F128	y,y,y,i	1	1			1		2		1	AVX
VPERM2F128	y,y,m,i	2	1			1	1+			1	AVX
BLENDPS/PD	x,x,i	1	1	x		x		1		0.5	SSE4.1
BLENDPS/PD	x,m128,i	2	1	x		x	1			0.5	SSE4.1
VBLENDPS/PD	y,y,i	1	1	x		x		1		0.5	AVX
VBLENDPS/PD	y,m256,i	2	1	x		x	1+			1	AVX
BLENDVPS/PD	x,x,xmm0	2	2	x		x		2		1	SSE4.1
BLENDVPS/PD	x,m,xmm0	3	2	x		x	1			1	SSE4.1
VBLENDVPS/PD	y,y,y,y	2	2	x		x		2		1	AVX
VBLENDVPS/PD	y,y,m,y	3	2	x		x	1+			1	AVX
MOVDDUP	x,x	1	1			1		1		1	SSE3
MOVDDUP	x,m64	1					1	3		0.5	SSE3
VMOVDDUP	y,y	1	1			1		1		1	AVX
VMOVDDUP	y,m256	1					1+	3		1	AVX
VBROADCASTSS	x,m32	1					1	4		0.5	AVX
VBROADCASTSS	y,m32	2	1			1	1	5		1	AVX
VBROADCASTSD	y,m64	2	1			1	1	5		1	AVX
VBROADCASTF128	y,m128	2	1			1	1	5		1	AVX
MOVSH/LDUP	x,x	1	1			1		1		1	SSE3
MOVSH/LDUP	x,m128	1					1	3		0.5	SSE3
VMOVSH/LDUP	y,y	1	1			1		1		1	AVX
VMOVSH/LDUP	y,m256	1					1+	1		1	AVX
UNPCKH/LPS/D	x,x	1	1			1		1		1	SSE3
UNPCKH/LPS/D	x,m128	1	1			1	1			1	SSE3
VUNPCKH/LPS/D	y,y,y	1	1			1		1		1	AVX
VUNPCKH/LPS/D	y,y,m256	1	1			1	1+			1	AVX
EXTRACTPS	r32,x,i	2	2	x		x		2		1	SSE4.1
EXTRACTPS	m32,x,i	3	2	x		x	1	1		1	SSE4.1
VEXTRACTF128	x,y,i	1	1			1		2		1	AVX
VEXTRACTF128	m128,y,i	2	0				1	1		4	AVX
INSERTPS	x,x,i	1	1			1		1		1	SSE4.1
INSERTPS	x,m32,i	2	1			1	1			1	SSE4.1
VINSERTF128	y,y,x,i	1	1			1		2		1	AVX
VINSERTF128	y,y,m128,i	2	1	x		x	1	4		1	AVX
VMASKMOVPS/D	x,x,m128	3	2	x		x	1	4		1	AVX
VMASKMOVPS/D	y,y,m256	3	2				1+	5		1	AVX
VMASKMOVPS/D	m128,x,x	4	2	x	x		1	1		1	AVX
VMASKMOVPS/D	m256,y,y	4	2	x	x		1	1+		2	AVX
<b>Conversion</b>											
CVTPD2PS	x,x	2	2			1	1			4	1
CVTPD2PS	x,m128	2	2			1	1	1			1
VCVTPD2PS	x,y	2	2			1	1			4	1
VCVTPD2PS	x,m256	2	2			1	1	1+			1

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CVTSD2SS	x,x	2	2		1	1			4	1	
CVTSD2SS	x,m64	2	2		1	1	1			1	
CVTPS2PD	x,x	2	2	1		1			1	1	
CVTPS2PD	x,m64	2	1	1			1			1	
VCVTPS2PD	y,x	2	2	1		1			4	1	AVX
VCVTPS2PD	y,m128	3	2	1		1	1			1	AVX
CVTSS2SD	x,x	2	2	1		1			2	1	
CVTSS2SD	x,m32	2	1	1			1			1	
CVTDQ2PS	x,x	1	1		1				3	1	
CVTDQ2PS	x,m128	1	1		1		1			1	
VCVTDQ2PS	y,y	1	1		1				3	1	AVX
VCVTDQ2PS	y,m256	1	1		1		1+			1	AVX
CVT(T) PS2DQ	x,x	1	1		1				3	1	
CVT(T) PS2DQ	x,m128	1	1		1		1			1	
VCVT(T) PS2DQ	y,y	1	1		1				3	1	AVX
VCVT(T) PS2DQ	y,m256	1	1		1		1+			1	AVX
CVTDQ2PD	x,x	2	2		1	1			4	1	
CVTDQ2PD	x,m64	2	2		1	1	1			1	
VCVTDQ2PD	y,x	2	2		1	1			5	1	AVX
VCVTDQ2PD	y,m128	2	2		1	1	1			1	AVX
CVT(T)PD2DQ	x,x	2	2		1	1			4	1	
CVT(T)PD2DQ	x,m128	2	2		1	1	1			1	
VCVT(T)PD2DQ	x,y	2	2		1	1			5	1	AVX
VCVT(T)PD2DQ	x,m256	2	2		1	1	1+			1	AVX
CVTPI2PS	x,mm	1	1		1				4		
CVTPI2PS	x,m64	1	1		1		1			3	
CVT(T)PS2PI	mm,x	2	2		1	1			4	1	
CVT(T)PS2PI	mm,m128	2	1		1		1			1	
CVTPI2PD	x,mm	2	2		1	1			4	1	
CVTPI2PD	x,m64	2	2		1	1	1			1	
CVT(T) PD2PI	mm,x	2	2		1	1			4	1	
CVT(T) PD2PI	mm,m128	2	2		1	1	1			1	
CVTSI2SS	x,r32	2	2		1	1			4	3	
CVTSI2SS	x,m32	1	1		1		1			3	
CVT(T)SS2SI	r32,x	2	2	1	1				4	1	
CVT(T)SS2SI	r32,m32	2	2	1	1		1			1	
CVTSI2SD	x,r32	2	2		1	1			4	3	
CVTSI2SD	x,m32	2	1		1		1			3	
CVT(T)SD2SI	r32,x	2	2	1	1				4	1	
CVT(T)SD2SI	r32,m64	2	2	1	1		1			1	
VCVTPS2PH	x,v,i	3	3	1	1	1			10	1	F16C
VCVTPS2PH	m,v,i	3	2	1	1		1	1		1	F16C
VCVTPH2PS	v,x	2	2	1		1			6	1	F16C
VCVTPH2PS	v,m	2	1		1		1			1	F16C
<b>Arithmetic</b>											
ADDSS/D SUBSS/D	x,x	1	1		1				3	1	
ADDSS/D SUBSS/D	x,m32/64	1	1		1		1			1	
ADDPS/D SUBPS/D	x,x	1	1		1				3	1	
ADDPS/D SUBPS/D	x,m128	1	1		1		1			1	
VADDPS/D VSUBPS/D	y,y,y	1	1		1				3	1	AVX
VADDPS/D VSUBPS/D	y,y,m256	1	1		1		1+			1	AVX
ADDSUBPS/D	x,x	1	1		1				3	1	SSE3

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ADDSUBPS/D	x,m128	1	1	1	1			1	SSE3	
VADDSUBPS/D	y,y,y	1	1	1			3	1	AVX	
VADDSUBPS/D	y,y,m256	1	1	1		1+		1	AVX	
HADDPS/D HSUBPS/D	x,x	3	3	1	2			5	2	SSE3
HADDPS/D HSUBPS/D	x,m128	4	3	1	2	1			2	SSE3
VHADDPS/D										
VHSUBPS/D	y,y,y	3	3		1	2		5	2	AVX
VHADDPS/D										
VHSUBPS/D	y,y,m256	4	3		1	2	1+		2	AVX
MULSS MULPS	x,x	1	1	1				5	1	
MULSS MULPS	x,m	1	1	1			1		1	
VMULPS	y,y,y	1	1	1				5	1	AVX
VMULPS	y,y,m256	1	1	1			1+		1	AVX
MULSD MULPD	x,x	1	1	1				5	1	
MULSD MULPD	x,m	1	1	1			1		1	
VMULPD	y,y,y	1	1	1				5	1	AVX
VMULPD	y,y,m256	1	1	1			1+		1	AVX
DIVSS DIVPS	x,x	1	1	1				10-13	7	
DIVSS DIVPS	x,m	1	1	1			1		7	
VDIVPS	y,y,y	3	3	2		1		19-21	14	AVX
VDIVPS	y,y,m256	4	3	2		1	1+		14	AVX
DIVSD DIVPD	x,x	1	1	1				10-20	8-14	
DIVSD DIVPD	x,m	1	1	1			1		8-14	
VDIVPD	y,y,y	3	3	2		1		20-35	16-28	AVX
VDIVPD	y,y,m256	4	3	2		1	1+		16-28	AVX
RCPSS/PS	x,x	1	1	1				5	1	
RCPSS/PS	x,m128	1	1	1			1		1	
VRCPPS	y,y	3	3	2		1		7	2	AVX
VRCPPS	y,m256	4	3	2		1	1+		2	AVX
CMPccSS/D CMPccPS/D										
CMPccSS/D CMPccPS/D	x,x	1	1		1			3	1	
CMPccSS/D CMPccPS/D										
CMPccSS/D CMPccPS/D	x,m128	2	1		1		1		1	
VCMPccPS/D	y,y,y	1	1		1			3	1	AVX
VCMPccPS/D	y,y,m256	2	1		1		1+		1	AVX
COMISS/D UCOMISS/D	x,x	2	2	1	1				1	
COMISS/D UCOMISS/D	x,m32/64	2	2	1	1		1		1	
MAXSS/D MINSS/D	x,x	1	1		1			3	1	
MAXSS/D MINSS/D	x,m32/64	1	1		1		1		1	
MAXPS/D MINPS/D	x,x	1	1		1			3	1	
MAXPS/D MINPS/D	x,m128	1	1		1		1		1	
VMAXPS/D VMINPS/D	y,y,y	1	1		1			3	1	AVX
VMAXPS/D VMINPS/D	y,y,m256	1	1		1		1+		1	AVX
ROUNDSS/SD/PS/PD	x,x,i	1	1		1			3	1	SSE4.1
ROUNDSS/SD/PS/PD	x,m128,i	2	1		1		1		1	SSE4.1
VROUNDSS/SD/PS/PD	y,y,i	1	1		1			3	1	AVX
VROUNDSS/SD/PS/PD	y,m256,i	2	1		1		1+		1	AVX
DPPS	x,x,i	4	4	1	2	1		12	2	SSE4.1
DPPS	x,m128,i	6	5	1	2	2	1		4	SSE4.1
VDPPS	y,y,y,i	4	4	1	2	1		12	2	AVX
VDPPS	y,m256,i	6	5	1	2	2	1+		4	AVX
DPPD	x,x,i	3	3	1	1	1		9	1	SSE4.1
DPPD	x,m128,i	4	3	1	1	1	1		1	SSE4.1

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<b>Math</b>										
SQRTSS/PS	x,x	1	1	1				11	7	
SQRTSS/PS	x,m128	1	1	1			1		7	
VSQRTPS	y,y	3	3	2		1		19	14	AVX
VSQRTPS	y,m256	4	3	2		1	1+		14	AVX
SQRTSD/PD	x,x	1	1	1				16	8-14	
SQRTSD/PD	x,m128	1	1	1			1		8-14	
VSQRTPD	y,y	3	3	2		1		28	16-28	AVX
VSQRTPD	y,m256	4	3	2		1	1+		16-28	AVX
RSQRTSS/PS	x,x	1	1	1				5	1	
RSQRTSS/PS	x,m128	1	1	1			1		1	
VRSQRTPS	y,y	3	3	2		1		7	2	AVX
VRSQRTPS	y,m256	4	3	2		1	1+		2	AVX
<b>Logic</b>										
AND/ANDN/OR/XORPS/PD	x,x	1	1			1		1	1	
AND/ANDN/OR/XORPS/PD	x,m128	1	1			1	1		1	
VAND/ANDN/OR/XORPS/PD	y,y,y	1	1			1		1	1	AVX
VAND/ANDN/OR/XORPS/PD	y,y,m256	1	1			1	1+		1	AVX
<b>Other</b>										
VZEROUPPER		4	0						1	AVX
VZEROALL		12	2						11	32 bit
VZEROALL		20	2						9	64 bit
LDMXCSR	m32	3	2	1		1	1	6	3	
STMXCSR	m32	3	2	1		1	1	7	1	
FXSAVE	m4096	130							66	
FXRSTOR	m4096	116							68	
XSAVEOPT	m	100-161						60-500		

## Intel Haswell

### List of instruction timings and $\mu$ op breakdown

*Explanation of column headings:*

**Instruction:** Name of instruction. Multiple names mean that these instructions have the same data. Instructions with or without V name prefix behave the same unless otherwise noted.

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, v = any vector register (mmx, xmm, ymm). same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.

**$\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename and allocate stages in the pipeline. Fused  $\mu$ ops count as one.

**$\mu$ ops unfused domain:** The total number of  $\mu$ ops for all execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if this number is higher than the number under fused domain. Some operations are not counted here if they do not go to any execution port or if the counters are inaccurate.

**$\mu$ ops each port:** The number of  $\mu$ ops for each execution port. p0 means a  $\mu$ op to execution port 0. p01 means a  $\mu$ op that can go to either port 0 or port 1. p0 p1 means two  $\mu$ ops going to port 0 and 1, respectively.  
 Port 0: Integer, f.p. and vector ALU, mul, div, branch  
 Port 1: Integer, f.p. and vector ALU  
 Port 2: Load  
 Port 3: Load  
 Port 4: Store  
 Port 5: Integer and vector ALU  
 Port 6: Integer ALU, branch  
 Port 7: Store address

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Where hyperthreading is enabled, the use of the same execution units in the other thread leads to inferior performance. Denormal numbers, NAN's and infinity do not increase the latency. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOV	r,i	1	1	p0156		0.25	
MOV	r8/16,r8/16	1	1	p0156	1	0.25	
MOV	r32/64,r32/64	1	1	p0156	0-1	0.25	may be elim.
MOV	r8l,m	1	2	p23 p0156		0.5	
MOV	r8h,m	1	1	p23		0.5	
MOV	r16,m	1	2	p23 p0156		0.5	
MOV	r32/64,m	1	1	p23	2	0.5	all addressing modes
MOV	m,r	1	2	p237 p4	3	1	

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MOV	m,i	1	2	p237 p4		1	
MOVNTI	m,r	2	2	p23 p4	~400	1	
MOVSX MOVZX	r,r	1	1	p0156	1	0.25	
MOVSXD							
MOVSX MOVZX	r16,m8	1	2	p23 p0156		0.5	
MOVSX MOVZX	r,m	1	1	p23		0.5	all other combinations
MOVSXD							
CMOVcc	r,r	2	2	2p0156	2	0.5	
CMOVcc	r,m	3	3	2p0156 p23		1	
XCHG	r,r	3	3	3p0156	2	1	
XCHG	r,m	8	8		21		implicit lock
XLAT		3	3		7	2	
PUSH	r	1	2	p237 p4	3	1	
PUSH	i	1	2	p237 p4		1	
PUSH	m	2	3	p4 2p237		1	
PUSH	stack pointer	2	3	p0156 p237 p4		1	
PUSHF(D/Q)		3	4	p1 p4 p237 p06		1	
PUSHA(D)		11	19			8	not 64 bit
POP	r	1	1	p23	2	0.5	
POP	stack pointer	3	3	p23 2p0156		4	
POP	m	2	3	2p237 p4		1	
POPF(D/Q)		9	9			18	
POPA(D)		18	18			9	not 64 bit
LAHF SAHF		1	1	p06	1	1	
SALC		3	3	3p0156	1	1	not 64 bit
LEA	r16,m	2	2	p1 p0156	4	1	16 or 32 bit address size
LEA	r32/64,m	1	1	p15	1	0.5	1 or 2 components in address
LEA	r32/64,m	1	1	p1	3	1	3 components in address
LEA	r32/64,m	1	1	p1		1	rip relative address
BSWAP	r32	1	1	p15	1	0.5	
BSWAP	r64	2	2	p06 p15	2	1	
MOVBE	r16,m16	3	3	2p0156 p23		0.5	MOVBE
MOVBE	r32,m32	2	2	p15 p23		0.5	MOVBE
MOVBE	r64,m64	3	3	2p0156 p23		0.5	MOVBE
MOVBE	m16,r16	2	3	p06 p237 p4		1	MOVBE
MOVBE	m32,r32	2	3	p15 p237 p4		1	MOVBE
MOVBE	m64,r64	3	4	p06 p15 p237 p4		1	MOVBE
PREFETCHNTA/0/1/2	m	1	1	p23		0.5	
LFENCE		2		none counted		4	
MFENCE		3	2	p23 p4		33	
SFENCE		2	2	p23 p4		5	
<b>Arithmetic instructions</b>							
ADD SUB	r,r/i	1	1	p0156	1	0.25	
ADD SUB	r,m	1	2	p0156 p23		0.5	



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ADD SUB	m,r/i	2	4	2p0156 2p237 p4	6	1	
ADC SBB	r,r/i	2	2	2p0156	2	1	
ADC SBB	r,m	2	3	2p0156 p23		1	
ADC SBB	m,r/i	4	6	3p0156 2p237 p4	7	2	
CMP	r,r/i	1	1	p0156	1	0.25	
CMP	m,r/i	1	2	p0156 p23	1	0.5	
INC DEC NEG NOT	r	1	1	p0156	1	0.25	
INC DEC NOT	m	3	4	p0156 2p237 p4	6	1	
NEG	m	2	4	p0156 2p237 p4	6	1	
AAA		2	2	p1 p0156	4		not 64 bit
AAS		2	2	p1 p56	6		not 64 bit
DAA DAS		3	3	p1 2p0156	4		not 64 bit
AAD		3	3	p1 2p0156	4		not 64 bit
AAM		8	8	p0 p1 p5 p6	21	8	not 64 bit
MUL IMUL	r8	1	1	p1	3	1	
MUL IMUL	r16	4	4	p1 p0156	4	2	
MUL IMUL	r32	3	3	p1 p0156	4	2	
MUL IMUL	r64	2	2	p1 p6	3	1	
MUL IMUL	m8	1	2	p1 p23		1	
MUL IMUL	m16	4	5	p1 3p0156 p23		2	
MUL IMUL	m32	3	4	p1 2p0156 p23		2	
MUL IMUL	m64	2	3	p1 p6 p23		1	
IMUL	r,r	1	1	p1	3	1	
IMUL	r,m	1	2	p1 p23		1	
IMUL	r16,r16,i	2	2	p1 p0156	4	1	
IMUL	r32,r32,i	1	1	p1	3	1	
IMUL	r64,r64,i	1	1	p1	3	1	
IMUL	r16,m16,i	2	3	p1 p0156 p23		1	
IMUL	r32,m32,i	1	2	p1 p23		1	
IMUL	r64,m64,i	1	2	p1 p23		1	
MULX	r32,r32,r32	3	3	p1 2p056	4	1	BMI2
MULX	r32,r32,m32	3	4	p1 2p056 p23		1	BMI2
MULX	r64,r64,r64	2	2	p1 p6	4	1	BMI2
MULX	r64,r64,m64	2	3	p1 p6 p23		1	BMI2
DIV	r8	9	9	p0 p1 p5 p6	22-25	9	
DIV	r16	11	11	p0 p1 p5 p6	23-26	9	
DIV	r32	10	10	p0 p1 p5 p6	22-29	9-11	
DIV	r64	36	36	p0 p1 p5 p6	32-96	21-74	
IDIV	r8	9	9	p0 p1 p5 p6	23-26	8	
IDIV	r16	10	10	p0 p1 p5 p6	23-26	8	
IDIV	r32	9	9	p0 p1 p5 p6	22-29	8-11	
IDIV	r64	59	59	p0 p1 p5 p6	39-103	24-81	
CBW		1	1	p0156	1		
CWDE		1	1	p0156	1		
CDQE		1	1	p0156	1		
CWD		2	2	p0156	1		
CDQ		1	1	p06	1		
CQO		1	1	p06	1		
POPCNT	r,r	1	1	p1	3	1	SSE4.2
POPCNT	r,m	1	2	p1 p23		1	SSE4.2

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CRC32	r,r	1	1	p1	3	1	SSE4.2
CRC32	r,m	1	2	p1 p23		1	SSE4.2
<b>Logic instructions</b>							
AND OR XOR	r,r/i	1	1	p0156	1	0.25	
AND OR XOR	r,m	1	2	p0156 p23		0.5	
AND OR XOR	m,r/i	2	4	2p0156 2p237 p4	6	1	
TEST	r,r/i	1	1	p0156	1	0.25	
TEST	m,r/i	1	2	p0156 p23		0.5	
SHR SHL SAR	r,i	1	1	p06	1	0.5	
SHR SHL SAR	m,i	3	4	2p06 p237 p4		2	
SHR SHL SAR	r,cl	3	3	3p06	2	2	
SHR SHL SAR	m,cl	5	6	3p06 2p23 p4		4	
ROR ROL	r,1	2	2	2p06	1	1	short form
ROR ROL	r,i	1	1	p06	1	0.5	
ROR ROL	m,i	4	5	2p06 2p237 p4		2	
ROR ROL	r,cl	3	3	3p06	2	2	
ROR ROL	m,cl	5	6			4	
RCR RCL	r,1	3	3	2p06 p0156	2	2	
RCR RCL	m,1	4	6			3	
RCR RCL	r,i	8	8	p0156	6	6	
RCR RCL	m,i	11	11			6	
RCR RCL	r,cl	8	8	p0156	6	6	
RCR RCL	m,cl	11	11			6	
SHRD SHLD	r,r,i	1	1	p1	3	1	
SHRD SHLD	m,r,i	3	5			2	
SHLD	r,r,cl	4	4	p0156	3	2	
SHRD	r,r,cl	4	4	p0156	4	2	
SHRD SHLD	m,r,cl	5	7			4	
SHLX SHRX SARX	r,r,r	1	1	p06	1	0.5	BMI2
SHLX SHRX SARX	r,m,r	2	2	p06 p23		0.5	BMI2
RORX	r,r,i	1	1	p06	1	0.5	BMI2
RORX	r,m,i	2	2	p06 p23		0.5	BMI2
BT	r,r/i	1	1	p06	1	0.5	
BT	m,r	10	10			5	
BT	m,i	2	2	p06 p23		0.5	
BTR BTS BTC	r,r/i	1	1	p06	1	0.5	
BTR BTS BTC	m,r	10	11			5	
BTR BTS BTC	m,i	3	4	2p06 p23 p4		2	
BSF BSR	r,r	1	1	p1	3	1	
BSF BSR	r,m	1	2	p1 p23		1	
SETcc	r	1	1	p06	1	0.5	
SETcc	m	2	3	p06 p237 p4		1	
CLC		1	0	none		0.25	
STC		1	1	p0156		0.25	
CMC		1	1	p0156	1		
CLD STD		3	3	p15 p6		4	
LZCNT	r,r	1	1	p1	3	1	LZCNT
LZCNT	r,m	1	2	p1 p23		1	LZCNT
TZCNT	r,r	1	1	p1	3	1	BMI1
TZCNT	r,m	1	2	p1 p23		1	BMI1

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ANDN	r,r,r	1	1	p15	1	0.5	BMI1
ANDN	r,r,m	1	2	p15 p23	1	0.5	BMI1
BLSI BLSMSK BLSR	r,r	1	1	p15	1	0.5	BMI1
BLSI BLSMSK BLSR	r,m	1	2	p15 p23		0.5	BMI1
BEXTR	r,r,r	2	2	2p0156	2	0.5	BMI1
BEXTR	r,m,r	3	3	2p0156 p23		1	BMI1
BZHI	r,r,r	1	1	p15	1	0.5	BMI2
BZHI	r,m,r	1	2	p15 p23		0.5	BMI2
PDEP	r,r,r	1	1	p1	3	1	BMI2
PDEP	r,r,m	1	2	p1 p23		1	BMI2
PEXT	r,r,r	1	1	p1	3	1	BMI2
PEXT	r,r,m	1	2	p1 p23		1	BMI2
<b>Control transfer instructions</b>							
JMP	short/near	1	1	p6		1-2	
JMP	r	1	1	p6		2	
JMP	m	1	2	p23 p6		2	
Conditional jump	short/near	1	1	p6		1-2	predicted taken
Conditional jump	short/near	1	1	p06		0.5-1	predicted not taken
Fused arithmetic and branch		1	1	p6		1-2	predicted taken
Fused arithmetic and branch		1	1	p06		0.5-1	predicted not taken
J(E/R)CXZ	short	2	2	p0156 p6		0.5-2	
LOOP	short	7	7			5	
LOOP(N)E	short	11	11			6	
CALL	near	2	3	p237 p4 p6		2	
CALL	r	2	3	p237 p4 p6		2	
CALL	m	3	4	2p237 p4 p6		3	
RET		1	2	p237 p6		1	
RET	i	3	4	p23 2p6 p015		2	
BOUND	r,m	15	15			8	not 64 bit
INTO		4	4			5	not 64 bit
<b>String instructions</b>							
LODSB/W		3	3	2p0156 p23		1	
LODSD/Q		2	2	p0156 p23		1	
REP LODS		5n+12				~2n	
STOS		3	3	p23 p0156 p4		1	
REP STOS		<2n				~0.5n	worst case
REP STOS		2.6/32B				1/32B	best case aligned by 32
MOVS		5	5	2p23 p4 2p0156		4	
REP MOVS		~2n				~1.5 n	worst case
REP MOVS		4/32B				1/32B	best case aligned by 32
SCAS		3	3	p23 2p0156		1	
REP SCAS		≥6n				≥2n	

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CMPS		5	5	2p23 3p0156		4	
REP CMPS		≥8n				≥2n	
<b>Synchronization instructions</b>							
XADD	m,r	4	5			7	
LOCK XADD	m,r	9	9			19	
LOCK ADD	m,r	8	8			19	
CMPXCHG	m,r	5	6			8	
LOCK CMPXCHG	m,r	10	10			19	
CMPXCHG8B	m,r	15	15			9	
LOCK CMPXCHG8B	m,r	19	19			19	
CMPXCHG16B	m,r	22	22			15	
LOCK CMPXCHG16B	m,r	24	24			25	
<b>Other</b>							
NOP (90)		1	0	none		0.25	
Long NOP (0F 1F)		1	0	none		0.25	
PAUSE		5	5	p05 3p6		9	
ENTER	a,0	12	12			8	
ENTER	a,b	~14+7b	~45+7b		~87+2b		
LEAVE		3	3	2p0156 p23		6	
XGETBV		8	8			9	XGETBV
RDTSC		15	15			24	
RDPMC		34	34			37	
RDRAND	r	17	17	p23 16p0156		~320	RDRAND

**Floating point x87 instructions**

Instruction	Operands	μops fused domain	μops unfused domain	μops each port	Latency	Reciprocal through put	Comments
<b>Move instructions</b>							
FLD	r	1	1	p01	1	0.5	
FLD	m32/64	1	1	p23	3	0.5	
FLD	m80	4	4	2p01 2p23	4	2	
FBLD	m80	43	43		47	22	
FST(P)	r	1	1	p01	1	0.5	
FST(P)	m32/m64	1	2	p4 p237	4	1	
FSTP	m80	7	7	3p0156 2p23 2p4	1	5	
FBSTP	m80	238	226			265	
FXCH	r	2	0	none	0	0.5	
FILD	m	1	2	p01 p23	6	1	
FIST(P)	m	3	3	p1 p23 p4	7	1	
FISTTP	m	3	3	p1 p23 p4	7	2	SSE3
FLDZ		1	1	p01		1	
FLD1		2	2	2p01		2	
FLDPI FLDL2E etc.		2	2	2p01		2	
FCMOVcc	r	3	3	2p0 p5	2	2	
FNSTSW	AX	2	2	p0 p0156		1	
FNSTSW	m16	2	3	p0 p4 p237	6	1	
FLDCW	m16	3	3	p01 p23 p6	7	2	

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FNSTCW	m16	2	3	p237 p4 p6		1
FINCSTP FDECSTP		1	1	p01	0	0.5
FFREE(P)	r	1	1	p01		0.5
FNSAVE	m	147	147			150
FRSTOR	m	90	90			164
<b>Arithmetic instructions</b>						
FADD(P)						
FSUB(R)(P)	r	1	1	p1	3	1
FADD(P)						
FSUB(R)(P)	m	1	2	p1 p23		1
FMUL(P)	r	1	1	p0	5	1
FMUL(P)	m	1	2	p0 p23		1
FDIV(R)(P)	r	1	1	p0	10-24	8-18
FDIV(R)(P)	m	1	2	p0 p23		8-18
FABS		1	1	p0	1	1
FCHS		1	1	p0	1	1
FCOM(P) FUCOM	r	1	1	p1		1
FCOM(P) FUCOM	m	1	2	p1 p23		1
FCOMPP FUCOMPP		2	2	2p01		1
FCOMI(P) FUCOMI	r	3	3	3p01		1.5
FIADD FISUB(R)	m	2	3	2p1 p23		2
FIMUL	m	2	3	p0 p1 p23		2
FIDIV(R)	m	2	3	p0 p1 p23		
FICOM(P)	m	2	3	2p1 p23		2
FTST		1	1	p1		1
FXAM		2	2	2p1		2
FPREM		28	28		19	13
FPREM1		41	41		27	17
FRNDINT		17	17		11	23
<b>Math</b>						
FSCALE		25-75			49-125	
FEXTRACT		17	17		15	11
FSQRT		1	1	p0	10-23	8-17
FSIN		71-100			47-106	
FCOS		110			112	
FSINCOS		70-120			52-123	
F2XM1		58-89			63-68	
FYL2X		55-417			58-680	
FYL2XP1		55-228			58-360	
FPTAN		110-121			130	
FPATAN		78-160			96-156	
<b>Other</b>						
FNOP		1	1	p01		0.5
WAIT		2	2	p01		1
FNCLEX		5	5	p0156		22
FNINIT		26	26			83

**Integer vector instructions**

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Instruction	Operands	μops fused domain	μops unfused domain	μops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOVD	r32/64,(x)mm	1	1	p0	1	1	
MOVD	m32/64,(x)mm	1	2	p237 p4	3	1	
MOVD	(x)mm,r32/64	1	1	p5	1	1	
MOVD	(x)mm,m32/64	1	1	p23	3	0.5	
MOVQ	r64,(x)mm	1	1	p0	1	1	
MOVQ	(x)mm,r64	1	1	p5	1	1	
MOVQ	(x)mm,(x)mm	1		p015	1	0.33	
MOVQ	(x)mm,m64	1	1	p23	3	0.5	
MOVQ	m64, (x)mm	1	2	p237 p4	3	1	
MOVDQA/U	x,x	1	1	p015	0-1	0.33	may be elim.
MOVDQA/U	x, m128	1	1	p23	3	0.5	
MOVDQA/U	m128, x	1	2	p237 p4	3	1	
VMOVDQA/U	y,y	1	1	p015	0-1	0.33	AVX may be elim.
VMOVDQA/U	y,m256	1	1	p23	3	0.5	AVX
VMOVDQA/U	m256,y	1	2	p237 p4	4	1	AVX
LDDQU	x, m128	1	1	p23	3	0.5	SSE3
MOVDQ2Q	mm, x	2	2	p01 p5	1	1	
MOVQ2DQ	x,mm	1	1	p015	1	0.33	
MOVNTQ	m64,mm	1	2	p237 p4	~400	1	
MOVNTDQ	m128,x	1	2	p237 p4	~400	1	
VMOVNTDQ	m256,y	1	2	p237 p4	~400	1	AVX2
MOVNTDQA	x, m128	1	1	p23	3	0.5	SSE4.1
VMOVNTDQA	y,m256	1	1	p23	3	0.5	AVX2
PACKSSWB/DW							
PACKUSWB	mm,mm	3	3	p5	2	2	
PACKSSWB/DW							
PACKUSWB	mm,m64	3	3	p23 2p5		2	
PACKSSWB/DW							
PACKUSWB	x,x / y,y,y	1	1	p5	1	1	
PACKSSWB/DW							
PACKUSWB	x,m / y,y,m	1	2	p23 p5		1	
PACKUSDW	x,x / y,y,y	1	1	p5	1	1	SSE4.1
PACKUSDW	x,m / y,y,m	1	2	p23 p5		1	SSE4.1
PUNPCKH/L							
BW/WD/DQ	v,v / v,v,v	1	1	p5	1	1	
PUNPCKH/L							
BW/WD/DQ	v,m / v,v,m	1	2	p23 p5		1	
PUNPCKH/L							
QDQ	x,x / y,y,y	1	1	p5	1	1	
PUNPCKH/L							
QDQ	x,m / y,y,m	2	2	p23 p5		1	
PMOVSX/ZX BW							
BD BQ DW DQ	x,x	1	1	p5	1	1	SSE4.1
PMOVSX/ZX BW							
BD BQ DW DQ	x,m	1	2	p23 p5		1	SSE4.1
VPMOVSX/ZX BW							
BD BQ DW DQ	y,x	1	1	p5	3	1	AVX2

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VPMOVSX/ZX BW								
BD BQ DW DQ	y,m	2	2	p5 p23			1	AVX2
PSHUFB	v,v / v,v,v	1	1	p5	1		1	SSSE3
PSHUFB	v,m / v,v,m	2	2	p23 p5			1	SSSE3
PSHUFW	mm,mm,i	1	1	p5	1		1	
PSHUFW	mm,m64,i	2	2	p23 p5			1	
PSHUFD	v,v,i	1	1	p5	1		1	
PSHUFD	v,m,i	2	2	p23 p5			1	
PSHUFL/HW	v,v,i	1	1	p5	1		1	
PSHUFL/HW	v,m,i	2	2	p23 p5			1	
PALIGNR	v,v,i / v,v,v,i	1	1	p5	1		1	SSSE3
PALIGNR	v,m,i / v,v,m,i	2	2	p23 p5			1	SSSE3
PBLENDVB	x,x,xmm0	2	2	2p5	2		2	SSE4.1
PBLENDVB	x,m,xmm0	3	3	2p5 p23			2	SSE4.1
VPBLENDVB	v,v,v,v	2	2	2p5	2		2	AVX2
VPBLENDVB	v,v,m,v	3	3	2p5 p23			2	AVX2
PBLENDW	x,x,i / v,v,v,i	1	1	p5	1		1	SSE4.1
PBLENDW	x,m,i / v,v,m,i	2	2	p23 p5			1	SSE4.1
VPBLEND	v,v,v,i	1	1	p015	1		0.33	AVX2
VPBLEND	v,v,m,i	2	2	p015 p23			0.5	AVX2
VPERMD	y,y,y	1	1	p5	3		1	AVX2
VPERMD	y,y,m	1	2	p5 p23			1	AVX2
VPERMQ	y,y,i	1	1	p5	3		1	AVX2
VPERMQ	y,m,i	2	2	p5 p23			1	AVX2
VPERM2I128	y,y,y,i	1	1	p5	3		1	AVX2
VPERM2I128	y,y,m,i	2	2	p5 p23			1	AVX2
MASKMOVQ	mm,mm	4	4	p0 p4 2p23	13-413		1	
MASKMOVDQU	x,x	10	10	4p04 2p56 4p23	14-438		6	
VPMASKMOVD/Q	v,v,m	3	3	p23 2p5	4		2	AVX2
VPMASKMOVD/Q	m,v,v	4	4	p0 p1 p4 p23	13-14		1	AVX2
PMOVMASKB	r,v	1	1	p0	3		1	
PEXTRB/W/D/Q	r32,x,i	2	2	p0 p5	2		1	SSE4.1
PEXTRB/W/D/Q	m8,x,i	2	3	p23 p4 p5			1	SSE4.1
VEXTRACTI128	x,y,i	1	1	p5	3		1	AVX2
VEXTRACTI128	m,y,i	2	2	p23 p4	4		1	AVX2
PINSRB	x,r32,i	2	2	p5	2		2	SSE4.1
PINSRB	x,m8,i	2	2	p23 p5			1	SSE4.1
PINSRW	(x)mm,r32,i	2	2	p5	2		2	
PINSRW	(x)mm,m16,i	2	2	p23 p5			1	
PINSRD/Q	x,r32,i	2	2	p5	2		2	SSE4.1
PINSRD/Q	x,m32,i	2	2	p23 p5			1	SSE4.1
VINSERTI128	y,y,x,i	1	1	p5	3		1	AVX2
VINSERTI128	y,y,m,i	2	2	p015 p23	4		0.5	AVX2
VPBROADCAST								
B/W/D/Q	x,x	1	1	p5	1		1	AVX2
VPBROADCAST								
B/W	x,m8/16	3	3	p01 p23 p5	5		1	AVX2
VPBROADCAST								
D/Q	x,m32/64	1	1	p23	4		0.5	AVX2
VPBROADCAST								
B/W/D/Q	y,x	1	1	p5	3		1	AVX2
VPBROADCAST								
B/W	y,m8/16	3	3	p01 p23 p5	7		1	AVX2

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VPBROADCAST D/Q	y,m32/64	1	1	p23	5	0.5	AVX2
VBROADCAST1128	y,m128	1	1	p23	3	0.5	AVX2
VPGATHERDD	x,[r+s*x],x	20	20			9	AVX2
VPGATHERDD	y,[r+s*y],y	34	34			12	AVX2
VPGATHERQD	x,[r+s*x],x	15	15			8	AVX2
VPGATHERQD	x,[r+s*y],x	22	22			7	AVX2
VPGATHERDQ	x,[r+s*x],x	12	12			7	AVX2
VPGATHERDQ	y,[r+s*x],y	20	20			9	AVX2
VPGATHERQQ	x,[r+s*x],x	14	14			7	AVX2
VPGATHERQQ	y,[r+s*y],y	22	22			9	AVX2
<b>Arithmetic instructions</b>							
PADD/SUB(S,US) B/W/D/Q	v,v / v,v,v	1	1	p15	1	0.5	
PADD/SUB(S,US) B/W/D/Q	v,m / v,v,m	1	2	p15 p23		0.5	
PHADD(S)W/D							
PHSUB(S)W/D	v,v / v,v,v	3	3	p1 2p5	3	2	SSSE3
PHADD(S)W/D							
PHSUB(S)W/D	v,m / v,v,m	4	4	p1 2p5 p23		2	SSSE3
PCMPEQB/W/D							
PCMPGTB/W/D	v,v / v,v,v	1	1	p15	1	0.5	
PCMPEQB/W/D							
PCMPGTB/W/D	v,m / v,v,m	1	2	p15 p23		0.5	
PCMPEQQ	v,v / v,v,v	1	1	p15	1	0.5	SSE4.1
PCMPEQQ	v,m / v,v,m	1	2	p15 p23		0.5	SSE4.1
PCMPGTQ	v,v / v,v,v	1	1	p0	5	1	SSE4.2
PCMPGTQ	v,m / v,v,m	1	2	p0 p23		1	SSE4.2
PMULL/HW							
PMULHUW	v,v / v,v,v	1	1	p0	5	1	
PMULL/HW							
PMULHUW	v,m / v,v,m	1	2	p0 p23		1	
PMULHRSW	v,v / v,v,v	1	1	p0	5	1	SSSE3
PMULHRSW	v,m / v,v,m	1	2	p0 p23		1	SSSE3
PMULLD	x,x / y,y,y	2	2	2p0	10	2	SSE4.1
PMULLD	x,m / y,y,m	3	3	2p0 p23		2	SSE4.1
PMULDQ	x,x / y,y,y	1	1	p0	5	1	SSE4.1
PMULDQ	x,m / y,y,m	1	2	p0 p23		1	SSE4.1
PMULUDQ	v,v / v,v,v	1	1	p0	5	1	
PMULUDQ	v,m / v,v,m	1	2	p0 p23		1	
PMADDWD	v,v / v,v,v	1	1	p0	5	1	
PMADDWD	v,m / v,v,m	1	2	p0 p23		1	
PMADDUBSW	v,v / v,v,v	1	1	p0	5	1	SSSE3
PMADDUBSW	v,m / v,v,m	1	2	p0 p23		1	SSSE3
PAVGB/W	v,v / v,v,v	1	1	p15	1	0.5	
PAVGB/W	v,m / v,v,m	1	2	p15 p23		0.5	
PMIN/PMAX SB/SW/SD							
UB/UW/UD	x,x / y,y,y	1	1	p15	1	0.5	SSE4.1
PMIN/PMAX SB/SW/SD							
UB/UW/UD	x,m / y,y,m	1	2	p15 p23		0.5	SSE4.1



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PHMINPOSUW	x,x	1	1	p0	5	1	SSE4.1
PHMINPOSUW	x,m128	1	2	p0 p23		1	SSE4.1
PABSB/W/D	v,v	1	1	p15	1	0.5	SSSE3
PABSB/W/D	v,m	1	2	p15 p23		0.5	SSSE3
PSIGNB/W/D	v,v / v,v,v	1	1	p15	1	0.5	SSSE3
PSIGNB/W/D	v,m / v,v,m	1	2	p15 p23		0.5	SSSE3
PSADBW	v,v / v,v,v	1	1	p0	5	1	
PSADBW	v,m / v,v,m	1	2	p0 p23		1	
MPSADBW	x,x,i / v,v,v,i	3	3	p0 2p5	6	2	SSE4.1
MPSADBW	x,m,i / v,v,m,i	4	4	p0 2p5 p23		2	SSE4.1
<b>Logic instructions</b>							
PAND PANDN							
POR PXOR	v,v / v,v,v	1	1	p015	1	0.33	
PAND PANDN							
POR PXOR	v,m / v,v,m	1	2	p015 p23		0.5	
PTEST	v,v	2	2	p0 p5	2	1	SSE4.1
PTEST	v,m	2	3	p0 p5 p23		1	SSE4.1
PSLLW/D/Q							
PSRLW/D/Q							
PSRAW/D/Q	mm,mm	1	1	p0	1	1	
PSLLW/D/Q							
PSRLW/D/Q							
PSRAW/D/Q	mm,m64	1	2	p0 p23		1	
PSLLW/D/Q							
PSRLW/D/Q							
PSRAW/D/Q	x,x / v,v,x	2	2	p0 p5	2	1	
PSLLW/D/Q							
PSRLW/D/Q							
PSRAW/D/Q	x,m / v,v,m	2	2	p0 p23		1	
PSLLW/D/Q							
PSRLW/D/Q							
PSRAW/D/Q	v,i / v,v,i	1	1	p0	1	1	
VPSLLVD/Q							
VPSRAVD							
VPSRLVD/Q	v,v,v	3	3	2p0 p5	2	2	AVX2
VPSLLVD/Q							
VPSRAVD							
VPSRLVD/Q	v,v,m	4	4	2p0 p5 p23		2	AVX2
PSLLDQ							
PSRLDQ	x,i / v,v,i	1	1	p5	1	1	
<b>String instructions</b>							
PCMPSTRM	x,x,i	8	8	6p05 2p16	11	4	SSE4.2
PCMPSTRM	x,m128,i	8	8	3p0 2p16 2p5 p23		4	SSE4.2
PCMPSTRM	x,x,i	9	9	3p0 2p16 4p5	10	5	SSE4.2
PCMPSTRM	x,m128,i	9	9	6p05 2p16 p23		5	SSE4.2
PCMPSTRM	x,x,i	3	3	3p0	11	3	SSE4.2
PCMPSTRM	x,m128,i	4	4	3p0 p23		3	SSE4.2
PCMPSTRM	x,x,i	3	3	3p0	10	3	SSE4.2
PCMPSTRM	x,m128,i	4	4	3p0 p23		3	SSE4.2

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Encryption instructions							
PCLMULQDQ	x,x,i	3	3	2p0 p5	7	2	CLMUL
PCLMULQDQ	x,m,i	4	4	2p0 p5 p23		2	CLMUL
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,x	1	1	p5	7	1	AES
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,m	2	2	p5 p23		1.5	AES
AESIMC	x,x	2	2	2p5	14	2	AES
AESIMC	x,m	3	3	2p5 p23		2	AES
AESKEYGENAS SIST	x,x,i	10	10	2p0 8p5	10	9	AES
AESKEYGENAS SIST	x,m,i	10	10	2p0 p23 7p5		8	AES
<b>Other</b>							
EMMS		31	31			13	

**Floating point XMM and YMM instructions**

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal through put	Comments
<b>Move instructions</b>							
MOVAPS/D	x,x	1	1	p5	0-1	1	may be elim. may be elim.
VMOVAPS/D	y,y	1	1	p5	0-1	1	
MOVAPS/D MOVUPS/D	x,m128	1	1	p23	3	0.5	AVX
VMOVAPS/D VMOVUPS/D	y,m256	1	1	p23	3	0.5	
MOVAPS/D MOVUPS/D	m128,x	1	2	p237 p4	3	1	AVX
VMOVAPS/D VMOVUPS/D	m256,y	1	2	p237 p4	4	1	
MOVSS/D	x,x	1	1	p5	1	1	AVX
MOVSS/D	x,m32/64	1	1	p23	3	0.5	
MOVSS/D	m32/64,x	1	2	p237 p4	3	1	AVX
MOVHPS/D	x,m64	1	2	p23 p5	4	1	
MOVHPS/D	m64,x	1	2	p4 p237	3	1	AVX
MOVLPS/D	x,m64	1	2	p23 p5	4	1	
MOVLPS/D	m64,x	1	2	p4 p237	3	1	AVX
MOVHLPS	x,x	1	1	p5	1	1	
MOVLHPS	x,x	1	1	p5	1	1	AVX
MOVMSKPS/D	r32,x	1	1	p0	3	1	
VMOVMSKPS/D	r32,y	1	1	p0	2	1	AVX
MOVNTPS/D	m128,x	1	2	p4 p237	~400	1	
VMOVNTPS/D	m256,y	1	2	p4 p237	~400	1	AVX
SHUFPS/D	x,x,i / v,v,v,i	1	1	p5	1	1	
SHUFPS/D	x,m,i / v,v,m,i	2	2	p5 p23		1	

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VPERMILPS/PD	v,v,i	1	1	p5	1	1	AVX
VPERMILPS/PD	v,m,i	2	2	p5 p23		1	AVX
VPERMILPS/PD	v,v,v	1	1	p5	1	1	AVX
VPERMILPS/PD	v,v,m	2	2	p5 p23		1	AVX
VPERM2F128	y,y,y,i	1	1	p5	3	1	AVX
VPERM2F128	y,y,m,i	2	2	p5 p23		1	AVX
VPERMPS	y,y,y	1	1	p5	3	1	AVX2
VPERMPS	y,y,m	1	2	p5 p23		1	AVX2
VPERMPD	y,y,i	1	1	p5	3	1	AVX2
VPERMPD	y,m,i	2	2	p5 p23		1	AVX2
BLENDPS/PD	x,x,i / v,v,v,i	1	1	p015	1	0.33	SSE4.1
BLENDPS/PD	x,m,i / v,v,m,i	2	2	p015 p23		0.5	SSE4.1
BLENDVPS/PD	x,x,xmm0	2	2	2p5	2	2	SSE4.1
BLENDVPS/PD	x,m,xmm0	3	3	2p5 p23		2	SSE4.1
VBLENDVPS/PD	v,v,v,v	2	2	2p5	2	2	AVX
VBLENDVPS/PD	v,v,m,v	3	3	2p5 p23		2	AVX
MOVDDUP	v,v	1	1	p5	1	1	SSE3
MOVDDUP	v,m	1	1	p23	3	0.5	SSE3
VBROADCASTSS	x,m32	1	1	p23	4	0.5	AVX
VBROADCASTSS	y,m32	1	1	p23	5	0.5	AVX
VBROADCASTSS	x,x	1	1	p5	1	1	AVX2
VBROADCASTSS	y,x	1	1	p5	3	1	AVX2
VBROADCASTSD	y,m64	1	1	p23	5	0.5	AVX
VBROADCASTSD	y,x	1	1	p5	3	1	AVX2
VBROADCASTF128	y,m128	1	1	p23	3	0.5	AVX
MOVSH/LDUP	v,v	1	1	p5	1	1	SSE3
MOVSH/LDUP	v,m	1	1	p23	3	0.5	SSE3
UNPCKH/LPS/D	x,x / v,v,v	1	1	p5	1	1	SSE3
UNPCKH/LPS/D	x,m / v,v,m	1	2	p5 p23		1	SSE3
EXTRACTPS	r32,x,i	2	2	p0 p5		1	SSE4.1
EXTRACTPS	m32,x,i	3	3	p0 p5 p23	4	1	SSE4.1
VEEXTRACTF128	x,y,i	1	1	p5	3	1	AVX
VEEXTRACTF128	m128,y,i	2	2	p23 p4	4	1	AVX
INSERTPS	x,x,i	1	1	p5	1	1	SSE4.1
INSERTPS	x,m32,i	2	2	p23 p5	4	1	SSE4.1
VINSERTF128	y,y,x,i	1	1	p5	3	1	AVX
VINSERTF128	y,y,m128,i	2	2	p015 p23	4	2	AVX
VMASKMOVPS/D	v,v,m	3	3	2p5 p23	4	2	AVX
VMASKMOVPS/D	m128,x,x	4	4	p0 p1 p4 p23	13	1	AVX
VMASKMOVPS/D	m256,y,y	4	4	p0 p1 p4 p23	14	2	AVX
VGATHERDPS	x,[r+s*x],x	20	20			9	AVX2
VGATHERDPS	y,[r+s*y],y	34	34			12	AVX2
VGATHERQPS	x,[r+s*x],x	15	15			8	AVX2
VGATHERQPS	x,[r+s*y],x	22	22			7	AVX2
VGATHERDPD	x,[r+s*x],x	12	12			7	AVX2
VGATHERDPD	y,[r+s*x],y	20	20			9	AVX2
VGATHERQPD	x,[r+s*x],x	14	14			7	AVX2
VGATHERQPD	y,[r+s*y],y	22	22			9	AVX2
<b>Conversion</b>							
CVTPD2PS	x,x	2	2	p1 p5	4	1	
CVTPD2PS	x,m128	2	3	p1 p5 p23		1	
VCVTPD2PS	x,y	2	2	p1 p5	5	1	AVX

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VCVTPD2PS	x,m256	2	3	p1 p5 p23		1	AVX
CVTSD2SS	x,x	2	2	p1 p5	4	1	
CVTSD2SS	x,m64	2	3	p1 p5 p23		1	
CVTPS2PD	x,x	2	2	p0 p5	2	1	
CVTPS2PD	x,m64	2	2	p0 p23		1	
VCVTPS2PD	y,x	2	2	p0 p5	5	1	AVX
VCVTPS2PD	y,m128	2	2	p0 p23		1	AVX
CVTSS2SD	x,x	2	2	p0 p5	2	1	
CVTSS2SD	x,m32	2	2	p0 p23		1	
CVTDQ2PS	x,x	1	1	p1	3	1	
CVTDQ2PS	x,m128	1	2	p1 p23		1	
VCVTDQ2PS	y,y	1	1	p1	3	1	AVX
VCVTDQ2PS	y,m256	1	2	p1 p23		1	AVX
CVT(T) PS2DQ	x,x	1	1	p1	3	1	
CVT(T) PS2DQ	x,m128	1	2	p1 p23		1	
VCVT(T) PS2DQ	y,y	1	1	p1	3	1	AVX
VCVT(T) PS2DQ	y,m256	1	2	p1 p23		1	AVX
CVTDQ2PD	x,x	2	2	p1 p5	4	1	
CVTDQ2PD	x,m64	2	2	p1 p23		1	
VCVTDQ2PD	y,x	2	2	p1 p5	6	1	AVX
VCVTDQ2PD	y,m128	2	2	p1 p23		1	AVX
CVT(T)PD2DQ	x,x	2	2	p1 p5	4	1	
CVT(T)PD2DQ	x,m128	2	3	p1 p5 p23		1	
VCVT(T)PD2DQ	x,y	2	2	p1 p5	6	1	AVX
VCVT(T)PD2DQ	x,m256	2	3	p1 p5 p23		1	AVX
CVTPI2PS	x,mm	1	1	p1	4	4	
CVTPI2PS	x,m64	1	2	p1 p23		3	
CVT(T)PS2PI	mm,x	2	2	p1 p5	4	1	
CVT(T)PS2PI	mm,m128	2	2	p1 p23		1	
CVTPI2PD	x,mm	2	2	p1 p5	4	1	
CVTPI2PD	x,m64	2	2	p1 p23		1	
CVT(T) PD2PI	mm,x	2	2	p1 p5	4	1	
CVT(T) PD2PI	mm,m128	2	3	p1 p5 p23		1	
CVTSI2SS	x,r32	2	2	p1 p5	4	3	
CVTSI2SS	x,m32	1	2	p1 p23		3	
CVT(T)SS2SI	r32,x	2	2	p0 p1	4	1	
CVT(T)SS2SI	r32,m32	2	3	p0 p1 p23		1	
CVTSI2SD	x,r32/64	2	2	p1 p5	4	3	
CVTSI2SD	x,m32	2	2	p1 p23		3	
CVT(T)SD2SI	r32/64,x	2	2	p0 p1	4	1	
CVT(T)SD2SI	r32,m64	2	3	p0 p1 p23		1	
VCVTPS2PH	x,v,i	2	2	p1 p5	4	1	F16C
VCVTPS2PH	m,v,i	4	4	p1 p4 p5 p23		1	F16C
VCVTPH2PS	v,x	2	2	p1 p5	4	1	F16C
VCVTPH2PS	v,m	2	2	p1 p23		1	F16C
<b>Arithmetic</b>							
ADDSS/D PS/D SUBSS/D PS/D	x,x / v,v,v	1	1	p1	3	1	
ADDSS/D PS/D SUBSS/D PS/D	x,m / v,v,m	1	2	p1 p23		1	
ADDSUBPS/D	x,x / v,v,v	1	1	p1	3	1	SSE3
ADDSUBPS/D	x,m / v,v,m	1	2	p1 p23		1	SSE3

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HADDPS/D							
HSUBPS/D	x,x / v,v,v	3	3	p1 2p5	5	2	SSE3
HADDPS/D							
HSUBPS/D	x,m / v,v,m	4	4	p1 2p5 p23		2	SSE3
MULSS/D PS/D	x,x / v,v,v	1	1	p01	5	0.5	
MULSS/D PS/D	x,m / v,v,m	1	2	p01 p23		0.5	
DIVSS DIVPS	x,x	1	1	p0	10-13	7	
DIVSS DIVPS	x,m	1	2	p0 p23		7	
DIVSD DIVPD	x,x	1	1	p0	10-20	8-14	
DIVSD DIVPD	x,m	1	2	p0 p23		8-14	
VDIVPS	y,y,y	3	3	2p0 p15	18-21	14	AVX
VDIVPS	y,y,m256	4	4	2p0 p15 p23		14	AVX
VDIVPD	y,y,y	3	3	2p0 p15	19-35	16-28	AVX
VDIVPD	y,y,m256	4	4	2p0 p15 p23		16-28	AVX
RCPSS/PS	x,x	1	1	p0	5	1	
RCPSS/PS	x,m128	1	2	p0 p23		1	
VRCPPS	y,y	3	3	2p0 p15	7	2	AVX
VRCPPS	y,m256	4	4	2p0 p15 p23		2	AVX
CMPccSS/D							
CMPccPS/D	x,x / v,v,v	1	1	p1	3	1	
CMPccSS/D							
CMPccPS/D	x,m / v,v,m	2	2	p1 p23		1	
(U)COMISS/D	x,x	1	1	p1		1	
(U)COMISS/D	x,m32/64	2	2	p1 p23		1	
MAXSS/D PS/D							
MINSS/D PS/D	x,x / v,v,v	1	1	p1	3	1	
MAXSS/D PS/D							
MINSS/D PS/D	x,m / v,v,m	1	2	p1 p23		1	
ROUNDSS/D PS/D	v,v,i	2	2	2p1	6	2	SSE4.1
ROUNDSS/D PS/D	v,m,i	3	3	2p1 p23		2	SSE4.1
DPPS	x,x,i / v,v,v,i	4	4	2p0 p1 p5	14	2	SSE4.1
DPPS	x,m,i / v,v,m,i	6	6	2p0 p1 p5 p23 p6		4	SSE4.1
DPPD	x,x,i	3	3	p0 p1 p5	9	1	SSE4.1
DPPD	x,m128,i	4	4	p0 p1 p5 p23		1	SSE4.1
VFMADD...							
(all FMA instr.)	v,v,v	1	1	p01	5	0.5	FMA
VFMADD...							
(all FMA instr.)	v,v,m	1	2	p01 p23		0.5	FMA
<b>Math</b>							
SQRTSS/PS	x,x	1	1	p0	11	7	
SQRTSS/PS	x,m128	1	2	p0 p23		7	
VSQRTPS	y,y	3	3	2p0 p15	19	14	AVX
VSQRTPS	y,m256	4	4	2p0 p15 p23		14	AVX
SQRTSD/PD	x,x	1	1	p0	16	8-14	
SQRTSD/PD	x,m128	1	2	p0 p23		8-14	
VSQRTPD	y,y	3	3	2p0 p15	28-29	16-28	AVX
VSQRTPD	y,m256	4	4	2p0 p15 p23		16-28	AVX
RSQRTSS/PS	x,x	1	1	p0	5	1	
RSQRTSS/PS	x,m128	1	2	p0 p23		1	
VRSQRTPS	y,y	3	3	2p0 p15	7	2	AVX

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VRSQRTPS	y,m256	4	4	2p0 p15 p23		2	AVX
<b>Logic</b>							
AND/ANDN/OR/XORPS/PD	x,x / v,v,v	1	1	p5	1	1	
AND/ANDN/OR/XORPS/PD	x,m / v,v,m	1	2	p5 p23		1	
<b>Other</b>							
VZEROUPPER		4	4	none		1	AVX
VZEROALL		12	12	none		10	AVX, 32 bit
VZEROALL		20	20	none		8	AVX, 64 bit
LDMXCSR	m32	3	3	p0 p6 p23	6	3	
STMXCSR	m32	3	4	p0 p4 p6 p237	7	1	
VSTMXCSR	m32	3				1	AVX
FXSAVE	m4096	130				68	
FXRSTOR	m4096	116				72	
XSAVE		224				84	
XRSTOR		173				111	
XSAVEOPT	m						

## Intel Broadwell

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

**Instruction:** Name of instruction. Multiple names mean that these instructions have the same data. Instructions with or without V name prefix behave the same unless otherwise noted.

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, v = any vector register (mmx, xmm, ymm). same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.

**$\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename and allocate stages in the pipeline. Fused  $\mu$ ops count as one.

**$\mu$ ops unfused domain:** The total number of  $\mu$ ops for all execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if this number is higher than the number under fused domain. Some operations are not counted here if they do not go to any execution port or if the counters are inaccurate.

**$\mu$ ops each port:** The number of  $\mu$ ops for each execution port. p0 means a  $\mu$ op to execution port 0. p01 means a  $\mu$ op that can go to either port 0 or port 1. p0 p1 means two  $\mu$ ops going to port 0 and 1, respectively.

Port 0: Integer, f.p. and vector ALU, mul, div, branch

Port 1: Integer, f.p. and vector ALU

Port 2: Load

Port 3: Load

Port 4: Store

Port 5: Integer and vector ALU

Port 6: Integer ALU, branch

Port 7: Store address

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Where hyperthreading is enabled, the use of the same execution units in the other thread leads to inferior performance. Denormal numbers, NAN's and infinity do not increase the latency. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

### Integer instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOV	r,i	1	1	p0156		0.25	
MOV	r8/16,r8/16	1	1	p0156	1	0.25	
MOV	r32/64,r32/64	1	1	p0156	0-1	0.25	may be elim.
MOV	r8l,m	1	2	p23 p0156		0.5	
MOV	r8h,m	1	1	p23		0.5	
MOV	r16,m	1	2	p23 p0156		0.5	
MOV	r32/64,m	1	1	p23	2	0.5	all addressing modes
MOV	m,r	1	2	p237 p4	3	1	

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MOV	m,i	1	2	p237 p4		1	
MOVNTI	m,r	2	2	p23 p4	~400	1	
MOVSX MOVZX	r,r	1	1	p0156	1	0.25	
MOVSXD							
MOVSX MOVZX	r16,m8	1	2	p23 p0156		0.5	
MOVSX MOVZX	r,m	1	1	p23		0.5	all other combinations
MOVSXD							
CMOVcc	r,r	1	1	p06	1	0.5	
CMOVcc	r,m	2	2	p06 p23		0.5	
XCHG	r,r	3	3	3p0156	2	1	
XCHG	r,m	8	8		21		implicit lock
XLAT		3	3	p23 2p0156	7	2	
PUSH	r	1	2	p237 p4	3	1	
PUSH	i	1	2	p237 p4		1	
PUSH	m	2	3	p4 2p237		1	
PUSH	stack pointer	2	3	p0156 p237 p4		1	
PUSHF(D/Q)		3	4	p1 p4 p237 p06		1	
PUSHA(D)		11	19			8	not 64 bit
POP	r	1	1	p23	2	0.5	
POP	stack pointer	3	3	p23 2p0156		4	
POP	m	2	3	2p237 p4		1	
POPF(D/Q)		9	9			18	
POPA(D)		18	18			8	not 64 bit
LAHF SAHF		1	1	p06	1	1	
SALC		3	3	3p0156	1	1	not 64 bit
LEA	r16,m	2	2	p1 p05	2-4	1	16 or 32 bit address size
LEA	r32/64,m	1	1	p15	1	0.5	1 or 2 components in address
LEA	r32/64,m	1	1	p1	3	1	3 components in address
LEA	r32/64,m	1	1	p1		1	rip relative address
BSWAP	r32	1	1	p15	1	0.5	
BSWAP	r64	2	2	p06 p15	2	1	
MOVBE	r16,m16	3	3	2p0156 p23		0.5-1	MOVBE
MOVBE	r32,m32	2	2	p15 p23		0.5	MOVBE
MOVBE	r64,m64	3	3	2p0156 p23		0.5	MOVBE
MOVBE	m16,r16	2	3	p06 p237 p4		1	MOVBE
MOVBE	m32,r32	2	3	p15 p237 p4		1	MOVBE
MOVBE	m64,r64	3	4	p06 p15 p237 p4		1	MOVBE
PREFETCHNTA/0/1/2	m	1	1	p23		0.5	
PREFETCHW	m	1	1	p23		1	PREFETCHW
LFENCE		2		none counted		4	
MFENCE		3	3	p23 p4		33	
SFENCE		2	2	p23 p4		6	
<b>Arithmetic instructions</b>							
ADD SUB	r,r/i	1	1	p0156	1	0.25	



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ADD SUB	r,m	1	2	p0156 p23		0.5	
ADD SUB	m,r/i	2	4	2p0156 2p237 p4	6	1	
ADC SBB	r,r/i	1	1	p06	1	1	
ADC SBB	r,m	2	2	p06 p23		1	
ADC SBB	m,r/i	4	6	3p0156 2p237 p4	7	2	
CMP	r,r/i	1	1	p0156	1	0.25	
CMP	m,r/i	1	2	p0156 p23	1	0.5	
INC DEC NEG NOT	r	1	1	p0156	1	0.25	
INC DEC NOT	m	3	4	p0156 2p237 p4	6	1	
NEG	m	2	4	p0156 2p237 p4	6	1	
AAA		2	2	p1 p56	4		not 64 bit
AAS		2	2	p1 p056	6		not 64 bit
DAA DAS		3	3	p1 2p056	4		not 64 bit
AAD		3	3	p1 2p056	6		not 64 bit
AAM		8	8	p0 p1 p5 p6	21	7	not 64 bit
MUL IMUL	r8	1	1	p1	3	1	
MUL IMUL	r16	4	4	p1 p0156	4	2	
MUL IMUL	r32	3	3	p1 p0156	4	2	
MUL IMUL	r64	2	2	p1 p6	3	1	
MUL IMUL	m8	1	2	p1 p23		1	
MUL IMUL	m16	4	5	p1 3p0156 p23		2	
MUL IMUL	m32	3	4	p1 2p0156 p23		2	
MUL IMUL	m64	2	3	p1 p6 p23		1	
IMUL	r,r	1	1	p1	3	1	
IMUL	r,m	1	2	p1 p23		1	
IMUL	r16,r16,i	2	2	p1 p0156	4	1	
IMUL	r32,r32,i	1	1	p1	3	1	
IMUL	r64,r64,i	1	1	p1	3	1	
IMUL	r16,m16,i	2	3	p1 p0156 p23		1	
IMUL	r32,m32,i	1	2	p1 p23		1	
IMUL	r64,m64,i	1	2	p1 p23		1	
MULX	r32,r32,r32	3	3	p1 2p056	4	1	BMI2
MULX	r32,r32,m32	3	4	p1 2p056 p23		1	BMI2
MULX	r64,r64,r64	2	2	p1 p5	4	1	BMI2
MULX	r64,r64,m64	2	3	p1 p6 p23		1	BMI2
DIV	r8	9	9	p0 p1 p5 p6	22-25	9	
DIV	r16	11	11	p0 p1 p5 p6	23-26	9	
DIV	r32	10	10	p0 p1 p5 p6	22-29	9	
DIV	r64	36	36	p0 p1 p5 p6	32-95	21-73	
IDIV	r8	9	9	p0 p1 p5 p6	23-26	6	
IDIV	r16	10	10	p0 p1 p5 p6	23-26	6	
IDIV	r32	9	9	p0 p1 p5 p6	22-29	6	
IDIV	r64	59	59	p0 p1 p5 p6	39-103	24-81	
CBW		1	1	p0156	1		
CWDE		1	1	p0156	1		
CDQE		1	1	p0156	1		
CWD		2	2	p0156	1		
CDQ		1	1	p06	1		
CQO		1	1	p06	1		

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POPCNT	r,r	1	1	p1	3	1	SSE4.2
POPCNT	r,m	1	2	p1 p23		1	SSE4.2
CRC32	r,r	1	1	p1	3	1	SSE4.2
CRC32	r,m	1	2	p1 p23		1	SSE4.2
<b>Logic instructions</b>							
AND OR XOR	r,r/i	1	1	p0156	1	0.25	
AND OR XOR	r,m	1	2	p0156 p23		0.5	
AND OR XOR	m,r/i	2	4	2p0156 2p237 p4	6	1	
TEST	r,r/i	1	1	p0156	1	0.25	
TEST	m,r/i	1	2	p0156 p23	1	0.5	
SHR SHL SAR	r,i	1	1	p06	1	0.5	
SHR SHL SAR	m,i	3	4	2p06 p237 p4		2	
SHR SHL SAR	r,cl	3	3	3p06	2	2	
SHR SHL SAR	m,cl	5	6	3p06 2p23 p4		4	
ROR ROL	r,1	2	2	2p06	1	1	short form
ROR ROL	r,i	1	1	p06	1	0.5	
ROR ROL	m,i	4	5	2p06 2p237 p4		2	
ROR ROL	r,cl	3	3	3p06	2	2	
ROR ROL	m,cl	5	6	3p06 p23 p4		4	
RCR RCL	r,1	3	3	2p06 p0156	2	2	
RCR RCL	m,1	4	6			3	
RCR RCL	r,i	8	8	p0156	6	6	
RCR RCL	m,i	11	11			6	
RCR RCL	r,cl	8	8	p0156	6	6	
RCR RCL	m,cl	11	11			6	
SHRD SHLD	r,r,i	1	1	p1	3	1	
SHRD SHLD	m,r,i	3	5			2	
SHLD	r,r,cl	4	4	p0156	3	2	
SHRD	r,r,cl	4	4	p0156	4	2	
SHRD SHLD	m,r,cl	5	7			4	
SHLX SHRX SARX	r,r,r	1	1	p06	1	0.5	BMI2
SHLX SHRX SARX	r,m,r	2	2	p06 p23		0.5	BMI2
RORX	r,r,i	1	1	p06	1	0.5	BMI2
RORX	r,m,i	2	2	p06 p23		0.5	BMI2
BT	r,r/i	1	1	p06	1	0.5	
BT	m,r	10	10			5	
BT	m,i	2	2	p06 p23		0.5	
BTR BTS BTC	r,r/i	1	1	p06	1	0.5	
BTR BTS BTC	m,r	10	10			5	
BTR BTS BTC	m,i	2	2	p06 p23		0.5	
BSF BSR	r,r	1	1	p1	3	1	
BSF BSR	r,m	1	2	p1 p23		1	
SETcc	r	1	1	p06	1	0.5	
SETcc	m	2	3	p06 p237 p4		1	
CLC		1	0	none		0.25	
STC		1	1	p0156		0.25	
CMC		1	1	p0156	1	1	
CLD STD		3	3	p15 p6		4	
LZCNT	r,r	1	1	p1	3	1	LZCNT
LZCNT	r,m	1	2	p1 p23		1	LZCNT

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TZCNT	r,r	1	1	p1	3	1	BMI1
TZCNT	r,m	1	2	p1 p23		1	BMI1
ANDN	r,r,r	1	1	p15	1	0.5	BMI1
ANDN	r,r,m	1	2	p15 p23	1	0.5	BMI1
BLSI BLSMSK BLSR	r,r	1	1	p15	1	0.5	BMI1
BLSI BLSMSK BLSR	r,m	1	2	p15 p23		0.5	BMI1
BEXTR	r,r,r	2	2	2p0156	2	0.5	BMI1
BEXTR	r,m,r	3	3	2p0156 p23		1	BMI1
BZHI	r,r,r	1	1	p15	1	0.5	BMI2
BZHI	r,m,r	1	2	p15 p23		0.5	BMI2
PDEP	r,r,r	1	1	p1	3	1	BMI2
PDEP	r,r,m	1	2	p1 p23		1	BMI2
PEXT	r,r,r	1	1	p1	3	1	BMI2
PEXT	r,r,m	1	2	p1 p23		1	BMI2
<b>Control transfer instructions</b>							
JMP	short/near	1	1	p6		1-2	
JMP	r	1	1	p6		2	
JMP	m	1	2	p23 p6		2	
Conditional jump	short/near	1	1	p6		1-2	predicted taken
Conditional jump	short/near	1	1	p06		0.5-1	predicted not taken
Fused arithmetic and branch		1	1	p6		1-2	predicted taken
Fused arithmetic and branch		1	1	p06		0.5-1	predicted not taken
J(E/R)CXZ	short	2	2	p0156 p6		0.5-2	
LOOP	short	7	7			5	
LOOP(N)E	short	11	11			6	
CALL	near	2	3	p237 p4 p6		2	
CALL	r	2	3	p237 p4 p6		2	
CALL	m	3	4	2p237 p4 p6		3	
RET		1	2	p237 p6		1	
RET	i	3	4	p23 2p6 p015		2	
BOUND	r,m	15	15			8	not 64 bit
INTO		4	4			5	not 64 bit
<b>String instructions</b>							
LODSB/W		3	3	2p0156 p23		1	
LODSD/Q		2	2	p0156 p23		1	
REP LODS		5n+12				~2n	
STOS		3	3	p23 p0156 p4		1	
REP STOS		<2n				~0.5n	worst case
REP STOS		2.6/32B				1/32B	best case aligned by 32
MOVS		5	5	2p23 p4 2p0156		4	
REP MOVS		~2n				< 1n	worst case
REP MOVS		4/32B				1/32B	best case aligned by 32

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SCAS		3	3	p23 2p0156		1	
REP SCAS		≥6n				≥2n	
CMPS		5	5	2p23 3p0156		4	
REP CMPS		≥8n				≥2n	
<b>Synchronization instructions</b>							
XADD	m,r	4	5			6	
LOCK XADD	m,r	9	9			21	
LOCK ADD	m,r	8	8			21	
CMPXCHG	m,r	5	6			7	
LOCK CMPXCHG	m,r	10	10			21	
CMPXCHG8B	m,r	15	15			8	
LOCK CMPXCHG8B	m,r	19	19			21	
CMPXCHG16B	m,r	22	22			15	
LOCK CMPXCHG16B	m,r	24	24			27	
<b>Other</b>							
NOP (90)		1	0	none		0.25	
Long NOP (0F 1F)		1	0	none		0.25	
PAUSE		5	5	p05 3p6		9	
ENTER	a,0	12	12			8	
ENTER	a,b	~14+7b	~45+7b		~87+2b		
LEAVE		3	3	2p0156 p23		5	
XGETBV		8	8			5	XGETBV
RDTSC		15	15			24	
RDTSCP		21	21			30	RDTSCP
RDPMC		34	34			37	
RDRAND	r	16	16	p23 15p0156		~230	RDRAND
RDSEED	r	16	16	p23 15p0156		~230	RDSEED

## Floating point x87 instructions

Instruction	Operands	μops fused domain	μops unfused domain	μops each port	Latency	Reciprocal through put	Comments
<b>Move instructions</b>							
FLD	r	1	1	p01	1	0.5	
FLD	m32/64	1	1	p23	3	0.5	
FLD	m80	4	4	2p01 2p23	4	2	
FBLD	m80	43	43		47	22	
FST(P)	r	1	1	p01	1	0.5	
FST(P)	m32/m64	1	2	p4 p237	4	1	
FSTP	m80	7	7	3p0156 2p23 2p4	5	5	
FBSTP	m80	238	226		269	267	
FXCH	r	2	0	none	0	0.5	
FILD	m	1	2	p01 p23	6	1	
FIST(P)	m	3	3	p1 p23 p4	7	1	
FISTTP	m	3	3	p1 p23 p4	7	2	SSE3
FLDZ		1	1	p01		1	
FLD1		2	2	2p01		2	

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FLDPI FLDL2E etc.		2	2	2p01		2
FCMOVcc	r	3	3	2p0 p5	2	2
FNSTSW	AX	2	2	p0 p0156	6	1
FNSTSW	m16	2	3	p0 p4 p237	6	1
FLDCW	m16	3	3	p01 p23 p6	7	2
FNSTCW	m16	2	3	p237 p4 p6	6	1
FINCSTP FDECSTP		1	1	p01	0	0.5
FFREE(P)	r	1	1	p01		0.5
FNSAVE	m	152	152		173	173
FRSTOR	m	95	95		175	175
<b>Arithmetic instructions</b>						
FADD(P)						
FSUB(R)(P)	r	1	1	p1	3	1
FADD(P)						
FSUB(R)(P)	m	1	2	p1 p23		1
FMUL(P)	r	1	1	p0	5	1
FMUL(P)	m	1	2	p0 p23		1
FDIV(R)(P)	r	1	1	p0	10-15	4-5
FDIV(R)(P)	m	1	2	p0 p23		4-5
FABS		1	1	p0	1	1
FCHS		1	1	p0	1	1
FCOM(P) FUCOM	r	1	1	p1	3	1
FCOM(P) FUCOM	m	1	2	p1 p23		1
FCOMPP FUCOMPP		2	2	2p01		1
FCOMI(P)						
FUCOMI(P)	r	3	3	3p01	7	1.5
FIADD FISUB(R)	m	2	3	2p1 p23		2
FIMUL	m	2	3	p0 p1 p23		2
FIDIV(R)	m	2	3	p0 p1 p23		
FICOM(P)	m	2	3	2p1 p23		2
FTST		1	1	p1	3	1
FXAM		2	2	2p1	6	2
FPREM		28	28		20-24	13
FPREM1		28	28		23-48	13
FRNDINT		17	17		11	23
<b>Math</b>						
FSCALE		27	27		125	130
FEXTRACT		17	17		12	11
FSQRT		1	1	p0	10-23	4-9
FSIN		75-100			48-106	
FCOS		70-100			49-112	
FSINCOS		70-110			52-124	
F2XM1		16-86			63-68	
FYL2X		55-96			92	
FYL2XP1		56			74	
FPTAN		71-102			132	
FPATAN		27-71			97-147	
<b>Other</b>						
FNOP		1	1	p01		0.5

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WAIT		2	2	p01		1
FNCLEX		5	5	p0156		22
FNINIT		26	26			84

## Integer vector instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOVD	r32/64,(x)mm	1	1	p0	1	1	
MOVD	m32/64,(x)mm	1	2	p237 p4	3	1	
MOVD	(x)mm,r32/64	1	1	p5	1	1	
MOVD	(x)mm,m32/64	1	1	p23	3	0.5	
MOVQ	r64,(x)mm	1	1	p0	1	1	
MOVQ	(x)mm,r64	1	1	p5	1	1	
MOVQ	(x)mm,(x)mm	1		p015	1	0.33	
MOVQ	(x)mm,m64	1	1	p23	3	0.5	
MOVQ	m64, (x)mm	1	2	p237 p4	3	1	
MOVDQA/U	x,x	1	1	p015	0-1	0.25	may be elim.
MOVDQA/U	x, m128	1	1	p23	3	0.5	
MOVDQA/U	m128, x	1	2	p237 p4	3	1	
VMOVDQA/U	y,y	1	1	p015	0-1	0.25	AVX may be elim.
VMOVDQA/U	y,m256	1	1	p23	3	0.5	AVX
VMOVDQA/U	m256,y	1	2	p237 p4	4	1	AVX
LDDQU	x, m128	1	1	p23	3	0.5	SSE3
MOVDQ2Q	mm, x	2	2	p01 p5	1	1	
MOVQ2DQ	x,mm	1	1	p015	1	0.33	
MOVNTQ	m64,mm	1	2	p237 p4	~400	1	
MOVNTDQ	m128,x	1	2	p237 p4	~400	1	
VMOVNTDQ	m256,y	1	2	p237 p4	~400	1	AVX2
MOVNTDQA	x, m128	1	1	p23	3	0.5	SSE4.1
VMOVNTDQA	y,m256	1	1	p23	3	0.5	AVX2
PACKSSWB/DW							
PACKUSWB	mm,mm	3	3	p5	2	2	
PACKSSWB/DW							
PACKUSWB	mm,m64	3	3	p23 2p5		2	
PACKSSWB/DW							
PACKUSWB	x,x / y,y,y	1	1	p5	1	1	
PACKSSWB/DW							
PACKUSWB	x,m / y,y,m	1	2	p23 p5		1	
PACKUSDW	x,x / y,y,y	1	1	p5	1	1	SSE4.1
PACKUSDW	x,m / y,y,m	1	2	p23 p5		1	SSE4.1
PUNPCKH/L							
BW/WD/DQ	v,v / v,v,v	1	1	p5	1	1	
PUNPCKH/L							
BW/WD/DQ	v,m / v,v,m	1	2	p23 p5		1	
PUNPCKH/L							
QDQ	x,x / y,y,y	1	1	p5	1	1	
PUNPCKH/L							
QDQ	x,m / y,y,m	2	2	p23 p5		1	

## Broadwell

PMOVSX/ZX BW BD BQ DW DQ	x,x	1	1	p5	1	1	SSE4.1
PMOVSX/ZX BW BD BQ DW DQ	x,m	1	2	p23 p5		1	SSE4.1
VPMOVSX/ZX BW BD BQ DW DQ	y,x	1	1	p5	3	1	AVX2
VPMOVSX/ZX BW BD BQ DW DQ	y,m	2	2	p5 p23		1	AVX2
PSHUFB	v,v / v,v,v	1	1	p5	1	1	SSSE3
PSHUFB	v,m / v,v,m	2	2	p23 p5		1	SSSE3
PSHUFW	mm,mm,i	1	1	p5	1	1	
PSHUFW	mm,m64,i	2	2	p23 p5		1	
PSHUFD	v,v,i	1	1	p5	1	1	
PSHUFD	v,m,i	2	2	p23 p5		1	
PSHUFL/HW	v,v,i	1	1	p5	1	1	
PSHUFL/HW	v,m,i	2	2	p23 p5		1	
PALIGNR	v,v,i / v,v,v,i	1	1	p5	1	1	SSSE3
PALIGNR	v,m,i / v,v,m,i	2	2	p23 p5		1	SSSE3
PBLENDVB	x,x,xmm0	2	2	2p5	2	2	SSE4.1
PBLENDVB	x,m,xmm0	3	3	2p5 p23		2	SSE4.1
VPBLENDVB	v,v,v,v	2	2	2p5	2	2	AVX2
VPBLENDVB	v,v,m,v	3	3	2p5 p23		2	AVX2
PBLENDW	x,x,i / v,v,v,i	1	1	p5	1	1	SSE4.1
PBLENDW	x,m,i / v,v,m,i	2	2	p23 p5		1	SSE4.1
VPBLEND	v,v,v,i	1	1	p015	1	0.33	AVX2
VPBLEND	v,v,m,i	2	2	p015 p23		0.5	AVX2
VPERMD	y,y,y	1	1	p5	3	1	AVX2
VPERMD	y,y,m	1	2	p5 p23		1	AVX2
VPERMQ	y,y,i	1	1	p5	3	1	AVX2
VPERMQ	y,m,i	2	2	p5 p23		1	AVX2
VPERM21128	y,y,y,i	1	1	p5	3	1	AVX2
VPERM21128	y,y,m,i	2	2	p5 p23		1	AVX2
MASKMOVQ	mm,mm	4	4	p0 p4 2p23	18-500	1	
MASKMOVQ	x,x	10	10	4p04 2p56 4p23	18-500	6	
VPMASKMOVQ	v,v,m	3	3	p23 2p5	4	2	AVX2
VPMASKMOVQ	m,v,v	4	4	p0 p1 p4 p23	15	1	AVX2
PMOVMASKB	r,v	1	1	p0	3	1	
PEXTRB/W/D/Q	r32,x,i	2	2	p0 p5	2	1	SSE4.1
PEXTRB/W/D/Q	m8,x,i	2	3	p23 p4 p5		1	SSE4.1
VEXTRACT1128	x,y,i	1	1	p5	3	1	AVX2
VEXTRACT1128	m,y,i	2	2	p23 p4	4	1	AVX2
PINSRB	x,r32,i	2	2	p5	2	2	SSE4.1
PINSRB	x,m8,i	2	2	p23 p5		1	SSE4.1
PINSRW	(x)mm,r32,i	2	2	p5	2	2	
PINSRW	(x)mm,m16,i	2	2	p23 p5		1	
PINSRD/Q	x,r32,i	2	2	p5	2	2	SSE4.1
PINSRD/Q	x,m32,i	2	2	p23 p5		1	SSE4.1
VINSERT1128	y,y,x,i	1	1	p5	3	1	AVX2
VINSERT1128	y,y,m,i	2	2	p015 p23	4	0.5	AVX2
VPBROADCAST B/W/D/Q	x,x	1	1	p5	1	1	AVX2
VPBROADCAST B/W	x,m8/16	3	3	p01 p23 p5	5	1	AVX2

## Broadwell

VPBROADCAST D/Q	x,m32/64	1	1	p23	4	0.5	AVX2
VPBROADCAST B/W/D/Q	y,x	1	1	p5	3	1	AVX2
VPBROADCAST B/W	y,m8/16	3	3	p01 p23 p5	7	1	AVX2
VPBROADCAST D/Q	y,m32/64	1	1	p23	5	0.5	AVX2
VPBROADCASTI128	y,m128	1	1	p23	3	0.5	AVX2
VPGATHERDD	x,[r+s*x],x	10	10			6	AVX2
VPGATHERDD	y,[r+s*y],y	14	14			7	AVX2
VPGATHERQD	x,[r+s*x],x	9	9			6	AVX2
VPGATHERQD	x,[r+s*y],x	10	10			6	AVX2
VPGATHERDQ	x,[r+s*x],x	7	7			5	AVX2
VPGATHERDQ	y,[r+s*x],y	9	9			6	AVX2
VPGATHERQQ	x,[r+s*x],x	7	7			5	AVX2
VPGATHERQQ	y,[r+s*y],y	9	9			6	AVX2
<b>Arithmetic instructions</b>							
PADD/SUB(S,US) B/W/D/Q	v,v / v,v,v	1	1	p15	1	0.5	
PADD/SUB(S,US) B/W/D/Q	v,m / v,v,m	1	2	p15 p23		0.5	
PHADD(S)W/D							
PHSUB(S)W/D	v,v / v,v,v	3	3	p1 2p5	3	2	SSSE3
PHADD(S)W/D							
PHSUB(S)W/D	v,m / v,v,m	4	4	p1 2p5 p23		2	SSSE3
PCMPEQB/W/D							
PCMPGTB/W/D	v,v / v,v,v	1	1	p15	1	0.5	
PCMPEQB/W/D							
PCMPGTB/W/D	v,m / v,v,m	1	2	p15 p23		0.5	
PCMPEQQ	v,v / v,v,v	1	1	p15	1	0.5	SSE4.1
PCMPEQQ	v,m / v,v,m	1	2	p15 p23		0.5	SSE4.1
PCMPGTQ	v,v / v,v,v	1	1	p0	5	1	SSE4.2
PCMPGTQ	v,m / v,v,m	1	2	p0 p23		1	SSE4.2
PMULL/HW							
PMULHUW	v,v / v,v,v	1	1	p0	5	1	
PMULL/HW							
PMULHUW	v,m / v,v,m	1	2	p0 p23		1	
PMULHRWS	v,v / v,v,v	1	1	p0	5	1	SSSE3
PMULHRWS	v,m / v,v,m	1	2	p0 p23		1	SSSE3
PMULLD	x,x / y,y,y	2	2	2p0	10	2	SSE4.1
PMULLD	x,m / y,y,m	3	3	2p0 p23		2	SSE4.1
PMULDQ	x,x / y,y,y	1	1	p0	5	1	SSE4.1
PMULDQ	x,m / y,y,m	1	2	p0 p23		1	SSE4.1
PMULUDQ	v,v / v,v,v	1	1	p0	5	1	
PMULUDQ	v,m / v,v,m	1	2	p0 p23		1	
PMADDWD	v,v / v,v,v	1	1	p0	5	1	
PMADDWD	v,m / v,v,m	1	2	p0 p23		1	
PMADDUBSW	v,v / v,v,v	1	1	p0	5	1	SSSE3
PMADDUBSW	v,m / v,v,m	1	2	p0 p23		1	SSSE3
PAVGB/W	v,v / v,v,v	1	1	p15	1	0.5	
PAVGB/W	v,m / v,v,m	1	2	p15 p23		0.5	



## Broadwell

PMIN/PMAX SB/SW/SD UB/UW/UD	x,x / y,y,y	1	1	p15	1	0.5	SSE4.1
PMIN/PMAX SB/SW/SD UB/UW/UD	x,m / y,y,m	1	2	p15 p23		0.5	SSE4.1
PHMINPOSUW	x,x	1	1	p0	5	1	SSE4.1
PHMINPOSUW	x,m128	1	2	p0 p23		1	SSE4.1
PABSB/W/D	v,v	1	1	p15	1	0.5	SSSE3
PABSB/W/D	v,m	1	2	p15 p23		0.5	SSSE3
PSIGNB/W/D	v,v / v,v,v	1	1	p15	1	0.5	SSSE3
PSIGNB/W/D	v,m / v,v,m	1	2	p15 p23		0.5	SSSE3
PSADBW	v,v / v,v,v	1	1	p0	5	1	
PSADBW	v,m / v,v,m	1	2	p0 p23		1	
MPSADBW	x,x,i / v,v,v,i	3	3	p0 2p5	6	2	SSE4.1
MPSADBW	x,m,i / v,v,m,i	4	4	p0 2p5 p23		2	SSE4.1
<b>Logic instructions</b>							
PAND PANDN POR PXOR	v,v / v,v,v	1	1	p015	1	0.33	
PAND PANDN POR PXOR	v,m / v,v,m	1	2	p015 p23		0.5	
PTEST	v,v	2	2	p0 p5	2	1	SSE4.1
PTEST	v,m	2	3	p0 p5 p23		1	SSE4.1
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	mm,mm	1	1	p0	1	1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	mm,m64	1	2	p0 p23		1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	x,x / v,v,x	2	2	p0 p5	2	1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	x,m / v,v,m	2	2	p0 p23		1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	v,i / v,v,i	1	1	p0	1	1	
VPSLLVD/Q VPSRAVD VPSRLVD/Q	v,v,v	3	3	2p0 p5	2	2	AVX2
VPSLLVD/Q VPSRAVD VPSRLVD/Q	v,v,m	4	4	2p0 p5 p23		2	AVX2
PSLLDQ PSRLDQ	x,i / v,v,i	1	1	p5	1	1	
<b>String instructions</b>							
PCMPSTR	x,x,i	8	8	6p05 2p16	4	4	SSE4.2
PCMPSTR	x,m128,i	8	8	3p0 2p16 2p5 p23		4	SSE4.2
PCMPSTRM	x,x,i	9	9	3p0 2p16 4p5	11	11	SSE4.2

## Broadwell

PCMPESTRM	x,m128,i	9	9	6p05 2p16 p23		5	SSE4.2
PCMPISTRI	x,x,i	3	3	3p0	3	3	SSE4.2
PCMPISTRI	x,m128,i	4	4	3p0 p23		3	SSE4.2
PCMPISTRM	x,x,i	3	3	3p0	11	11	SSE4.2
PCMPISTRM	x,m128,i	4	4	3p0 p23		3	SSE4.2
<b>Encryption instructions</b>							
PCLMULQDQ	x,x,i	1	1	p0	5	1	CLMUL
PCLMULQDQ	x,m,i	2	2	p0 p23		1	CLMUL
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,x	1	1	p5	7	1	AES
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,m	2	2	p5 p23		1.5	AES
AESIMC	x,x	2	2	2p5	14	2	AES
AESIMC	x,m	3	3	2p5 p23		2	AES
AESKEYGENAS SIST	x,x,i	10	10	2p0 8p5	10	9	AES
AESKEYGENAS SIST	x,m,i	10	10	2p0 p23 7p5		8	AES
<b>Other</b>							
EMMS		31	31			12	

## Floating point XMM and YMM instructions

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal through put	Comments
<b>Move instructions</b>							
MOVAPS/D	x,x	1	1	p5	0-1	1	may be elim. may be elim.
VMOVAPS/D	y,y	1	1	p5	0-1	1	
MOVUPS/D	x,m128	1	1	p23	3	0.5	AVX
VMOVUPS/D	y,m256	1	1	p23	3	0.5	
MOVAPS/D	m128,x	1	2	p237 p4	3	1	AVX
VMOVAPS/D	m256,y	1	2	p237 p4	4	1	
MOVSS/D	x,x	1	1	p5	1	1	0.5
MOVSS/D	x,m32/64	1	1	p23	3	0.5	
MOVSS/D	m32/64,x	1	2	p237 p4	3	1	1
MOVHPS/D	x,m64	1	2	p23 p5	4	1	
MOVHPS/D	m64,x	1	2	p4 p237	3	1	1
MOVLPD/D	x,m64	1	2	p23 p5	4	1	
MOVLPD/D	m64,x	1	2	p4 p237	3	1	1
MOVHLPS	x,x	1	1	p5	1	1	
MOVLHPS	x,x	1	1	p5	1	1	

## Broadwell

MOVMSKPS/D	r32,x	1	1	p0	3	1	
VMOVMSKPS/D	r32,y	1	1	p0	3	1	
MOVNTPS/D	m128,x	1	2	p4 p237	~400	1	
VMOVNTPS/D	m256,y	1	2	p4 p237	~400	1	AVX
SHUFPS/D	x,x,i / v,v,v,i	1	1	p5	1	1	
SHUFPS/D	x,m,i / v,v,m,i	2	2	p5 p23		1	
VPERMILPS/PD	v,v,i	1	1	p5	1	1	AVX
VPERMILPS/PD	v,m,i	2	2	p5 p23		1	AVX
VPERMILPS/PD	v,v,v	1	1	p5	1	1	AVX
VPERMILPS/PD	v,v,m	2	2	p5 p23		1	AVX
VPERM2F128	y,y,y,i	1	1	p5	3	1	AVX
VPERM2F128	y,y,m,i	2	2	p5 p23		1	AVX
VPERMPS	y,y,y	1	1	p5	3	1	AVX2
VPERMPS	y,y,m	1	2	p5 p23		1	AVX2
VPERMPD	y,y,i	1	1	p5	3	1	AVX2
VPERMPD	y,m,i	2	2	p5 p23		1	AVX2
BLENDPS/PD	x,x,i / v,v,v,i	1	1	p015	1	0.33	SSE4.1
BLENDPS/PD	x,m,i / v,v,m,i	2	2	p015 p23		0.5	SSE4.1
BLENDVPS/PD	x,x,xmm0	2	2	2p5	2	2	SSE4.1
BLENDVPS/PD	x,m,xmm0	3	3	2p5 p23		2	SSE4.1
VBLENDVPS/PD	v,v,v,v	2	2	2p5	2	2	AVX
VBLENDVPS/PD	v,v,m,v	3	3	2p5 p23		2	AVX
MOVDDUP	v,v	1	1	p5	1	1	SSE3
MOVDDUP	v,m	1	1	p23	3	0.5	SSE3
VBROADCASTSS	x,m32	1	1	p23	4	0.5	AVX
VBROADCASTSS	y,m32	1	1	p23	5	0.5	AVX
VBROADCASTSS	x,x	1	1	p5	1	1	AVX2
VBROADCASTSS	y,x	1	1	p5	3	1	AVX2
VBROADCASTSD	y,m64	1	1	p23	5	0.5	AVX
VBROADCASTSD	y,x	1	1	p5	3	1	AVX2
VBROADCASTF128	y,m128	1	1	p23	4	0.5	AVX
MOVSH/LDUP	v,v	1	1	p5	1	1	SSE3
MOVSH/LDUP	v,m	1	1	p23	3	0.5	SSE3
UNPCKH/LPS/D	x,x / v,v,v	1	1	p5	1	1	SSE3
UNPCKH/LPS/D	x,m / v,v,m	1	2	p5 p23		1	SSE3
EXTRACTPS	r32,x,i	2	2	p0 p5		1	SSE4.1
EXTRACTPS	m32,x,i	2	3	p0 p5 p23	4	1	SSE4.1
VEXTRACTF128	x,y,i	1	1	p5	3	1	AVX
VEXTRACTF128	m128,y,i	2	2	p23 p4	4	1	AVX
INSERTPS	x,x,i	1	1	p5	1	1	SSE4.1
INSERTPS	x,m32,i	2	2	p23 p5	4	1	SSE4.1
VINSERTF128	y,y,x,i	1	1	p5	3	1	AVX
VINSERTF128	y,y,m128,i	2	2	p015 p23	4	2	AVX
VMASKMOVPS/D	v,v,m	3	3	2p5 p23	4	2	AVX
VMASKMOVPS/D	m128,x,x	4	4	p0 p1 p4 p23	15	1	AVX
VMASKMOVPS/D	m256,y,y	4	4	p0 p1 p4 p23	16	1	AVX
VGATHERDPS	x,[r+s*x],x	10	10			6	AVX2
VGATHERDPS	y,[r+s*y],y	14	14			7	AVX2
VGATHERQPS	x,[r+s*x],x	9	9			6	AVX2
VGATHERQPS	x,[r+s*y],x	10	10			6	AVX2
VGATHERDPD	x,[r+s*x],x	7	7			5	AVX2
VGATHERDPD	y,[r+s*x],y	9	9			6	AVX2
VGATHERQPD	x,[r+s*x],x	7	7			5	AVX2

## Broadwell

VGATHERQPD	y,[r+s*y],y	9	9			6	AVX2
<b>Conversion</b>							
CVTPD2PS	x,x	2	2	p1 p5	4	1	
CVTPD2PS	x,m128	2	3	p1 p5 p23		1	
VCVTPD2PS	x,y	2	2	p1 p5	5	1	AVX
VCVTPD2PS	x,m256	2	3	p1 p5 p23		1	AVX
CVTSD2SS	x,x	2	2	p1 p5	4	1	
CVTSD2SS	x,m64	2	3	p1 p5 p23		1	
CVTPS2PD	x,x	2	2	p0 p5	2	1	
CVTPS2PD	x,m64	2	2	p0 p23		1	
VCVTPS2PD	y,x	2	2	p0 p5	5	1	AVX
VCVTPS2PD	y,m128	2	2	p0 p23		1	AVX
CVTSS2SD	x,x	2	2	p0 p5	2	1	
CVTSS2SD	x,m32	2	2	p0 p23		1	
CVTDQ2PS	x,x	1	1	p1	3	1	
CVTDQ2PS	x,m128	1	2	p1 p23		1	
VCVTDQ2PS	y,y	1	1	p1	3	1	AVX
VCVTDQ2PS	y,m256	1	2	p1 p23		1	AVX
CVT(T) PS2DQ	x,x	1	1	p1	3	1	
CVT(T) PS2DQ	x,m128	1	2	p1 p23		1	
VCVT(T) PS2DQ	y,y	1	1	p1	3	1	AVX
VCVT(T) PS2DQ	y,m256	1	2	p1 p23		1	AVX
CVTDQ2PD	x,x	2	2	p1 p5	4	1	
CVTDQ2PD	x,m64	2	2	p1 p23		1	
VCVTDQ2PD	y,x	2	2	p1 p5	6	1	AVX
VCVTDQ2PD	y,m128	2	2	p1 p23		1	AVX
CVT(T)PD2DQ	x,x	2	2	p1 p5	4	1	
CVT(T)PD2DQ	x,m128	2	3	p1 p5 p23		1	
VCVT(T)PD2DQ	x,y	2	2	p1 p5	6	1	AVX
VCVT(T)PD2DQ	x,m256	2	3	p1 p5 p23		1	AVX
CVTPI2PS	x,mm	1	1	p1	4	4	
CVTPI2PS	x,m64	1	2	p1 p23		3	
CVT(T)PS2PI	mm,x	2	2	p1 p5	4	1	
CVT(T)PS2PI	mm,m128	2	2	p1 p23		1	
CVTPI2PD	x,mm	2	2	p1 p5	4	1	
CVTPI2PD	x,m64	2	2	p1 p23		1	
CVT(T) PD2PI	mm,x	2	2	p1 p5	4	1	
CVT(T) PD2PI	mm,m128	2	3	p1 p5 p23		1	
CVTSI2SS	x,r32	2	2	p1 p5	4	3	
CVTSI2SS	x,r64	3	3	p1 2p5	5	4	
CVTSI2SS	x,m32	1	2	p1 p23		3	
CVT(T)SS2SI	r32,x	2	2	p0 p1	4	1	
CVT(T)SS2SI	r32,m32	2	3	p0 p1 p23		1	
CVTSI2SD	x,r32/64	2	2	p1 p5	4	3	
CVTSI2SD	x,m32	2	2	p1 p23		3	
CVT(T)SD2SI	r32/64,x	2	2	p0 p1	4	1	
CVT(T)SD2SI	r32,m64	2	3	p0 p1 p23		1	
VCVTPS2PH	x,v,i	2	2	p1 p5	4-6	1	F16C
VCVTPS2PH	m,v,i	3	3	p1 p4 p23		1	F16C
VCVTPH2PS	v,x	2	2	p1 p5	4-6	1	F16C
VCVTPH2PS	v,m	2	2	p1 p23		1	F16C

## Broadwell

<b>Arithmetic</b>							
ADDSS/D PS/D							
SUBSS/D PS/D	x,x / v,v,v	1	1	p1	3	1	
ADDSS/D PS/D							
SUBSS/D PS/D	x,m / v,v,m	1	2	p1 p23		1	
ADDSUBPS/D	x,x / v,v,v	1	1	p1	3	1	SSE3
ADDSUBPS/D	x,m / v,v,m	1	2	p1 p23		1	SSE3
HADDPS/D							
HSUBPS/D	x,x / v,v,v	3	3	p1 2p5	5	2	SSE3
HADDPS/D							
HSUBPS/D	x,m / v,v,m	4	4	p1 2p5 p23		2	SSE3
MULSS/D PS/D	x,x / v,v,v	1	1	p01	3	0.5	
MULSS/D PS/D	x,m / v,v,m	1	2	p01 p23		0.5	
DIVSS	x,x	1	1	p0	11	2.5	
DIVPS	x,x	1	1	p0	11	5	
DIVSS DIVPS	x,m	1	2	p0 p23		3-5	
DIVSD	x,x	1	1	p0	10-14	4-5	
DIVPD	x,x	1	1	p0	10-14	8	
DIVSD DIVPD	x,m	1	2	p0 p23		4-5	
VDIVPS	y,y,y	3	3	2p0 p15	17	10	AVX
VDIVPS	y,y,m256	4	4	2p0 p15 p23		10	AVX
VDIVPD	y,y,y	3	3	2p0 p15	19-23	16	AVX
VDIVPD	y,y,m256	4	4	2p0 p15 p23		16	AVX
RCPSS/PS	x,x	1	1	p0	5	1	
RCPSS/PS	x,m128	1	2	p0 p23		1	
VRCPPS	y,y	3	3	2p0 p15	7	2	AVX
VRCPPS	y,m256	4	4	2p0 p15 p23		2	AVX
CMPccSS/D							
CMPccPS/D	x,x / v,v,v	1	1	p1	3	1	
CMPccSS/D							
CMPccPS/D	x,m / v,v,m	2	2	p1 p23		1	
(U)COMISS/D	x,x	1	1	p1		1	
(U)COMISS/D	x,m32/64	2	2	p1 p23		1	
MAXSS/D PS/D							
MINSS/D PS/D	x,x / v,v,v	1	1	p1	3	1	
MAXSS/D PS/D							
MINSS/D PS/D	x,m / v,v,m	1	2	p1 p23		1	
ROUNDSS/D PS/D	v,v,i	2	2	2p1	6	2	SSE4.1
ROUNDSS/D PS/D	v,m,i	3	3	2p1 p23		2	SSE4.1
DPPS	x,x,i / v,v,v,i	4	4	2p0 p1 p5	12	2	SSE4.1
DPPS	x,m,i / v,v,m,i	6	6	2p0 p1 p5 p23 p6		4	SSE4.1
DPPD	x,x,i	3	3	p0 p1 p5	7	1	SSE4.1
DPPD	x,m128,i	4	4	p0 p1 p5 p23		1	SSE4.1
VFMADD...							
(all FMA instr.)	v,v,v	1	1	p01	5	0.5	FMA
VFMADD...							
(all FMA instr.)	v,v,m	1	2	p01 p23		0.5	FMA
<b>Math</b>							
SQRTSS	x,x	1	1	p0	11	4	

## Broadwell

SQRTPS	x,x	1	1	p0	11	7	
SQRTSS/PS	x,m128	1	2	p0 p23		4-7	
VSQRTPS	y,y	3	3	2p0 p15	19	14	AVX
VSQRTPS	y,m256	4	4	2p0 p15 p23		14	AVX
SQRTPD	x,x	1	1	p0	15-16	4-8	
SQRTPD	x,x	1	1	p0	15-16	8-14	
SQRTPD/PS	x,m128	1	2	p0 p23		4-14	
VSQRTPD	y,y	3	3	2p0 p15	27-29	16-28	AVX
VSQRTPD	y,m256	4	4	2p0 p15 p23		16-28	AVX
RSQRTPS/PS	x,x	1	1	p0	5	1	
RSQRTPS/PS	x,m128	1	2	p0 p23		1	
VRSQRTPS	y,y	3	3	2p0 p15	7	2	AVX
VRSQRTPS	y,m256	4	4	2p0 p15 p23		2	AVX
<b>Logic</b>							
AND/ANDN/OR/XOR/PS/PD	x,x / v,v,v	1	1	p5	1	1	
AND/ANDN/OR/XOR/PS/PD	x,m / v,v,m	1	2	p5 p23		1	
<b>Other</b>							
VZEROUPPER		4	4	none		1	AVX
VZEROALL		12	12	none		10	AVX, 32 bit
VZEROALL		20	20	none		8	AVX, 64 bit
LDMXCSR	m32	3	3	p0 p6 p23	6	3	
STMXCSR	m32	3	4	p0 p4 p6 p237	7	1	
FXSAVE	m4096	111			66	66	32 bit mode
FXSAVE	m4096	141			66	66	64 bit mode
FXRSTOR	m4096	107			80	80	32 bit mode
FXRSTOR	m4096	115			80	80	64 bit mode
XSAVE		174			70	70	32 bit mode
XSAVE		224			84	84	64 bit mode
XRSTOR		172			111	111	32 bit mode
XRSTOR		173			112	112	64 bit mode
XSAVEOPT	m	114			51	51	

**Intel Skylake****List of instruction timings and  $\mu$ op breakdown***Explanation of column headings:*

**Instruction:** Name of instruction. Multiple names mean that these instructions have the same data. Instructions with or without V name prefix behave the same unless otherwise noted.

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, v = any vector register (mmx, xmm, ymm). same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.

**$\mu$ ops fused domain:** The number of  $\mu$ ops at the decode, rename and allocate stages in the pipeline. Fused  $\mu$ ops count as one.

**$\mu$ ops unfused domain:** The total number of  $\mu$ ops for all execution port. Fused  $\mu$ ops count as two. Fused macro-ops count as one. The instruction has  $\mu$ op fusion if this number is higher than the number under fused domain. Some operations are not counted here if they do not go to any execution port or if the counters are inaccurate.

**$\mu$ ops each port:** The number of  $\mu$ ops for each execution port. p0 means a  $\mu$ op to execution port 0. p01 means a  $\mu$ op that can go to either port 0 or port 1. p0 p1 means two  $\mu$ ops going to port 0 and 1, respectively.

Port 0: Integer, f.p. and vector ALU, mul, div, branch

Port 1: Integer, f.p. and vector ALU

Port 2: Load

Port 3: Load

Port 4: Store

Port 5: Integer and vector ALU

Port 6: Integer ALU, branch

Port 7: Store address

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Where hyperthreading is enabled, the use of the same execution units in the other thread leads to inferior performance. Denormal numbers, NAN's and infinity do not increase the latency. The time unit used is core clock cycles, not the reference clock cycles given by the time stamp counter.

**Reciprocal throughput:** The average number of core clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

**Integer instructions**

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOV	r,i	1	1	p0156		0.25	
MOV	r8/16,r8/16	1	1	p0156	1	0.25	
MOV	r32/64,r32/64	1	1	p0156	0-1	0.25	may be elim.
MOV	r8l,m	1	2	p23 p0156		0.5	
MOV	r8h,m	1	1	p23		0.5	
MOV	r16,m	1	2	p23 p0156		0.5	
MOV	r32/64,m	1	1	p23	2	0.5	all addressing modes

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MOV	m,r	1	2	p237 p4	2	1	
MOV	m,i	1	2	p237 p4		1	
MOVNTI	m,r	2	2	p23 p4	~400	1	
MOVSX MOVZX	r,r	1	1	p0156	1	0.25	
MOVSXD							
MOVSX MOVZX	r16,m8	1	2	p23 p0156		0.5	
MOVSX MOVZX	r,m	1	1	p23		0.5	all other combinations
MOVSXD							
CMOVcc	r,r	1	1	p06	1	0.5	
CMOVcc	r,m	2	2	p06 p23		0.5	
XCHG	r,r	3	3	3p0156	2	1	
XCHG	r,m	8	8		23		implicit lock
XLAT		3	3	p23 2p0156	7	2	
PUSH	r	1	2	p237 p4	3	1	
PUSH	i	1	2	p237 p4		1	
PUSH	m	2	3	p4 2p237		1	
PUSH	stack pointer	2	3	p0156 p237 p4		1	
PUSHF(D/Q)		3	4	p1 p4 p237 p06		1	
PUSHA(D)		11	19			8	not 64 bit
POP	r	1	1	p23	2	0.5	
POP	stack pointer	3	3	p23 2p0156		3	
POP	m	2	3	2p237 p4		1	
POPF(D/Q)		9	9			20	
POPA(D)		18	18			8	not 64 bit
LAHF SAHF		1	1	p06	1	1	
SALC		3	3	3p0156	1	1	not 64 bit
LEA	r16,m	2	2	p1 p05	2-4	1	16 or 32 bit address size
LEA	r32/64,m	1	1	p15	1	0.5	1 or 2 components in address
LEA	r32/64,m	1	1	p1	3	1	3 components in address
LEA	r32/64,m	1	1	p1		1	rip relative address
BSWAP	r32	1	1	p15	1	0.5	
BSWAP	r64	2	2	p06 p15	2	1	
MOVBE	r16,m16	3	3	2p0156 p23		0.5-1	MOVBE
MOVBE	r32,m32	2	2	p15 p23		0.5	MOVBE
MOVBE	r64,m64	3	3	2p0156 p23		0.75	MOVBE
MOVBE	m16,r16	2	3	p06 p237 p4		1	MOVBE
MOVBE	m32,r32	2	3	p15 p237 p4		1	MOVBE
MOVBE	m64,r64	3	4	p06 p15 p237 p4		1	MOVBE
PREFETCHNTA/0/1/2	m	1	1	p23		0.5	
PREFETCHW	m	1	1	p23		1	PREFETCHW
LFENCE		2		none counted		4	
MFENCE		4	4	p23 p4		33	
SFENCE		2	2	p23 p4		6	
<b>Arithmetic instructions</b>							



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ADD SUB	r,r/i	1	1	p0156	1	0.25	
ADD SUB	r,m	1	2	p0156 p23		0.5	
ADD SUB	m,r/i	2	4	2p0156 2p237 p4	5	1	
ADC SBB	r,r/i	1	1	p06	1	1	
ADC SBB	r,m	2	2	p06 p23		1	
ADC SBB	m,r/i	4	6	3p0156 2p237 p4	5	2	
CMP	r,r/i	1	1	p0156	1	0.25	
CMP	m,r/i	1	2	p0156 p23	1	0.5	
INC DEC NEG NOT	r	1	1	p0156	1	0.25	
INC DEC NOT	m	3	4	p0156 2p237 p4	5-6	1	
NEG	m	2	4	p0156 2p237 p4	5-6	1	
AAA		2	2	p1 p56	4		not 64 bit
AAS		2	2	p1 p056	4		not 64 bit
DAA DAS		3	3	p1 2p056	4		not 64 bit
AAD		3	3	p1 2p056	4		not 64 bit
AAM		11	11	p0 p1 p5 p6	23	7	not 64 bit
MUL IMUL	r8	1	1	p1	3	1	
MUL IMUL	r16	4	4	p1 p0156	4	2	
MUL IMUL	r32	3	3	p1 p0156	4	1	
MUL IMUL	r64	2	2	p1 p6	3	1	
MUL IMUL	m8	1	2	p1 p23		1	
MUL IMUL	m16	4	5	p1 3p0156 p23		2	
MUL IMUL	m32	3	4	p1 2p0156 p23		2	
MUL IMUL	m64	2	3	p1 p6 p23		1	
IMUL	r,r	1	1	p1	3	1	
IMUL	r,m	1	2	p1 p23		1	
IMUL	r16,r16,i	2	2	p1 p0156	4	1	
IMUL	r32,r32,i	1	1	p1	3	1	
IMUL	r64,r64,i	1	1	p1	3	1	
IMUL	r16,m16,i	2	3	p1 p0156 p23		1	
IMUL	r32,m32,i	1	2	p1 p23		1	
IMUL	r64,m64,i	1	2	p1 p23		1	
MULX	r32,r32,r32	3	3	p1 2p056	4	1	BMI2
MULX	r32,r32,m32	3	4	p1 2p056 p23		1	BMI2
MULX	r64,r64,r64	2	2	p1 p5	4	1	BMI2
MULX	r64,r64,m64	2	3	p1 p6 p23		1	BMI2
DIV	r8	10	10	p0 p1 p5 p6	23	6	
DIV	r16	10	10	p0 p1 p5 p6	23	6	
DIV	r32	10	10	p0 p1 p5 p6	26	6	
DIV	r64	36	36	p0 p1 p5 p6	35-88	21-83	
IDIV	r8	11	11	p0 p1 p5 p6	24	6	
IDIV	r16	10	10	p0 p1 p5 p6	23	6	
IDIV	r32	10	10	p0 p1 p5 p6	26	6	
IDIV	r64	57	57	p0 p1 p5 p6	42-95	24-90	
CBW		1	1	p0156	1		
CWDE		1	1	p0156	1		
CDQE		1	1	p0156	1		
CWD		2	2	p0156	1		
CDQ		1	1	p06	1		

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CQO		1	1	p06	1		
POPCNT	r,r	1	1	p1	3	1	SSE4.2
POPCNT	r,m	1	2	p1 p23		1	SSE4.2
CRC32	r,r	1	1	p1	3	1	SSE4.2
CRC32	r,m	1	2	p1 p23		1	SSE4.2
<b>Logic instructions</b>							
AND OR XOR	r,r/i	1	1	p0156	1	0.25	
AND OR XOR	r,m	1	2	p0156 p23		0.5	
AND OR XOR	m,r/i	2	4	2p0156 2p237 p4	5	1	
TEST	r,r/i	1	1	p0156	1	0.25	
TEST	m,r/i	1	2	p0156 p23	1	0.5	
SHR SHL SAR	r,i	1	1	p06	1	0.5	
SHR SHL SAR	m,i	3	4	2p06 p237 p4		2	
SHR SHL SAR	r,cl	3	3	3p06	2	2	
SHR SHL SAR	m,cl	5	6	3p06 2p23 p4		4	
ROR ROL	r,1	2	2	2p06	1	1	short form
ROR ROL	r,i	1	1	p06	1	0.5	
ROR ROL	m,i	4	5	2p06 2p237 p4		2	
ROR ROL	r,cl	3	3	3p06	2	2	
ROR ROL	m,cl	5	6	3p06 p23 p4		4	
RCR RCL	r,1	3	3	2p06 p0156	2	2	
RCR RCL	m,1	4	6			3	
RCR RCL	r,i	8	8	p0156	6	6	
RCR RCL	m,i	11	11			6	
RCR RCL	r,cl	8	8	p0156	6	6	
RCR RCL	m,cl	11	11			6	
SHRD SHLD	r,r,i	1	1	p1	3	1	
SHRD SHLD	m,r,i	3	5			2	
SHLD	r,r,cl	4	4	p0156	3	2	
SHRD	r,r,cl	4	4	p0156	4	2	
SHRD SHLD	m,r,cl	5	7			4	
SHLX SHRX SARX	r,r,r	1	1	p06	1	0.5	BMI2
SHLX SHRX SARX	r,m,r	2	2	p06 p23		0.5	BMI2
RORX	r,r,i	1	1	p06	1	0.5	BMI2
RORX	r,m,i	2	2	p06 p23		0.5	BMI2
BT	r,r/i	1	1	p06	1	0.5	
BT	m,r	10	10			5	
BT	m,i	2	2	p06 p23		0.5	
BTR BTS BTC	r,r/i	1	1	p06	1	0.5	
BTR BTS BTC	m,r	10	11			5	
BTR BTS BTC	m,i	3	4	p06 p4 p23		1	
BSF BSR	r,r	1	1	p1	3	1	
BSF BSR	r,m	1	2	p1 p23		1	
SETcc	r	1	1	p06	1	0.5	
SETcc	m	2	3	p06 p237 p4		1	
CLC		1	0	none		0.25	
STC		1	1	p0156		0.25	
CMC		1	1	p0156	1	1	
CLD STD		3	3	p15 p6		4	
LZCNT	r,r	1	1	p1	3	1	LZCNT

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LZCNT	r,m	1	2	p1 p23		1	LZCNT
TZCNT	r,r	1	1	p1	3	1	BMI1
TZCNT	r,m	1	2	p1 p23		1	BMI1
ANDN	r,r,r	1	1	p15	1	0.5	BMI1
ANDN	r,r,m	1	2	p15 p23	1	0.5	BMI1
BLSI BLSMSK	r,r	1	1	p15	1	0.5	BMI1
BLSR							
BLSI BLSMSK	r,m	1	2	p15 p23		0.5	BMI1
BLSR							
BEXTR	r,r,r	2	2	2p0156	2	0.5	BMI1
BEXTR	r,m,r	3	3	2p0156 p23		1	BMI1
BZHI	r,r,r	1	1	p15	1	0.5	BMI2
BZHI	r,m,r	1	2	p15 p23		0.5	BMI2
PDEP	r,r,r	1	1	p1	3	1	BMI2
PDEP	r,r,m	1	2	p1 p23		1	BMI2
PEXT	r,r,r	1	1	p1	3	1	BMI2
PEXT	r,r,m	1	2	p1 p23		1	BMI2
<b>Control transfer instructions</b>							
JMP	short/near	1	1	p6		1-2	
JMP	r	1	1	p6		2	
JMP	m	1	2	p23 p6		2	
Conditional jump	short/near	1	1	p6		1-2	predicted taken
Conditional jump	short/near	1	1	p06		0.5-1	predicted not taken
Fused arithmetic and branch		1	1	p6		1-2	predicted taken
Fused arithmetic and branch		1	1	p06		0.5-1	predicted not taken
J(E/R)CXZ	short	2	2	p0156 p6		0.5-2	
LOOP	short	7	7			5	
LOOP(N)E	short	11	11			6	
CALL	near	2	3	p237 p4 p6		3	
CALL	r	2	3	p237 p4 p6		2	
CALL	m	3	4	2p237 p4 p6		3	
RET		1	2	p237 p6		1	
RET	i		2			2	
BOUND	r,m	15	15			8	not 64 bit
INTO		5	5			6	not 64 bit
<b>String instructions</b>							
LODSB/W		3	3	2p0156 p23		1	
LODSD/Q		2	2	p0156 p23		1	
REP LODS		5n+12				~2n	
STOS		3	3	p23 p0156 p4		1	
REP STOS		<2n				~0.5n	worst case
REP STOS		2.6/32B				1/32B	best case aligned by 32
MOVS		5	5	2p23 p4 2p0156		4	
REP MOVS		~2n				< 1n	worst case

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REP MOVS		4/32B				1/32B	best case aligned by 32
SCAS		3	3	p23 2p0156		1	
REP SCAS		≥6n				≥2n	
CMPS		5	5	2p23 3p0156		4	
REP CMPS		≥8n				≥2n	
<b>Synchronization instructions</b>							
XADD	m,r	4	5			5	
LOCK XADD	m,r	9	9			18	
LOCK ADD	m,r	8	8			18	
CMPXCHG	m,r	5	6			6	
LOCK CMPXCHG	m,r	10	10			18	
CMPXCHG8B	m,r	16	16			11	
LOCK CMPXCHG8B	m,r	20	20			19	
CMPXCHG16B	m,r	23	23			16	
LOCK CMPXCHG16B	m,r	25	25			26	
<b>Other</b>							
NOP (90)		1	0	none		0.25	
Long NOP (0F 1F)		1	0	none		0.25	
PAUSE		4	4	p6			
ENTER	a,0	12	12			8	
ENTER	a,b	~14+7b	~45+7b		~87+2b		
LEAVE		3	3	2p0156 p23		5	
XGETBV		15	15			9	XGETBV
RDTSC		20	20			25	
RDTSCP		22	22			32	RDTSCP
RDPMSR		35	35			40	
RDRAND	r	16	16	p23 15p0156		~460	RDRAND
RDSEED	r	16	16	p23 15p0156		~460	RDSEED

**Floating point x87 instructions**

Instruction	Operands	μops fused domain	μops unfused domain	μops each port	Latency	Reciprocal through put	Comments
<b>Move instructions</b>							
FLD	r	1	1	p05	1	0.5	
FLD	m32/64	1	1	p23	3	0.5	
FLD	m80	4	4	2p01 2p23	4	2	
FBLD	m80	43	43		46	22	
FST(P)	r	1	1	p05	1	0.5	
FST(P)	m32/m64	1	2	p4 p237	3	1	
FSTP	m80	7	7	3p0156 2p23 2p4	4	5	
FBSTP	m80	244	226		264	266	
FXCH	r	2	0	none	0	0.5	
FILD	m	1	2	p05 p23	5	1	
FIST(P)	m	3	3	p5 p23 p4	7	1	
FISTTP	m	3	3	p1 p23 p4	7	2	SSE3

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FLDZ		1	1	p05		1
FLD1		2	2	2p05		2
FLDPI FLDL2E etc.		2	2	2p05		2
FCMOVcc	r	4	4	p0 p1 p56	3	2
FNSTSW	AX	2	2	p0 p0156	6	2
FNSTSW	m16	2	3	p0 p4 p237	6	1
FLDCW	m16	3	3	p01 p23 p6	7	2
FNSTCW	m16	2	3	p237 p4 p6	6	1
FINCSTP FDECSTP		1	1	p05	0	0.5
FFREE(P)	r	1	1	p05		0.5
FNSAVE	m	133	133		176	176
FRSTOR	m	89	89		175	175
<b>Arithmetic in- structions</b>						
FADD(P)						
FSUB(R)(P)	r	1	1	p5	3	1
FADD(P)						
FSUB(R)(P)	m	2	3	p5 p23		1
FMUL(P)	r	1	1	p0	5	1
FMUL(P)	m	2	3	p0 p23		1
FDIV(R)(P)	r	1	1	p0	14-16	4-5
FDIV(R)(P)	m	1	2	p0 p23		4-5
FABS		1	1	p0	1	1
FCHS		1	1	p0	1	1
FCOM(P) FUCOM	r	1	1	p5	3	1
FCOM(P) FUCOM	m	1	2	p5 p23		1
FCOMPP FUCOMPP		2	2	p0 p5		1
FCOMI(P)						
FUCOMI(P)	r	3	3	p5		1
FIADD FISUB(R)	m	3	4	2p5 p23		2
FIMUL	m	2	3	p0 p5 p23		1
FIDIV(R)	m	2	3	p0 p5 p23		
FICOM(P)	m	2	3	2p5 p23		2
FTST		1	1	p5	3	1
FXAM		2	2	2p5	6	2
FPREM		31	31		26-30	17
FPREM1		31	31		30-57	17
FRNDINT		17	17		21	11
<b>Math</b>						
FSCALE		27	27		130	130
FXTRACT		17	17		11	11
FSQRT		1	1	p0	14-21	4-7
FSIN		53-105			50-120	
FCOS		53-105			50-130	
FSINCOS		55-120			55-150	
F2XM1		16-90			65-80	
FYL2X		40-100			103	
FYL2XP1		56			77	
FPTAN		40-112			140-160	
FPATAN		30-160			100-160	

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<b>Other</b>						
FNOP		1	1	p05		0.5
WAIT		2	2	p05		2
FNCLEX		5	5	p156		22
FNINIT		18	18			78

**Integer vector instructions**

Instruction	Operands	μops fused domain	μops unfused domain	μops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOVD	r32/64,(x)mm	1	1	p0	2	1	
MOVD	m32/64,(x)mm	1	2	p237 p4	3	1	
MOVD	(x)mm,r32/64	1	1	p5	2	1	
MOVD	(x)mm,m32/64	1	1	p23	2	0.5	
MOVQ	r64,(x)mm	1	1	p0	2	1	
MOVQ	(x)mm,r64	1	1	p5	1	1	
MOVQ	mm,mm	1		p05	1	0.5	
MOVQ	x,x	1		p015	1	0.33	
MOVQ	(x)mm,m64	1	1	p23	2	0.5	
MOVQ	m64, (x)mm	1	2	p237 p4	3	1	
MOVDQA/U	x,x	1	1	p015	0-1	0.25	may eliminate
MOVDQA/U	x, m128	1	1	p23	2	0.5	
MOVDQA/U	m128, x	1	2	p237 p4	3	1	
VMOVDQA/U	y,y	1	1	p015	0-1	0.25	may eliminate
VMOVDQA/U	y,m256	1	1	p23	3	0.5	AVX
VMOVDQA/U	m256,y	1	2	p237 p4	3	1	AVX
LDDQU	x, m128	1	1	p23	3	0.5	SSE3
MOVDQ2Q	mm, x	2	2	p0 p5	2	1	
MOVQ2DQ	x,mm	2	2	p0 p15	2	1	
MOVNTQ	m64,mm	1	2	p237 p4	~418	1	
MOVNTDQ	m128,x	1	2	p237 p4	~450	1	
VMOVNTDQ	m256,y	1	2	p237 p4	~400	1	AVX2
MOVNTDQA	x, m128	2	2	p23 p015	3	0.5	SSE4.1
VMOVNTDQA	y,m256	2	2	p23 p015	3	0.5	AVX2
PACKSSWB/DW							
PACKUSWB	mm,mm	3	3	p5	2	2	
PACKSSWB/DW							
PACKUSWB	mm,m64	3	3	p23 2p5		2	
PACKSSWB/DW							
PACKUSWB	x,x / y,y,y	1	1	p5	1	1	
PACKSSWB/DW							
PACKUSWB	x,m / y,y,m	1	2	p23 p5		1	
PACKUSDW	x,x / y,y,y	1	1	p5	1	1	SSE4.1
PACKUSDW	x,m / y,y,m	1	2	p23 p5		1	SSE4.1
PUNPCKH/L							
BW/WD/DQ	v,v / v,v,v	1	1	p5	1	1	
PUNPCKH/L							
BW/WD/DQ	v,m / v,v,m	1	2	p23 p5		1	
PUNPCKH/L							
QDQ	x,x / y,y,y	1	1	p5	1	1	

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PUNPCKH/L QDQ	x,m / y,y,m	1	2	p23 p5		1	
PMOVSX/ZX BW BD BQ DW DQ	x,x	1	1	p5	1	1	SSE4.1
PMOVSX/ZX BW BD BQ DW DQ	x,m	1	2	p23 p5		1	SSE4.1
VPMOVSX/ZX BW BD BQ DW DQ	y,x	1	1	p5	3	1	AVX2
VPMOVSX/ZX BW BD BQ DW DQ	y,m	2	2	p5 p23		1	AVX2
PSHUFB	v,v / v,v,v	1	1	p5	1	1	SSSE3
PSHUFB	v,m / v,v,m	2	2	p23 p5		1	SSSE3
PSHUFW	mm,mm,i	1	1	p5	1	1	
PSHUFW	mm,m64,i	2	2	p23 p5		1	
PSHUFD	v,v,i	1	1	p5	1	1	
PSHUFD	v,m,i	1-2	2	p23 p5		1	
PSHUFL/HW	v,v,i	1	1	p5	1	1	
PSHUFL/HW	v,m,i	2	2	p23 p5		1	
PALIGNR	v,v,i / v,v,v,i	1	1	p5	1	1	SSSE3
PALIGNR	v,m,i / v,v,m,i	2	2	p23 p5		1	SSSE3
PBLENDVB	x,x,xmm0	1	1	p015	1	1	SSE4.1
PBLENDVB	x,m,xmm0	2	2	p015 p23		2	SSE4.1
VPBLENDVB	v,v,v,v	2	2	2p015	2	1	AVX2
VPBLENDVB	v,v,m,v	3	3	2p015 p23		2	AVX2
PBLENDW	x,x,i / v,v,v,i	1	1	p5	1	1	SSE4.1
PBLENDW	x,m,i / v,v,m,i	2	2	p23 p5		1	SSE4.1
VPBLEND	v,v,v,i	1	1	p015	1	0.33	AVX2
VPBLEND	v,v,m,i	2	2	p015 p23		0.5	AVX2
VPERMD	y,y,y	1	1	p5	3	1	AVX2
VPERMD	y,y,m	1	2	p5 p23		1	AVX2
VPERMQ	y,y,i	1	1	p5	3	1	AVX2
VPERMQ	y,m,i	2	2	p5 p23		1	AVX2
VPERM2128	y,y,y,i	1	1	p5	3	1	AVX2
VPERM2128	y,y,m,i	2	2	p5 p23		1	AVX2
MASKMOVQ	mm,mm	4	4	p0 p4 2p23	~450	2	
MASKMOVDQU	x,x	10	10	4p04 2p56 4p23	18-500	6	
VPMASKMOVD/Q	v,v,m	2	2	p23 p015	4	0.5	AVX2
VPMASKMOVD/Q	m,v,v	3	3	p0 p4 p23	14	1	AVX2
PMOVMASKB	r,v	1	1	p0	2-3	1	
PEXTRB/W/D/Q	r32,x,i	2	2	p0 p5	3	1	SSE4.1
PEXTRB/W/D/Q	m8,x,i	2	3	p23 p4 p5		1	SSE4.1
VEEXTRACT128	x,y,i	1	1	p5	3	1	AVX2
VEEXTRACT128	m,y,i	2	2	p23 p4	4	1	AVX2
PINSRB	x,r32,i	2	2	2p5	3	2	SSE4.1
PINSRB	x,m8,i	2	2	p23 p5		1	SSE4.1
PINSRW	(x)mm,r32,i	2	2	p5	3	2	
PINSRW	(x)mm,m16,i	2	2	p23 p5		1	
PINSRD/Q	x,r32,i	2	2	2p5	3	2	SSE4.1
PINSRD/Q	x,m32,i	2	2	p23 p5		1	SSE4.1
VINSERTI128	y,y,x,i	1	1	p5	3	1	AVX2
VINSERTI128	y,y,m,i	2	2	p015 p23	3	0.5	AVX2
VPBROADCAST B/W/D/Q	x,x	1	1	p5	1	1	AVX2

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VPBROADCAST B/W	x,m8/16	2	2	p23 p5	7	1	AVX2
VPBROADCAST D/Q	x,m32/64	1	1	p23	4	0.5	AVX2
VPBROADCAST B/W/D/Q	y,x	1	1	p5	3	1	AVX2
VPBROADCAST B/W	y,m8/16	2	2	p23 p5	7	1	AVX2
VPBROADCAST D/Q	y,m32/64	1	1	p23	3	0.5	AVX2
VBROADCASTI128	y,m128	1	1	p23	3	0.5	AVX2
VPGATHERDD	x,[r+s*x],x	4	4	p0 p1 p23 p5		4	AVX2
VPGATHERDD	y,[r+s*y],y	4	4	p0 p1 p23 p5		5	AVX2
VPGATHERQD	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VPGATHERQD	x,[r+s*y],x	4	4	p0 p1 p23 p5		4	AVX2
VPGATHERDQ	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VPGATHERDQ	y,[r+s*x],y	4	4	p0 p1 p23 p5		4	AVX2
VPGATHERQQ	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VPGATHERQQ	y,[r+s*y],y	4	4	p0 p1 p23 p5		4	AVX2
<b>Arithmetic instructions</b>							
PADD/SUB(S,US) B/W/D/Q	v,v / v,v,v	1	1	p015	1	0.33	
PADD/SUB(S,US) B/W/D/Q	v,m / v,v,m	1	2	p015 p23		0.5	
PHADD(S)W/D							
PHSUB(S)W/D	v,v / v,v,v	3	3	p01 2p5	3	2	SSSE3
PHADD(S)W/D							
PHSUB(S)W/D	v,m / v,v,m	4	4	p01 2p5 p23		2	SSSE3
PCMPEQB/W/D							
PCMPGTB/W/D	mm,mm	1	1	p0	1	1	
PCMPEQB/W/D							
PCMPGTB/W/D	x,x / y,y,y	1	1	p01	1	0.5	
PCMPEQB/W/D							
PCMPGTB/W/D	x,m / y,y,m	1	2	p01 p23		0.5	
PCMPEQQ	v,v / v,v,v	1	1	p01	1	0.5	SSE4.1
PCMPEQQ	v,m / v,v,m	1	2	p01 p23		0.5	SSE4.1
PCMPGTQ	v,v / v,v,v	1	1	p5	3	1	SSE4.2
PCMPGTQ	v,m / v,v,m	1	2	p5 p23		1	SSE4.2
PMULL/HW							
PMULHUW	mm,mm	1	1	p0	5	1	
PMULL/HW							
PMULHUW	x,x / y,y,y	1	1	p01	5	0.5	
PMULL/HW							
PMULHUW	x,m / y,y,m	1	2	p01 p23		0.5	
PMULHRSW	mm,mm	1	1	p0	5	1	SSSE3
PMULHRSW	x,x / y,y,y	1	1	p01	5	0.5	SSSE3
PMULHRSW	x,m / y,y,m	1	2	p01 p23		0.5	SSSE3
PMULLD	x,x / y,y,y	2	2	2p01	10	1	SSE4.1
PMULLD	x,m / y,y,m	3	3	2p01 p23		1	SSE4.1
PMULDQ	x,x / y,y,y	1	1	p01	5	0.5	SSE4.1
PMULDQ	x,m / y,y,m	1	2	p01 p23		0.5	SSE4.1
PMULUDQ	mm,mm	1	1	p0	5	1	



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PMULUDQ	x,x / y,y,y	1	1	p01	5	0.5	
PMULUDQ	x,m / y,y,m	1	2	p01 p23		0.5	
PMADDWD	mm,mm	1	1	p0	5	1	
PMADDWD	x,x / y,y,y	1	1	p01	5	0.5	
PMADDWD	x,m / y,y,m	1	2	p01 p23		0.5	
PMADDUBSW	mm,mm	1	1	p0	5	1	SSSE3
PMADDUBSW	x,x / y,y,y	1	1	p01	5	0.5	SSSE3
PMADDUBSW	x,m / y,y,m	1	2	p01 p23		0.5	SSSE3
PAVGB/W	mm,mm	1	1	p0	1	1	
PAVGB/W	x,x / y,y,y	1	1	p01	1	0.5	
PAVGB/W	x,m / y,y,m	1	2	p01 p23		0.5	
PMIN/PMAX SB/SW/SD UB/UW/UD	mm,mm	1	1	p0	1	1	SSE4.1
PMIN/PMAX SB/SW/SD UB/UW/UD	x,x / y,y,y	1	1	p01	1	0.5	SSE4.1
PMIN/PMAX SB/SW/SD UB/UW/UD	x,m / y,y,m	1	2	p01 p23		0.5	SSE4.1
PHMINPOSUW	x,x	1	1	p0	4	1	SSE4.1
PHMINPOSUW	x,m128	1	2	p0 p23		1	SSE4.1
PABSB/W/D	mm,mm	1	1	p0	1	1	SSSE3
PABSB/W/D	x,x / y,y	1	1	p01	1	0.5	SSSE3
PABSB/W/D	x,m / y,m	1	2	p01 p23		0.5	SSSE3
PSIGNB/W/D	mm,mm	1	1	p0	1	1	SSSE3
PSIGNB/W/D	x,x / y,y,y	1	1	p01	1	0.5	SSSE3
PSIGNB/W/D	x,m / y,y,m	1	2	p01 p23		0.5	SSSE3
PSADBW	v,v / v,v,v	1	1	p5	3	1	
PSADBW	v,m / v,v,m	1	2	p5 p23		1	
MPSADBW	x,x,i / v,v,v,i	2	2	2p5	4	2	SSE4.1
MPSADBW	x,m,i / v,v,m,i	3	3	2p5 p23		2	SSE4.1
<b>Logic instructions</b>							
PAND PANDN POR PXOR	mm,mm	1	1	p05	1	0.5	
PAND PANDN POR PXOR	x,x / y,y,y	1	1	p015	1	0.33	
PAND PANDN POR PXOR	v,m / v,v,m	1	2	p015 p23		0.5	
PTEST	v,v	2	2	p0 p5	3	1	SSE4.1
PTEST	v,m	2	3	p0 p5 p23		1	SSE4.1
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	mm,mm	1	1	p0	1	1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	mm,m64	2	2	p0 p23		1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	x,x / v,v,x	2	2	p01 p5	1	1	

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PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	x,m / v,v,m	2	2	p01 p23		0.5	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	mm,i	1	1	p0	1	1	
PSLLW/D/Q PSRLW/D/Q PSRAW/D/Q	x,i / y,y,i	1	1	p01	1	0.5	
VPSLLVD/Q VPSRAVD VPSRLVD/Q	v,v,v	1	1	p01	1	0.5	AVX2
VPSLLVD/Q VPSRAVD VPSRLVD/Q	v,v,m	1	2	p01 p23		0.5	AVX2
PSLLDQ PSRLDQ	x,i / v,v,i	1	1	p5	1	1	
<b>String instructions</b>							
PCMPESTRI	x,x,i	8	8	6p05 2p16	12	4	SSE4.2
PCMPESTRI	x,m128,i	8	8	3p0 2p16 2p5 p23		4	SSE4.2
PCMPESTRM	x,x,i	9	9	3p0 2p16 4p5	9	5	SSE4.2
PCMPESTRM	x,m128,i	9	9	6p05 2p16 p23		5	SSE4.2
PCMPISTRI	x,x,i	3	3	3p0	12	3	SSE4.2
PCMPISTRI	x,m128,i	4	4	3p0 p23		3	SSE4.2
PCMPISTRM	x,x,i	3	3	3p0	9	3	SSE4.2
PCMPISTRM	x,m128,i	4	4	3p0 p23		3	SSE4.2
<b>Encryption instructions</b>							
PCLMULQDQ	x,x,i	1	1	p5	7	1	CLMUL
PCLMULQDQ	x,m,i	2	2	p5 p23		1	CLMUL
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,x	1	1	p0	4	1	AES
AESDEC, AESDECLAST, AESENC, AESENCLAST	x,m	2	2	p0 p23		1.5	AES
AESIMC	x,x	2	2	2p0	8	2	AES
AESIMC	x,m	3	3	2p0 p23		2	AES
AESKEYGENAS SIST	x,x,i	13	13	p0 p5	12	12	AES
AESKEYGENAS SIST	x,m,i	13	13			12	AES
<b>Other</b>							
EMMS		10	10	p05		6	

**Floating point XMM and YMM instructions**

## Skylake

Instruction	Operands	$\mu$ ops fused domain	$\mu$ ops unfused domain	$\mu$ ops each port	Latency	Reciprocal throughput	Comments
<b>Move instructions</b>							
MOVAPS/D	x,x	1	1	p015	0-1	0.25	may eliminate
VMOVAPS/D	y,y	1	1	p015	0-1	0.25	may eliminate
MOVAPS/D MOVUPS/D	x,m128	1	1	p23	2	0.5	
VMOVAPS/D VMOVUPS/D	y,m256	1	1	p23	3	0.5	AVX
MOVAPS/D MOVUPS/D	m128,x	1	2	p237 p4	3	1	
VMOVAPS/D VMOVUPS/D	m256,y	1	2	p237 p4	3	1	AVX
MOVSS/D	x,x	1	1	p5	1	1	
MOVSS/D	x,m32/64	1	1	p23	3	0.5	
MOVSS/D	m32/64,x	1	2	p237 p4	3	1	
MOVHPS/D	x,m64	1	2	p23 p5	4	1	
MOVHPS/D	m64,x	1	2	p4 p237	3	1	
MOVLPS/D	x,m64	1	2	p23 p5	4	1	
MOVLPS/D	m64,x	1	2	p4 p237	3	1	
MOVHLP	x,x	1	1	p5	1	1	
MOVLHP	x,x	1	1	p5	1	1	
MOVMSKPS/D	r32,x	1	1	p0	2	1	
VMOVMSKPS/D	r32,y	1	1	p0	3	1	
MOVNTPS/D	m128,x	1	2	p4 p237	~400	1	
VMOVNTPS/D	m256,y	1	2	p4 p237	~400	1	AVX
SHUFPS/D	x,x,i / v,v,v,i	1	1	p5	1	1	
SHUFPS/D	x,m,i / v,v,m,i	2	2	p5 p23		1	
VPERMILPS/PD	v,v,i	1	1	p5	1	1	AVX
VPERMILPS/PD	v,m,i	2	2	p5 p23		1	AVX
VPERMILPS/PD	v,v,v	1	1	p5	1	1	AVX
VPERMILPS/PD	v,v,m	2	2	p5 p23		1	AVX
VPERM2F128	y,y,y,i	1	1	p5	3	1	AVX
VPERM2F128	y,y,m,i	2	2	p5 p23		1	AVX
VPERMPS	y,y,y	1	1	p5	3	1	AVX2
VPERMPS	y,y,m	1	2	p5 p23		1	AVX2
VPERMPD	y,y,i	1	1	p5	3	1	AVX2
VPERMPD	y,m,i	2	2	p5 p23		1	AVX2
BLENDPS/PD	x,x,i / v,v,v,i	1	1	p015	1	0.33	SSE4.1
BLENDPS/PD	x,m,i / v,v,m,i	2	2	p015 p23		0.5	SSE4.1
BLENDVPS/PD	x,x,xmm0	1	1	p015	1	1	SSE4.1
BLENDVPS/PD	x,m,xmm0	2	2	p015 p23		1	SSE4.1
VBLENDVPS/PD	v,v,v,v	2	2	2p015	2	1	AVX
VBLENDVPS/PD	v,v,m,v	3	3	2p015 p23		1	AVX
MOVDDUP	v,v	1	1	p5	1	1	SSE3
MOVDDUP	v,m	1	1	p23	3	0.5	SSE3
VBROADCASTSS	x,m32	1	1	p23	2	0.5	AVX
VBROADCASTSS	y,m32	1	1	p23	3	0.5	AVX
VBROADCASTSS	x,x	1	1	p5	1	1	AVX2
VBROADCASTSS	y,x	1	1	p5	3	1	AVX2

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VBROADCASTSD	y,m64	1	1	p23	3	0.5	AVX
VBROADCASTSD	y,x	1	1	p5	3	1	AVX2
VBROADCASTF128	y,m128	1	1	p23	3	0.5	AVX
MOVSH/LDUP	v,v	1	1	p5	1	1	SSE3
MOVSH/LDUP	v,m	1	1	p23	3	0.5	SSE3
UNPCKH/LPS/D	x,x / v,v,v	1	1	p5	1	1	SSE3
UNPCKH/LPS/D	x,m / v,v,m	1	2	p5 p23		1	SSE3
EXTRACTPS	r32,x,i	2	2	p0 p5		1	SSE4.1
EXTRACTPS	m32,x,i	2	3	p4 p5 p23	5	1	SSE4.1
VEEXTRACTF128	x,y,i	1	1	p5	3	1	AVX
VEEXTRACTF128	m128,y,i	2	2	p23 p4	6	1	AVX
INSERTPS	x,x,i	1	1	p5	1	1	SSE4.1
INSERTPS	x,m32,i	2	2	p23 p5	4	1	SSE4.1
VINSERTF128	y,y,x,i	1	1	p5	3	1	AVX
VINSERTF128	y,y,m128,i	2	2	p015 p23	5	0.5	AVX
VMASKMOVPS/D	v,v,m	2	2	p015 p23	3	0.5	AVX
VMASKMOVPS/D	m128,x,x	4	4	p0 p4 p23	13	1	AVX
VMASKMOVPS/D	m256,y,y	4	4	p0 p4 p23	13	1	AVX
VGATHERDPS	x,[r+s*x],x	4	4	p0 p1 p23 p5	12	4	AVX2
VGATHERDPS	y,[r+s*y],y	4	4	p0 p1 p23 p5	13	5	AVX2
VGATHERQPS	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VGATHERQPS	x,[r+s*y],x	4	4	p0 p1 p23 p5		4	AVX2
VGATHERDPD	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VGATHERDPD	y,[r+s*x],y	4	4	p0 p1 p23 p5		4	AVX2
VGATHERQPD	x,[r+s*x],x	5	5	p0 p1 p23 p5		2	AVX2
VGATHERQPD	y,[r+s*y],y	4	4	p0 p1 p23 p5		4	AVX2
<b>Conversion</b>							
CVTPD2PS	x,x	2	2	p01 p5	5	1	
CVTPD2PS	x,m128	2	3	p01 p5 p23		1	
VCVTPD2PS	x,y	2	2	p01 p5	7	1	AVX
VCVTPD2PS	x,m256	2	3	p01 p5 p23		1	AVX
CVTSD2SS	x,x	2	2	p01 p5	5	1	
CVTSD2SS	x,m64	2	3	p01 p5 p23		1	
CVTPS2PD	x,x	2	2	p01 p5	5	1	
CVTPS2PD	x,m64	1	2	p01 p5 p23		0.5	
VCVTPS2PD	y,x	2	2	p01 p5	7	1	AVX
VCVTPS2PD	y,m128	1	2	p01 p5 p23		0.5	AVX
CVTSS2SD	x,x	2	2	p01 p5	5	2	
CVTSS2SD	x,m32	1	2	p01 p5 p23		2	
CVTDQ2PS	x,x	1	1	p01	4	0.5	
CVTDQ2PS	x,m128	1	2	p01 p23		0.5	
VCVTDQ2PS	y,y	1	1	p01	4	0.5	AVX
VCVTDQ2PS	y,m256	1	2	p01 p23		0.5	AVX
CVT(T) PS2DQ	x,x	1	1	p01	4	0.5	
CVT(T) PS2DQ	x,m128	1	2	p01 p23		0.5	
VCVT(T) PS2DQ	y,y	1	1	p01	4	0.5	AVX
VCVT(T) PS2DQ	y,m256	1	2	p01 p23		0.5	AVX
CVTDQ2PD	x,x	2	2	p01 p5	5	1	
CVTDQ2PD	x,m64	2	2	p01 p23		0.5	
VCVTDQ2PD	y,x	2	2	p01 p5	7	1	AVX
VCVTDQ2PD	y,m128	1	2	p01 p23		0.5	AVX
CVT(T)PD2DQ	x,x	2	2	p01 p5	5	1	

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CVT(T)PD2DQ	x,m128	3	3	p01 p23 p5		1	
VCVT(T)PD2DQ	x,y	2	2	p01 p5	7	1	AVX
VCVT(T)PD2DQ	x,m256	2	3	p01 p23 p5		1	AVX
CVTPI2PS	x,mm	2	2	p0 p1	6	2	
CVTPI2PS	x,m64	1	2	p01 p23		3	
CVT(T)PS2PI	mm,x	2	2	p0 p5	7	1	
CVT(T)PS2PI	mm,m128	2	2	p0 p23		1	
CVTPI2PD	x,mm	2	2	p01 p5	5	1	
CVTPI2PD	x,m64	1	2	p01 p23		0.5	
CVT(T) PD2PI	mm,x	2	2	p01 p5	5	1	
CVT(T) PD2PI	mm,m128	2	3	p01 p23 p5		1	
CVTSI2SS	x,r32	2	2	p01 p5	6	2	
CVTSI2SS	x,r64	3	3	p01 2p5	7	2	
CVTSI2SS	x,m32	1	2	p1 p23		3	
CVT(T)SS2SI	r32,x	2	2	2p01	6	1	
CVT(T)SS2SI	r64,x	3	3	2p01 p5	7	1	
CVT(T)SS2SI	r32,m32	3	3	2p01 p23		1	
CVTSI2SD	x,r32/64	2	2	p01 p5	6	2	
CVTSI2SD	x,m32	1	2	p01 p23		2	
CVT(T)SD2SI	r32/64,x	2	2	p0 p1	6	1	
CVT(T)SD2SI	r32,m64	3	3	2p01 p23		1	
VCVTPS2PH	x,v,i	2	2	p01 p5	5-7	1	F16C
VCVTPS2PH	m,v,i	3	3	p01 p4 p23		1	F16C
VCVTPH2PS	v,x	2	2	p01 p5	5-7	1	F16C
VCVTPH2PS	v,m	1	2	p01 p23		1	F16C
<b>Arithmetic</b>							
ADDSS/D PS/D							
SUBSS/D PS/D	x,x / v,v,v	1	1	p01	4	0.5	
ADDSS/D PS/D							
SUBSS/D PS/D	x,m / v,v,m	1	2	p01 p23		0.5	
ADDSS/D PS/D							
ADDSUBPS/D	x,x / v,v,v	1	1	p01	4	0.5	SSE3
ADDSUBPS/D	x,m / v,v,m	1	2	p01 p23		0.5	SSE3
HADDPS/D							
HSUBPS/D	x,x / v,v,v	3	3	p01 2p5	6	2	SSE3
HADDPS/D							
HSUBPS/D	x,m / v,v,m	4	4	p1 2p5 p23		2	SSE3
MULSS/D PS/D	x,x / v,v,v	1	1	p01	4	0.5	
MULSS/D PS/D	x,m / v,v,m	1	2	p01 p23		0.5	
DIVSS	x,x	1	1	p0	11	3	
DIVPS	x,x	1	1	p0	11	3	
DIVSS DIVPS	x,m	1	2	p0 p23		3-5	
DIVSD	x,x	1	1	p0	13-14	4	
DIVPD	x,x	1	1	p0	13-14	4	
DIVSD DIVPD	x,m	1	2	p0 p23		4	
VDIVPS	y,y,y	1	1	p0	11	5	AVX
VDIVPS	y,y,m256	1	2	p0 p23		5	AVX
VDIVPD	y,y,y	1	1	p0	13-14	8	AVX
VDIVPD	y,y,m256	4	4	p0 p23		8	AVX
RCPSS/PS	v,v	1	1	p0	4	1	
RCPSS/PS	v,m	1	2	p0 p23		1	
CMPccSS/D							
CMPccPS/D	x,x / v,v,v	1	1	p01	4	0.5	

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CMPccSS/D							
CMPccPS/D	x,m / v,v,m	2	2	p01 p23		0.5	
(U)COMISS/D	x,x	1	1	p0		1	
(U)COMISS/D	x,m32/64	2	2	p0 p23		1	
MAXSS/D PS/D							
MINSS/D PS/D	x,x / v,v,v	1	1	p01	4	0.5	
MAXSS/D PS/D							
MINSS/D PS/D	x,m / v,v,m	1	2	p01 p23		0.5	
ROUNDSS/D PS/D	v,v,i	2	2	2p01	8	1	SSE4.1
ROUNDSS/D PS/D	v,m,i	3	3	2p01 p23		1	SSE4.1
DPPS	x,x,i / v,v,v,i	4	4	3p01 p5	13	1.5	SSE4.1
DPPS	x,m,i / v,v,m,i	6	6	3p01 p23 p5 p6		1.5	SSE4.1
DPPD	x,x,i	3	3	2p01 p5	9	1	SSE4.1
DPPD	x,m128,i	4	4	2p01 p23 p5		1	SSE4.1
VFMADD...							
(all FMA instr.)	v,v,v	1	1	p01	4	0.5	FMA
VFMADD...							
(all FMA instr.)	v,v,m	1	2	p01 p23		0.5	FMA
<b>Math</b>							
SQRTSS/PS	x,x	1	1	p0	12	3	
SQRTSS/PS	x,m128	1	2	p0 p23		3	
VSQRTPS	y,y	1	1	p0	12	6	AVX
VSQRTPS	y,m256	4	4	p0 p23		6	AVX
SQRTSD	x,x	1	1	p0	15-16	4-6	
SQRTPD	x,x	1	1	p0	15-16	4-6	
SQRTSD/PD	x,m128	1	2	p0 p23		4-6	
VSQRTPD	y,y	1	1	p0	15-16	9-12	AVX
VSQRTPD	y,m256	4	4	p0 p23		9-12	AVX
RSQRTSS/PS	v,v	1	1	p0	4	1	
RSQRTSS/PS	v,m	1	2	p0 p23		1	
<b>Logic</b>							
AND/ANDN/OR/XO							
RPS/PD	x,x / v,v,v	1	1	p015	1	0.33	
AND/ANDN/OR/XO							
RPS/PD	x,m / v,v,m	1	2	p015 p23		0.5	
<b>Other</b>							
VZEROUPPER		4	4	none		1	AVX
VZEROALL		25	25	p0 p1 p5 p6		12	AVX, 32 bit
VZEROALL		34	34	p0 p1 p5 p6		12	AVX, 64 bit
LDMXCSR	m32	4	4	p0 p5 p6 p23	5	3	
STMXCSR	m32	3	4	p0 p4 p6 p237	5	2	
FXSAVE	m4096	106			78	78	32 bit mode
FXSAVE	m4096	136			64	64	64 bit mode
FXRSTOR	m4096	105			76	76	32 bit mode
FXRSTOR	m4096	121			77	77	64 bit mode
XSAVE		247			107	107	32 bit mode
XSAVE		304			107	107	64 bit mode

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XRSTOR		257			122	122	32 bit mode
XRSTOR		257			122	122	64 bit mode
XSAVEOPT	m	168			74	74	

## Intel Pentium 4

### List of instruction timings and $\mu$ op breakdown

This list is measured for a Pentium 4, model 2. Timings for model 3 may be more like the values for P4E, listed on the next sheet

#### Explanation of column headings:

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc.
<b><math>\mu</math>ops:</b>	Number of $\mu$ ops issued from instruction decoder and stored in trace cache.
<b>Microcode:</b>	Number of additional $\mu$ ops issued from microcode ROM.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain if the next dependent instruction starts in the same execution unit. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency of moves to and from memory cannot be measured accurately because of the problem with memory intermediates explained above under "How the values were measured".
<b>Additional latency:</b>	This number is added to the latency if the next dependent instruction is in a different execution unit. There is no additional latency between ALU0 and ALU1.
<b>Reciprocal throughput:</b>	This is also called issue latency. This value indicates the number of clock cycles from the execution of an instruction begins to a subsequent independent instruction can begin to execute in the same execution subunit. A value of 0.25 indicates 4 instructions per clock cycle in one thread.
<b>Port:</b>	The port through which each $\mu$ op goes to an execution unit. Two independent $\mu$ ops can start to execute simultaneously only if they are going through different ports.
<b>Execution unit:</b>	Use this information to determine additional latency. When an instruction with more than one $\mu$ op uses more than one execution unit, only the first and the last execution unit is listed.
<b>Execution subunit:</b>	Throughput measures apply only to instructions executing in the same subunit.
<b>Instruction set</b>	Indicates the compatibility of an instruction with other 80x86 family microprocessors. The instruction can execute on microprocessors that support the instruction set indicated.

### Integer instructions

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## Pentium 4

Instruction	Operands	µops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOV	r,r	1	0	0,5	0.5-1	0,25	0/1	alu0/1		86	c
MOV	r,i	1	0	0,5	0.5-1	0,25	0/1	alu0/1		86	
MOV	r32,m	1	0	2	0	1	2	load		86	
MOV	r8/16,m	2	0	3	0	1	2	load		86	
MOV	m,r	1	0	1		2	0	store		86	b, c
MOV	m,i	3	0			2	0,3	store		86	
MOV	r,sr	4	2			6				86	
MOV	sr,r/m	4	4	12	0	14				86	a, q
MOVNTI	m,r32	2	0			≈33				sse2	
MOVZX	r,r	1	0	0,5	0.5-1	0,25	0/1	alu0/1		386	c
MOVZX	r,m	1	0	2	0	1	2	load		386	
MOVSX	r,r	1	0	0,5	0.5-1	0,5	0	alu0		386	c
MOVSX	r,m	2	0	3	0.5-1	1	2,0			386	
CMOVcc	r,r/m	3	0	6	0	3				ppro	a, e
XCHG	r,r	3	0	1,5	0.5-1	1	0/1	alu0/1		86	
XCHG	r,m	4	8	>100						86	
XLAT		4	0	3						86	
PUSH	r	2	0	1		2				86	
PUSH	i	2	0	1		2				186	
PUSH	m	3	0			2				86	
PUSH	sr	4	4			7				86	
PUSHF(D)		4	4			10				86	
PUSHA(D)		4	10			19				186	
POP	r	2	0	1	0	1				86	
POP	m	4	8			14				86	
POP	sr	4	5			13				86	
POPF(D)		4	8			52				86	
POPA(D)		4	16			14				186	
LEA	r,[r+r/i]	1	0	0,5	0.5-1	0,25	0/1	alu0/1		86	
LEA	r,[r+r+i]	2	0	1	0.5-1	0,5	0/1	alu0/1		86	
LEA	r,[r*i]	3	0	4	0.5-1	1	1	int,alu		386	
LEA	r,[r+r*i]	2	0	4	0.5-1	1	1	int,alu		386	
LEA	r,[r+r*i+i]	3	0	4	0.5-1	1	1	int,alu		386	
LAHF		1	0	4	0	4	1	int		86	
SAHF		1	0	0,5	0.5-1	0,5	0/1	alu0/1		86	d
SALC		3	0	5	0	1	1	int		86	
LDS, LES, ...	r,m	4	7			15				86	
BSWAP	r	3	0	7	0	2		int,alu		486	
IN, OUT	r,r/i	8	64			>1000			86		
PREFETCHNTA	m	4	2			6				sse	
PREFETCH0/1/2	m	4	2			6				sse	

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SFENCE		4	2			40				sse	
LFENCE		4	2			38				sse2	
MFENCE		4	2			100				sse2	
<b>Arithmetic instructions</b>											
ADD, SUB	r,r	1	0	0,5	0.5-1	0,25	0/1	alu0/1		86	c
ADD, SUB	r,m	2	0	1	0.5-1	1				86	c
ADD, SUB	m,r	3	0	≥ 8		≥ 4				86	c
ADC, SBB	r,r	4	4	6	0	6	1	int,alu		86	
ADC, SBB	r,i	3	0	6	0	6	1	int,alu		86	
ADC, SBB	r,m	4	6	8	0	8	1	int,alu		86	
ADC, SBB	m,r	4	7	≥ 9		8				86	
CMP	r,r	1	0	0,5	0.5-1	0,25	0/1	alu0/1		86	c
CMP	r,m	2	0	1	0.5-1	1				86	c
INC, DEC	r	2	0	0,5	0.5-1	0,5	0/1	alu0/1		86	
INC, DEC	m	4	0	4		≥ 4				86	
NEG	r	1	0	0,5	0.5-1	0,5	0	alu0		86	
NEG	m	3	0			≥ 3				86	
AAA, AAS		4	27	90						86	
DAA, DAS		4	57	100						86	
AAD		4	10	22			1	int	fpmul	86	
AAM		4	22	56			1	int	fpdiv	86	
MUL, IMUL	r8/32	4	6	16	0	8	1	int	fpmul	86	
MUL, IMUL	r16	4	7	17	0	8	1	int	fpmul	86	
MUL, IMUL	m8/32	4	7-8	16	0	8	1	int	fpmul	86	
MUL, IMUL	m16	4	10	16	0	8	1	int	fpmul	86	
IMUL	r32,r	4	0	14	0	4,5	1	int	fpmul	386	
IMUL	r32,(r),i	4	0	14	0	4,5	1	int	fpmul	386	
IMUL	r16,r	4	5	16	0	9	1	int	fpmul	386	
IMUL	r16,r,i	4	5	15	0	8	1	int	fpmul	186	
IMUL	r16,m16	4	7	15	0	10	1	int	fpmul	386	
IMUL	r32,m32	4	0	14	0	8	1	int	fpmul	386	
IMUL	r,m,i	4	7	14	0	10	1	int	fpmul	186	
DIV	r8/m8	4	20	61	0	24	1	int	fpdiv	86	a
DIV	r16/m16	4	18	53	0	23	1	int	fpdiv	86	a
DIV	r32/m32	4	21	50	0	23	1	int	fpdiv	386	
IDIV	r8/m8	4	24	61	0	24	1	int	fpdiv	86	a
IDIV	r16/m16	4	22	53	0	23	1	int	fpdiv	86	a
IDIV	r32/m32	4	20	50	0	23	1	int	fpdiv	386	a
CBW		2	0	1	0.5-1	1	0	alu0		86	
CWD, CDQ		2	0	1	0.5-1	0,5	0/1	alu0/1		86	
CWDE		1	0	0,5	0.5-1	0,5	0	alu0		386	
<b>Logic instructions</b>											
AND, OR, XOR	r,r	1	0	0,5	0.5-1	0,5	0	alu0		86	c
AND, OR, XOR	r,m	2	0	≥ 1	0.5-1	≥ 1				86	c
AND, OR, XOR	m,r	3	0	≥ 8		≥ 4				86	c
TEST	r,r	1	0	0,5	0.5-1	0,5	0	alu0		86	c
TEST	r,m	2	0	≥ 1	0.5-1	≥ 1				86	c
NOT	r	1	0	0,5	0.5-1	0,5	0	alu0		86	

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NOT	m	4	0			≥ 4				86	
SHL, SHR, SAR	r,i	1	0	4	1	1	1	int	mmxsh	186	
SHL, SHR, SAR	r,CL	2	0	6	0	1	1	int	mmxsh	86	d
ROL, ROR	r,i	1	0	4	1	1	1	int	mmxsh	186	d
ROL, ROR	r,CL	2	0	6	0	1	1	int	mmxsh	86	d
RCL, RCR	r,1	1	0	4	1	1	1	int	mmxsh	86	d
RCL, RCR	r,i	4	15	16	0	15	1	int	mmxsh	186	d
RCL, RCR	r,CL	4	15	16	0	14	1	int	mmxsh	86	d
SHL,SHR,SAR,ROL, ROR	m,i/CL	4	7-8	10	0	10	1	int	mmxsh	86	d
RCL, RCR	m,1	4	7	10	0	10	1	int	mmxsh	86	d
RCL, RCR	m,i/CL	4	18	18-28		14	1	int	mmxsh	86	d
SHLD, SHRD	r,r,i/CL	4	14	14	0	14	1	int	mmxsh	386	
SHLD, SHRD	m,r,i/CL	4	18	14	0	14	1	int	mmxsh	386	
BT	r,i	3	0	4	0	2	1	int	mmxsh	386	d
BT	r,r	2	0	4	0	1	1	int	mmxsh	386	d
BT	m,i	4	0	4	0	2	1	int	mmxsh	386	d
BT	m,r	4	12	12	0	12	1	int	mmxsh	386	d
BTR, BTS, BTC	r,i	3	0	6	0	2	1	int	mmxsh	386	
BTR, BTS, BTC	r,r	2	0	6	0	4	1	int	mmxsh	386	
BTR, BTS, BTC	m,i	4	7	18	0	8	1	int	mmxsh	386	
BTR, BTS, BTC	m,r	4	15	14	0	14	1	int	mmxsh	386	
BSF, BSR	r,r	2	0	4	0	2	1	int	mmxsh	386	
BSF, BSR	r,m	3	0	4	0	3	1	int	mmxsh	386	
SETcc	r	3	0	5	0	1	1	int		386	
SETcc	m	4	0	5	0	3	1	int		386	
CLC, STC		3	0	10	0	2				86	d
CMC		3	0	10	0	2				86	
CLD		4	7	52	0	52				86	
STD		4	5	48	0	48				86	
CLI		4	5	35		35				86	
STI		4	12	43		43				86	
<b>Control transfer instructions</b>											
JMP	short/near	1	0	0	0	1	0	alu0	branch	86	
JMP	far	4	28	118		118	0			86	
JMP	r	3	0	4		4	0	alu0	branch	86	
JMP	m(near)	3	0	4		4	0	alu0	branch	86	
JMP	m(far)	4	31	11		11	0			86	
Jcc	short/near	1	0	0		2-4	0	alu0	branch	86	
J(E)CXZ	short	4	4	0		2-4	0	alu0	branch	86	
LOOP	short	4	4	0		2-4	0	alu0	branch	86	
CALL	near	3	0	2		2	0	alu0	branch	86	
CALL	far	4	34				0			86	
CALL	r	4	4	8			0	alu0	branch	86	
CALL	m(near)	4	4	9			0	alu0	branch	86	
CALL	m(far)	4	38				0			86	
RETN		4	0	2			0	alu0	branch	86	
RETN	i	4	0	2			0	alu0	branch	86	
RETF		4	33	11			0			86	

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RETf	i	4	33	11		0				86
IRET		4	48	24		0				86
ENTER	i,0	4	12	26			26			186
ENTER	i,n	4	45+24n				128+16n		186	
LEAVE		4	0	3			3			186
BOUND	m	4	14	14			14			186
INTO		4	5	18			18			86
INT	i	4	84	644						86
<b>String instructions</b>										
LODS		4	3	6			6			86
REP LODS		4	5n	≈ 4n+36				86		
STOS		4	2	6			6			86
REP STOS		4	2n+3	≈ 3n+10				86		
MOVS		4	4	6			4			86
REP MOVS		4	≈163+1.1n					86		
SCAS		4	3				6			86
REP SCAS		4	≈ 40+6n	≈4n				86		
CMPS		4	5				8			86
REP CMPS		4	≈ 50+8n	≈4n				86		
<b>Other</b>										
NOP (90)		1	0	0		0,25	0/1	alu0/1		86
Long NOP (0F 1F)		1	0	0		0,25	0/1	alu0/1		ppro sse2
PAUSE		4	2							
CPUID		4	39-81		200-500			p5		
RDTSC		4	7			80				p5

**Notes:**

- a) Add 1 μop if source is a memory operand.
- b) Uses an extra μop (port 3) if SIB byte used. A SIB byte is needed if the memory operand has more than one pointer register, or a scaled index, or ESP is used as base pointer.
- c) Add 1 μop if source or destination, but not both, is a high 8-bit register (AH, BH, CH, DH).
- d) Has (false) dependence on the flags in most cases.
- e) Not available on PMMX
- q) Latency is 12 in 16-bit real or virtual mode, 24 in 32-bit protected mode.

**Floating point x87 instructions**

Instruction	Operands	μops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
FLD	r	1	0	6	0	1	0	mov		87	
FLD	m32/64	1	0	≈ 7	0	1	2	load		87	

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FLD	m80	3	4			6	2	load		87	
FBLD	m80	3	75			90	2	load		87	
FST(P)	r	1	0	6	0	1	0	mov		87	
FST(P)	m32/64	2	0	≈ 7		2-3	0	store		87	
FSTP	m80	3	8			8	0	store		87	
FBSTP	m80	3	311			400	0	store		87	
FXCH	r	1	0	0	0	1	0	mov		87	
FILD	m16	3	3	≈ 10		6	2	load		87	
FILD	m32/64	2	0	≈ 10		1	2	load		87	
FIST	m16	3	0	≈ 10		2-4	0	store		87	
FIST	m32/64	2	0	≈ 10		2-3	0	store		87	
FISTP	m	3	0	≈ 10		2-4	0	store		87	
FLDZ		1	0			2	0	mov		87	
FLD1		2	0			2	0	mov		87	
FCMOVcc	st0,r	4	0	2-4	1	4	1	fp	PPro		e
FFREE	r	3	0			4	0	mov		87	
FINCSTP, FDECSTP		1	0	0	0	1	0	mov		87	
FNSTSW	AX	4	0	11	0	3	1			287	
FSTSW	AX	6	0	11	0	3	1			287	
FNSTSW	m16	4	4			6	0			87	
FNSTCW	m16	4	4			6	0			87	
FLDCW	m16	4	7	(3)		(8)	0,2			87	f
<b>Arithmetic instructions</b>											
FADD(P),FSUB(R)(P)	r	1	0	5	1	1	1	fp	add	87	
FADD,FSUB(R)	m	2	0	5	1	1	1	fp	add	87	
FIADD,FISUB(R)	m16	3	4	6	0	6	1	fp	add	87	
FIADD,FISUB(R)	m32	3	0	5	1	2	1	fp	add	87	
FMUL(P)	r	1	0	7	1	2	1	fp	mul	87	
FMUL	m	2	0	7	1	2	1	fp	mul	87	
FIMUL	m16	3	4	7	1	6	1	fp	mul	87	
FIMUL	m32	3	0	7	1	2	1	fp	mul	87	
FDIV(R)(P)	r	1	0	43	0	43	1	fp	div	87	g, h
FDIV(R)	m	2	0	43	0	43	1	fp	div	87	g, h
FIDIV(R)	m16	3	4	43	0	43	1	fp	div	87	g, h
FIDIV(R)	m32	3	0	43	0	43	1	fp	div	87	g, h
FABS		1	0	2	1	1	1	fp	misc	87	
FCHS		1	0	2	1	1	1	fp	misc	87	
FCOM(P), FUCOM(P)	r	1	0	2	0	1	1	fp	misc	87	
FCOM(P)	m	2	0	2	0	1	1	fp	misc	87	
FCOMPP, FUCOMPP		2	0	2	0	1	1	fp	misc	87	
FCOMI(P)	r	3	0	10	0	3	0,1	fp	misc	PPro	
FICOM(P)	m16	4	4			6	1	fp	misc	87	
FICOM(P)	m32	3	0	2	0	2	1,2	fp	misc	87	
FTST		1	0	2	0	1	1	fp	misc	87	
FXAM		1	0	2	0	1	1	fp	misc	87	
FRNDINT		3	15	23	0	15	0,1			87	
FPREM		6	84	212			1	fp		87	
FPREM1		6	84	212			1	fp		387	

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<b>Math</b>											
FSQRT	1	0	43	0	43	1	fp	div	87	g, h	
FLDPI, etc.	2	0			3	1	fp		87		
FSIN	6	≈150	≈180		≈170	1	fp		387		
FCOS	6	≈175	≈207		≈207	1	fp		387		
FSINCOS	7	≈178	≈216		≈211	1	fp		387		
FPTAN	6	≈160	≈230		≈200	1	fp		87		
FPATAN	3	92	≈187		≈153	1	fp		87		
FSCALE	3	24	57		66	1	fp		87		
FEXTRACT	3	15	20		20	1	fp		87		
F2XM1	3	45	≈165		63	1	fp		87		
FYL2X	3	60	≈200		90	1	fp		87		
FYL2XP1	11	134	≈242		≈220	1	fp		87		
<b>Other</b>											
FNOP	1	0	1	0	1	0		mov	87		
(F)WAIT	2	0	0	0	1	0		mov	87		
FNCLEX	4	4			96	1			87		
FNINIT	6	29			172				87		
FNSAVE	4	174	456		420	0,1			87		
FRSTOR	4	96	528		532				87		
FXSAVE	4	69	132		96				sse	i	
FXRSTOR	4	94	208		208				sse	i	

**Notes:**

- e) Not available on PMMX
- f) The latency for FLDCW is 3 when the new value loaded is the same as the value of the control word before the preceding FLDCW, i.e. when alternating between the same two values. In all other cases, the latency and reciprocal throughput is 143.
- g) Latency and reciprocal throughput depend on the precision setting in the F.P. control word. Single precision: 23, double precision: 38, long double precision (default): 43.
- h) Throughput of FP-MUL unit is reduced during the use of the FP-DIV unit.
- i) Takes 6 μops more and 40-80 clocks more when XMM registers are disabled.

**Integer MMX and XMM instructions**

Instruction	Operands	μops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOVD	r32, mm	2	0	5	1	1	0	fp		mmx	
MOVD	mm, r32	2	0	2	0	2	1	mmx	alu	mmx	
MOVD	mm,m32	1	0	≈ 8	0	1	2	load		mmx	
MOVD	r32, xmm	2	0	10	1	2	0	fp		sse2	

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MOVD	xmm, r32	2	0	6	1	2	1	mmx	shift	sse2	
MOVD	xmm,m32	1	0	≈ 8	0	1	2	load		sse2	
MOVD	m32, r	2	0	≈ 8		2	0,1			mmx	
MOVQ	mm,mm	1	0	6	0	1	0	mov		mmx	
MOVQ	xmm,xmm	1	0	2	1	2	1	mmx	shift	sse2	
MOVQ	r,m64	1	0	≈ 8		1	2	load		mmx	
MOVQ	m64,r	2	0	≈ 8		2	0	mov		mmx	
MOVDQA	xmm,xmm	1	0	6	0	1	0	mov		sse2	
MOVDQA	xmm,m	1	0	≈ 8		1	2	load		sse2	
MOVDQA	m,xmm	2	0	≈ 8		2	0	mov		sse2	
MOVDQU	xmm,m	4	0			2	2	load		sse2	k
MOVDQU	m,xmm	4	6			2	0	mov		sse2	k
MOVDQ2Q	mm,xmm	3	0	8	1	2	0,1	mov-mmx	sse2		
MOVQ2DQ	xmm,mm	2	0	8	1	2	0,1	mov-mmx	sse2		
MOVNTQ	m,mm	3	0			75	0	mov		sse	
MOVNTDQ	m,xmm	2	0			18	0	mov		sse2	
PACKSSWB/DW											
PACKUSWB	mm,r/m	1	0	2	1	1	1	mmx	shift	mmx	a
PACKSSWB/DW											
PACKUSWB	xmm,r/m	1	0	4	1	2	1	mmx	shift	mmx	a
PUNPCKH/LBW/WD/DQ	mm,r/m	1	0	2	1	1	1	mmx	shift	mmx	a
PUNPCKHBW/WD/DQ/QDQ	xmm,r/m	1	0	4	1	2	1	mmx	shift	sse2	a
PUNPCKLBW/WD/DQ/QDQ	xmm,r/m	1	0	2	1	2	1	mmx	shift	sse2	a
PSHUFD	xmm,xmm,i	1	0	4	1	2	1	mmx	shift	sse2	
PSHUFL/HW	xmm,xmm,i	1	0	2	1	2	1	mmx	shift	sse2	
PSHUFW	mm,mm,i	1	0	2	1	1	1	mmx	shift	mmx	
MASKMOVQ	mm,mm	4	4			7	0	mov		sse	
MASKMOVDQU	xmm,xmm	4	6			10	0	mov		sse2	
PMOVMSKB	r32,r	2	0	7	1	3	0,1	mmx-alu0	sse		
PEXTRW	r32,mm,i	3	0	8	1	2	1	mmx-int	sse		
PEXTRW	r32,xmm,i	3	0	9	1	2	1	mmx-int	sse2		
PINSRW	mm,r32,i	2	0	3	1	2	1	int-mmx	sse		
PINSRW	xmm,r32,i	2	0	4	1	2	1	int-mmx	sse2		
<b>Arithmetic instructions</b>											
PADDB/W/D											
PADD(U)SB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PSUBB/W/D											
PSUB(U)SB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PADDQ, PSUBQ	mm,r/m	1	0	2	1	1	1	mmx	alu	sse2	a
PADDQ, PSUBQ	xmm,r/m	1	0	4	1	2	1	fp	add	sse2	a
PCMPEQB/W/D											
PCMPGTB/W/D	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PMULLW PMULHW	r,r/m	1	0	6	1	1,2	1	fp	mul	mmx	a,j
PMULHUW	r,r/m	1	0	6	1	1,2	1	fp	mul	sse	a,j
PMADDWD	r,r/m	1	0	6	1	1,2	1	fp	mul	mmx	a,j
PMULUDQ	r,r/m	1	0	6	1	1,2	1	fp	mul	sse2	a,j
PAVGB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j

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PMIN/MAXUB	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j
PMIN/MAXSW	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j
PSADBW	r,r/m	1	0	4	1	1,2	1	mmx	alu	sse	a,j
<b>Logic</b>											
PAND, PANDN	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
POR, PXOR	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PSLL/RLW/D/Q, PSRAW/D	r,i/r/m	1	0	2	1	1,2	1	mmx	shift	mmx	a,j
PSLLDQ, PSRLDQ	xmm,i	1	0	4	1	2	1	mmx	shift	sse2	a
<b>Other</b>											
EMMS		4	11	12		12	0			mmx	

**Notes:**

- a) Add 1  $\mu$ op if source is a memory operand.
- j) Reciprocal throughput is 1 for 64 bit operands, and 2 for 128 bit operands.
- k) It may be advantageous to replace this instruction by two 64-bit moves

**Floating point XMM instructions**

Instruction	Operands	$\mu$ ops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOVAPS/D	r,r	1	0	6	0	1	0	mov		sse	
MOVAPS/D	r,m	1	0	$\approx 7$	0	1	2			sse	
MOVAPS/D	m,r	2	0	$\approx 7$		2	0			sse	
MOVUPS/D	r,r	1	0	6	0	1	0	mov		sse	
MOVUPS/D	r,m	4	0			2	2			sse	k
MOVUPS/D	m,r	4	6			8	0			sse	k
MOVSS	r,r	1	0	2	0	2	1	mmx	shift	sse	
MOVSD	r,r	1	0	2	1	2	1	mmx	shift	sse	
MOVSS, MOVSD	r,m	1	0	$\approx 7$	0	1	2			sse	
MOVSS, MOVSD	m,r	2	0			2	0			sse	
MOVHPS	r,r	1	0	4	0	2	1	mmx	shift	sse	
MOVLHPS	r,r	1	0	2	0	2	1	mmx	shift	sse	
MOVHPS/D, MOVLPS/D	r,m	3	0			4	2			sse	
MOVHPS/D, MOVLPS/D	m,r	2	0			2	0			sse	
MOVNTPS/D	m,r	2	0			4	0			sse/2	
MOVMSKPS/D	r32,r	2	0	6	1	3	1	fp		sse	
SHUFPS/D	r,r/m,i	1	0	4	1	2	1	mmx	shift	sse	
UNPCKHPS/D	r,r/m	1	0	4	1	2	1	mmx	shift	sse	
UNPCKLPS/D	r,r/m	1	0	2	1	2	1	mmx	shift	sse	



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<b>Conversion</b>											
CVTSP2PD	r,r/m	4	0	7	1	4	1	mmx	shift	sse2	a
CVTPD2PS	r,r/m	2	0	10	1	2	1	fp-mmx	sse2	a	
CVTSD2SS	r,r/m	4	0	14	1	6	1	mmx	shift	sse2	a
CVTSS2SD	r,r/m	4	0	10	1	6	1	mmx	shift	sse2	a
CVTDQ2PS	r,r/m	1	0	4	1	2	1	fp		sse2	a
CVTDQ2PD	r,r/m	3	0	9	1	4	1	mmx-fp	sse2	a	
CVT(T)PS2DQ	r,r/m	1	0	4	1	2	1	fp		sse2	a
CVT(T)PD2DQ	r,r/m	2	0	9	1	2	1	fp-mmx	sse2	a	
CVTPI2PS	xmm,mm	4	0	10	1	4	1	mmx		sse	a
CVTPI2PD	xmm,mm	4	0	11	1	5	1	fp-mmx	sse2	a	
CVT(T)PS2PI	mm,xmm	3	0	7	0	2	0,1	fp-mmx	sse	a	
CVT(T)PD2PI	mm,xmm	3	0	11	1	3	0,1	fp-mmx	sse2	a	
CVTSI2SS	xmm,r32	3	0	10	1	3	1	fp-mmx	sse	a	
CVTSI2SD	xmm,r32	4	0	15	1	6	1	fp-mmx	sse2	a	
CVT(T)SD2SI	r32,xmm	2	0	8	1	2,5	1	fp		sse2	a
CVT(T)SS2SI	r32,xmm	2	0	8	1	2,5	1	fp		sse	a
<b>Arithmetic</b>											
ADDPs/D ADDSS/D	r,r/m	1	0	4	1	2	1	fp	add	sse	a
SUBPs/D SUBSS/D	r,r/m	1	0	4	1	2	1	fp	add	sse	a
MULPs/D MULSS/D	r,r/m	1	0	6	1	2	1	fp	mul	sse	a
DIVSS	r,r/m	1	0	23	0	23	1	fp	div	sse	a,h
DIVPS	r,r/m	1	0	39	0	39	1	fp	div	sse	a,h
DIVSD	r,r/m	1	0	38	0	38	1	fp	div	sse2	a,h
DIVPD	r,r/m	1	0	69	0	69	1	fp	div	sse2	a,h
RCPPs RCPSS	r,r/m	2	0	4	1	4	1	mmx		sse	a
MAXPs/D MAXSS/D MINPs/D MINSS/D	r,r/m	1	0	4	1	2	1	fp	add	sse	a
CMPccPs/D CMPccSS/D	r,r/m	1	0	4	1	2	1	fp	add	sse	a
COMISS/D UCOMISS/D	r,r/m	2	0	6	1	3	1	fp	add	sse	a
<b>Logic</b>											
ANDPs/D ANDNPs/D ORPs/D XORPs/D	r,r/m	1	0	2	1	2	1	mmx	alu	sse	a
<b>Math</b>											
SQRTSS	r,r/m	1	0	23	0	23	1	fp	div	sse	a,h
SQRTPs	r,r/m	1	0	39	0	39	1	fp	div	sse	a,h
SQRTSD	r,r/m	1	0	38	0	38	1	fp	div	sse2	a,h
SQRTPD	r,r/m	1	0	69	0	69	1	fp	div	sse2	a,h
RSQRTSS	r,r/m	2	0	4	1	3	1	mmx		sse	a
RSQRTPs	r,r/m	2	0	4	1	4	1	mmx		sse	a
<b>Other</b>											
LDMXCSR	m	4	8	98		100	1			sse	
STMXCSR	m	4	4			6	1			sse	

Notes:

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- a)** Add 1  $\mu\text{op}$  if source is a memory operand.
- h)** Throughput of FP-MUL unit is reduced during the use of the FP-DIV unit.
- k)** It may be advantageous to replace this instruction by two 64-bit moves.

## Intel Pentium 4 w. EM64T (Prescott)

### List of instruction timings and $\mu$ op breakdown

*Explanation of column headings:*

- Instruction:** Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
- Operands:** i = immediate constant, r = any register, r32 = 32-bit register, etc., mm = 64 bit mmx register, xmm = 128 bit xmm register, sr = segment register, m = any memory operand including indirect operands, m64 means 64-bit memory operand, etc., mabs = memory operand with 64-bit absolute address.
- $\mu$ ops:** Number of  $\mu$ ops issued from instruction decoder and stored in trace cache.
- Microcode:** Number of additional  $\mu$ ops issued from microcode ROM.
- Latency:** This is the delay that the instruction generates in a dependency chain if the next dependent instruction starts in the same execution unit. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's, infinity and exceptions increase the delays. The latency of moves to and from memory cannot be measured accurately because of the problem with memory intermediates explained above under "How the values were measured".
- Additional latency:** This number is added to the latency if the next dependent instruction is in a different execution unit. There is no additional latency between ALU0 and ALU1.
- Reciprocal throughput:** This is also called issue latency. This value indicates the number of clock cycles from the execution of an instruction begins to a subsequent independent instruction can begin to execute in the same execution subunit. A value of 0.25 indicates 4 instructions per clock cycle in one thread.
- Port:** The port through which each  $\mu$ op goes to an execution unit. Two independent  $\mu$ ops can start to execute simultaneously only if they are going through different ports.
- Execution unit:** Use this information to determine additional latency. When an instruction with more than one  $\mu$ op uses more than one execution unit, only the first and the last execution unit is listed.
- Execution subunit:** Throughput measures apply only to instructions executing in the same subunit.
- Instruction set** Indicates the compatibility of an instruction with other 80x86 family microprocessors. The instruction can execute on microprocessors that support the instruction set indicated.

### Integer instructions

Instruction	Operands	$\mu$ ops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOV	r,r	1	0	1	0	0,25	0/1	alu0/1		86	c
MOV	r8/16/32,i	1	0	1	0	0,25	0/1	alu0/1		86	
MOV	r64,i32	1	0		0	0,5	0/1	alu0/1		x64	

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MOV	r64,i64	2	0		0	1	1	alu1	x64	
MOV	r8/16,m	2	0	3	0	1	2	load	86	
MOV	r32/64,m	1	0	2	0	1	2	load	86	
MOV	m,r	1	0			2	0	store	86	b,c
MOV	m,i	2	0			2	0,3	store	86	
MOV	m64,i32	2	0			2	0,3	store	x64	
MOV	r,sr	1	2			8			86	
MOV	sr,r/m	1	8			27			86	a,q
MOV	r,mabs	3	0			1			x64	l
MOV	mabs,r	3	0			2			x64	l
MOVNTI	m,r32	2	0			2			sse2	
MOVZX	r,r	1	0	1	0	0,25	0/1	alu0/1	386	c
MOVZX	r16,r8	2	0	2	0	1	0/1	alu0/1	386	c
MOVZX	r,m	1	0	2	0	1	2	load	386	
MOVSX	r16,r8	2	0	2	0	1	0	alu0	386	a,c,o
MOVSX	r32/64,r8/16	1	0	1	0	0,5	0	alu0	386	a,c,o
MOVSX	r,m	2	0	3	0	1	2	load	386	
MOVSXD	r64,r32	1	0	1	0	0,5	0	alu0	x64	a
CMOVcc	r,r/m	3	0	9,5	0	3			PPro	a,e
XCHG	r,r	3	0	2	0	1	0/1	alu0/1	86	
XCHG	r,m	2	6	≈100					86	
XLAT		4	0	6					86	
PUSH	r	2	0	2		2			86	
PUSH	i	2	0	2		2			186	
PUSH	m	3	0	2		2			86	
PUSH	sr	1	3			9			86	
PUSHF(D/Q)		1	3			9			86	
PUSHA(D)		1	9			16			186	m
POP	r	2	0	1	0	1			86	
POP	m	2	6			10			86	
POP	sr	1	8			30			86	
POPF(D/Q)		1	8			70			86	
POPA(D)		2	16			15			186	m
LEA	r,[m]	1	0			0,25	0/1	alu0/1	86	p
LEA	r,[r+r/i]	1	0	2,5	0	0,25	0/1	alu0/1	86	
LEA	r,[r+r+i]	2	0	3,5	0	0,5	0/1	alu0/1	86	
LEA	r,[r*i]	3	0	3,5	0	1	1	alu	386	
LEA	r,[r+r*i]	2	0	3,5	0	1	0,1	alu0,1	386	
LEA	r,[r+r*i+i]	3	0	3,5	0	1	1	alu	386	
LAHF		1	0	4	0		1	int	86	n
SAHF		1	0	5	0		0/1	alu0/1	86	d,n
SALC		2	0		0	1	1	int	86	m
LDS, LES, ...	r,m	2	10			28			86	m
LODS		1	3	8		8			86	
REP LODS		1	5n	≈ 4n+50				86		
STOS		1	2	8		8			86	
REP STOS		1	2.5n	≈ 3n				86		
MOVS		1	4	8		8			86	
REP MOVSB		9	≈.3n	≈.3n				86		
REP MOVSW		1	≈.5-1.1n	≈.6-1.4n				86		

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REP MOVSD		1	≈1.1n	≈ 1.4 n				86			
REP MOVSQ		1	≈1.1n	≈ 1.4 n				x64			
BSWAP	r	1	0	1	0	1		alu		486	
IN, OUT	r,r/i	1	52			>1000			86		
PREFETCHNTA	m	1	0			1				sse	
PREFETCHT0/1/2	m	1	0			1				sse	
SFENCE		1	2			50				sse	
LFENCE		1	2			50				sse2	
MFENCE		1	4			124				sse2	
<b>Arithmetic instructions</b>											
ADD, SUB	r,r	1	0	1	0	0,25	0/1	alu0/1		86	c
ADD, SUB	r,m	2	0	1	0	1				86	c
ADD, SUB	m,r	3	0	5		2				86	c
ADC, SBB	r,r/i	3	0	10	0	10	1	int,alu		86	
ADC, SBB	r,m	2	5	10	0	10	1	int,alu		86	
ADC, SBB	m,r	2	6	20		10				86	
ADC, SBB	m,i	3	5	22		10				86	
CMP	r,r	1	0	1	0	0,25	0/1	alu0/1		86	c
CMP	r,m	2	0	1	0	1				86	c
INC, DEC	r	2	0	1	0	0,5	0/1	alu0/1		86	
INC, DEC	m	4	0	5		3				86	
NEG	r	1	0	1	0	0,5	0	alu0		86	
NEG	m	3	0	5		3				86	
AAA, AAS		1	10	26						86	m
DAA, DAS		1	16	29						86	m
AAD		2	5	13			1	int	mul	86	m
AAM		2	17	71			1	int	fpdiv	86	m
MUL, IMUL	r8	1	0	10	0		1	int	mul	86	
MUL, IMUL	r16	4	0	11	0		1	int	mul	86	
MUL, IMUL	r32	3	0	11	0		1	int	mul	86	
MUL, IMUL	r64	1	5	11	0		1	int	mul	x64	
MUL, IMUL	m8	2	0	10	0		1	int	mul	86	
MUL, IMUL	m16	2	5	11	0		1	int	mul	86	
MUL, IMUL	m32	3	0	11	0		1	int	mul	86	
MUL, IMUL	m64	2	6	11	0		1	int	mul	x64	
IMUL	r16,r16	1	0	10	0	2,5	1	int	mul	386	
IMUL	r16,r16,i	2	0	11	0	2,5	1	int	mul	186	
IMUL	r32,r32	1	0	10	0	2,5	1	int	mul	386	
IMUL	r32,(r32),i	1	0	10	0	2,5	1	int	mul	386	
IMUL	r64,r64	1	0	10	0	2,5	1	int	mul	x64	
IMUL	r64,(r64),i	1	0	10	0	2,5	1	int	mul	x64	
IMUL	r16,m16	2	0	10	0	2,5	1	int	mul	386	
IMUL	r32,m32	2	0	10	0	2,5	1	int	mul	386	
IMUL	r64,m64	2	0	10	0	2,5	1	int	mul	x64	
IMUL	r,m,i	3	0	10	0	1-2.5	1	int	mul	186	
DIV	r8/m8	1	20	74	0	34	1	int	fpdiv	86	a
DIV	r16/m16	1	19	73	0	34	1	int	fpdiv	86	a
DIV	r32/m32	1	21	76	0	34	1	int	fpdiv	386	a
DIV	r64/m64	1	31	63	0	52	1	int	fpdiv	x64	a

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IDIV	r8/m8	1	21	76	0	34	1	int	fpdiv	86	a
IDIV	r16/m16	1	19	79	0	34	1	int	fpdiv	86	a
IDIV	r32/m32	1	19	79	0	34	1	int	fpdiv	386	a
IDIV	r64/m64	1	58	96	0	91	1	int	fpdiv	x64	a
CBW		2	0	2	0	1	0	alu0		86	
CWD		2	0	2	0	1	0/1	alu0/1		86	
CDQ		1	0	1	0	1	0/1	alu0/1		386	
CQO		1	0	7	0	1	0/1	alu0/1		x64	
CWDE		2	0	2	0	1	0/1	alu0/1		386	
CDQE		1	0	1	0	1	0/1	alu0/1		x64	
SCAS		1	3		0	8				86	
REP SCAS		1	$\approx 54+6n$		$\approx 4n$				86		
CMPS		1	5			10				86	
REP CMPS		1	$\approx 81+8n$		$\approx 5n$				86		
<b>Logic</b>											
AND, OR, XOR	r,r	1	0	1	0	0,5	0	alu0		86	c
AND, OR, XOR	r,m	2	0	1	0	1				86	c
AND, OR, XOR	m,r	3	0	5		2				86	c
TEST	r,r	1	0	1	0	0,5	0	alu0		86	c
TEST	r,m	2	0	1	0	1				86	c
NOT	r	1	0	1	0	0,5	0	alu0		86	
NOT	m	3	0	5		2				86	
SHL	r,i	1	0	1	0	0,5	1	alu1		186	
SHR, SAR	r8/16/32,i	1	0	1	0	0,5	1	alu1		186	
SHR, SAR	r64,i	1	0	7	0	2	1	alu1		x64	
SHL	r,CL	2	0	2	0	2	1	alu1		86	
SHR, SAR	r8/16/32,CL	2	0	2	0	2	1	alu1		86	
SHR, SAR	r64,CL	2	0	8	0		1	alu1		x64	
ROL, ROR	r8/16/32,i	1	0	1	0	1	1	alu1		186	d
ROL, ROR	r64,i	1	0	7	0	7	1	alu1		x64	d
ROL, ROR	r8/16/32,CL	2	0	2	0	2	1	alu1		86	d
ROL, ROR	r64,CL	2	0	8	0	8	1	alu1		x64	d
RCL, RCR	r,1	1	0	7	0	7	1	alu1		86	d
RCL	r,i	2	11	31	0	31	1	alu1		186	d
RCR	r,i	2	11	25	0	25	1	alu1		186	d
RCL	r,CL	1	11	31	0	31	1	alu1		86	d
RCR	r,CL	1	11	25	0	25	1	alu1		86	d
SHL, SHR, SAR	m8/16/32,i	3	6	10	0		1	alu1		86	
ROL, ROR	m8/16/32,i	3	6	10	0		1	alu1		86	d
SHL, SHR, SAR	m8/16/32,cl	2	6	10	0		1	alu1		86	
ROL, ROR	m8/16/32,cl	2	6	10	0		1	alu1		86	d
RCL, RCR	m8/16/32,1	2	5	27	0	27	1	alu1		86	d
RCL, RCR	m8/16/32,i	3	13	38	0	38	1	alu1		86	d
RCL, RCR	m8/16/32,cl	2	13	37	0	37	1	alu1		86	d
SHLD, SHRD	r8/16/32,r,i	3	0	8	0	7	1	alu1		386	
SHLD	r64,r64,i	4	5	10	0		1	alu1		x64	
SHRD	r64,r64,i	3	7	10	0		1	alu1		x64	
SHLD, SHRD	r8/16/32,r,cl	4	0	9	0	8	1	alu1		386	
SHLD	r64,r64,cl	4	5	14	0		1	alu1		x64	

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SHRD	r64,r64,cl	3	8	12	0		1	alu1		x64	
SHLD, SHRD	m,r,i	3	8	20	0	10	1	alu1		386	
SHLD, SHRD	m,r,CL	2	8	20	0	10	1	alu1		386	
BT	r,i	1	0	8	0	8	1	alu1		386	d
BT	r,r	2	0	9	0	9	1	alu1		386	d
BT	m,i	3	0	8	0	8	1	alu1		386	d
BT	m,r	2	7	10	0	10	1	alu1		386	d
BTR, BTS, BTC	r,i	1	0	8	0	8	1	alu1		386	
BTR, BTS, BTC	r,r	2	0	9	0	9	1	alu1		386	
BTR, BTS, BTC	m,i	3	6	28	0	10	1	alu1		386	
BTR, BTS, BTC	m,r	2	10	14	0	14	1	alu1		386	
BSF, BSR	r,r/m	2	0	16	0	4	1	alu1		386	
SETcc	r	2	0	9	0	1	1	int		386	
SETcc	m	3	0	9	0	2	1	int		386	
CLC, STC		2	0		0	8				86	d
CMC		3	0	15	0					86	
CLD, STD		1	8		0	53				86	
<b>Control transfer instructions</b>											
JMP	short/near	1	0	0	0	1	0	alu0	branch	86	
JMP	far	2	25			154	0			86	m
JMP	r	3	0			15	0	alu0	branch	86	
JMP	m(near)	3	0			10	0	alu0	branch	86	
JMP	m(far)	2	28			157	0			86	
Jcc	short/near	1	0			2-4	0	alu0	branch	86	
J(E)CXZ	short	4	0			4	0	alu0	branch	86	
LOOP	short	4	0			4	0	alu0	branch	86	
CALL	near	3	0			7	0	alu0	branch	86	
CALL	far	3	29			160	0			86	m
CALL	r	4	0			7	0	alu0	branch	86	
CALL	m(near)	4	0			9	0	alu0	branch	86	
CALL	m(far)	2	32			160	0			86	
RETN		4	0			7	0	alu0	branch	86	
RETN	i	4	0			7	0	alu0	branch	86	
RETF		1	30			160	0			86	
RETF	i	2	30			160	0			86	
IRET		1	49			325	0			86	
BOUND	m	2	11			12				186	m
INT	i	2	67			470				86	
INTO		1	4			26				86	m
<b>Other</b>											
NOP (90)		1	0	0		0,25	0/1	alu0/1		86	
Long NOP (0F 1F)		1	0	0		0,25	0/1	alu0/1		ppro	
PAUSE		1	2			50				sse2	
LEAVE		4	0	5		5				186	
CLI		1	5			52				86	
STI		1	11			64				86	
CPUID		1	49-90			300-500		p5			
RDTSC		1	12			100				p5	

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RDPMC (bit 31 = 1)	1	37		100				p5	
RDPMC (bit 31 = 0)	4	154		240				p5	
MONITOR									(sse3)
MWAIT									(sse3)

**Notes:**

- a) Add 1  $\mu$ op if source is a memory operand.
- b) Uses an extra  $\mu$ op (port 3) if SIB byte used.
- c) Add 1  $\mu$ op if source or destination, but not both, is a high 8-bit register (AH, BH, CH, DH).
- d) Has (false) dependence on the flags in most cases.
- e) Not available on PMMX
- l) Move accumulator to/from memory with 64 bit absolute address (opcode A0 - A3).
- m) Not available in 64 bit mode.
- n) Not available in 64 bit mode on some processors.
- o) MOVSX uses an extra  $\mu$ op if the destination register is smaller than the biggest register size available. Use a 32 bit destination register in 16 bit and 32 bit mode, and a 64 bit destination register in 64 bit mode for optimal performance.
- p) LEA with a direct memory operand has 1  $\mu$ op and a reciprocal throughput of 0.25. This also applies if there is a RIP-relative address in 64-bit mode. A sign-extended 32-bit direct memory operand in 64-bit mode without RIP-relative address takes 2  $\mu$ ops because of the SIB byte. The throughput is 1 in this case. You may use a MOV instead.
- q) These values are measured in 32-bit mode. In 16-bit real mode there is 1 microcode  $\mu$ op and a reciprocal throughput of 17.

**Floating point x87 instructions**

Instruction	Operands	$\mu$ ops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
FLD	r	1	0	7	0	1	0	mov		87	
FLD	m32/64	1	0		0	1	2	load		87	
FLD	m80	3	3			8	2	load		87	
FBLD	m80	3	74			90	2	load		87	
FST(P)	r	1	0	7	0	1	0	mov		87	
FST(P)	m32/64	2	0	7		2	0	store		87	
FSTP	m80	3	6			10	0	store		87	
FBSTP	m80	3	311			400	0	store		87	
FXCH	r	1	0	0	0	1	0	mov		87	
FILD	m16	3	2			8	2	load		87	
FILD	m32/64	2	0			2	2	load		87	
FIST(P)	m	3	0			2,5	0	store		87	
FISTTP	m	3	0			2,5	0	store		sse3	
FLDZ		1	0			2	0	mov		87	



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FLD1		2	0			2	0	mov		87	
FCMOVcc	st0,r	4	0	5	1	4	1	fp		PPro	e
FFREE	r	3	0			3	0	mov		87	
FINCSTP, FDECSTP		1	0	0	0	1	0	mov		87	
FNSTSW	AX	4	0		0	3	1			287	
FSTSW	AX	6	0		0	3	1			287	
FNSTSW	m16	2	3			8	0			87	
FNSTCW	m16	4	0			3	0			87	
FLDCW	m16	3	6			10	0,2			87	f
<b>Arithmetic instructions</b>											
FADD(P),FSUB(R)(P)	r	1	0	6	1	1	1	fp	add	87	
FADD,FSUB(R)	m	2	0	6	1	1	1	fp	add	87	
FIADD,FISUB(R)	m16	3	3	7	1	6	1	fp	add	87	
FIADD,FISUB(R)	m32	3	0	6	1	2	1	fp	add	87	
FMUL(P)	r	1	0	8	1	2	1	fp	mul	87	
FMUL	m	2	0	8	1	2	1	fp	mul	87	
FIMUL	m16	3	3	8	1	8	1	fp	mul	87	
FIMUL	m32	3	0	8	1	3	1	fp	mul	87	
FDIV(R)(P)	r	1	0	45	1	45	1	fp	div	87	g,h
FDIV(R)	m	2	0	45	1	45	1	fp	div	87	g,h
FIDIV(R)	m16	3	3	45	1	45	1	fp	div	87	g,h
FIDIV(R)	m32	3	3	45	1	45	1	fp	div	87	g,h
FABS		1	0	3	1	1	1	fp	misc	87	
FCHS		1	0	3	1	1	1	fp	misc	87	
FCOM(P), FUCOM(P)	r	1	0	3	0	1	1	fp	misc	87	
FCOM(P)	m	2	0	3	0	1	1	fp	misc	87	
FCOMPP, FUCOMPP		2	0	3	0	1	1	fp	misc	87	
FCOMI(P)	r	3	0			3	0,1	fp	misc	PPro	
FICOM(P)	m16	3	3			8	1	fp	misc	87	
FICOM(P)	m32	3	0			2	1,2	fp	misc	87	
FTST		1	0			1	1	fp	misc	87	
FXAM		1	0			1	1	fp	misc	87	
FRNDINT		3	14	28	1	16	0,1			87	
FPREM		8	86	220	1		1	fp		87	
FPREM1		9	92	220	1		1	fp		387	
<b>Math</b>											
FSQRT		1	0	45	1	45	1	fp	div	87	g,h
FLDPI, etc.		2	0			2	1	fp		87	
FSIN, FCOS		3	≈100	≈200		≈200	1	fp		387	
FSINCOS		5	≈150	≈200		≈200	1	fp		387	
FPTAN		8	≈170	≈270		≈270	1	fp		87	
FPATAN		4	97	≈250		≈250	1	fp		87	
FSCALE		3	25	96			1	fp		87	
FEXTRACT		4	16	27			1	fp		87	
F2XM1		3	190	≈270			1	fp		87	
FYL2X		3	63	≈170			1	fp		87	
FYL2XP1		3	58	≈170			1	fp		87	

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Other											
FNOP	1	0	1	0	1	0			mov	87	
(F)WAIT	2	0	0	0	1	0			mov	87	
FNCLEX	1	4			120	1				87	
FNINIT	1	30			200					87	
FNSAVE	2	181	500				0,1			87	
FRSTOR	2	96	570							87	
FXSAVE	2	121			160					sse	i
FXRSTOR	2	118			244					sse	i

Notes:

- e) Not available on PMMX
- f) The latency for FLDCW is 3 when the new value loaded is the same as the value of the control word before the preceding FLDCW, i.e. when alternating between the same two values. In all other cases, the latency and reciprocal throughput is > 100.
- g) Latency and reciprocal throughput depend on the precision setting in the F.P. control word. Single precision: 32, double precision: 40, long double precision (default): 45.
- h) Throughput of FP-MUL unit is reduced during the use of the FP-DIV unit.
- i) Takes fewer microcode  $\mu$ ops when XMM registers are disabled, but the throughput is the same.

Integer MMX and XMM instructions

Instruction	Operands	$\mu$ ops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOVD	r32, mm	2	0	6	1	1	0	fp		mmx	
MOVD	mm, r32	1	0	3	1	1	1	mmx	alu	mmx	
MOVD	mm,m32	1	0			1	2	load		mmx	
MOVD	r32, xmm	1	0	7	1	1	0	fp		sse2	
MOVD	xmm, r32	2	0	4	1	2	1	mmx	shift	sse2	
MOVD	xmm,m32	1	0			1	2	load		sse2	
MOVD	m32, r	2	0			2	0,1			mmx	
MOVQ	mm,mm	1	0	7	0	1	0	mov		mmx	
MOVQ	xmm,xmm	1	0	2	1	2	1	mmx	shift	sse2	
MOVQ	r,m64	1	0			1	2	load		mmx	
MOVQ	m64,r	2	0			2	0	mov		mmx	
MOVDQA	xmm,xmm	1	0	7	0	1	0	mov		sse2	
MOVDQA	xmm,m	1	0			1	2	load		sse2	
MOVDQA	m,xmm	2	0			2	0	mov		sse2	
MOVDQU	xmm,m	4	0			23	2	load		sse2	k
MOVDQU	m,xmm	4	2			8	0	mov		sse2	k
LDDQU	xmm,m	4	0			2,5	2	load		sse3	
MOVDQ2Q	mm,xmm	3	0	10	1	2	0,1	mov-mmx	sse2		

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MOVQ2DQ	xmm,mm	2	0	10	1	2	0,1	mov-mmx	sse2		
MOVNTQ	m,mm	3	0			4	0	mov		sse	
MOVNTDQ	m,xmm	2	0			4	0	mov		sse2	
MOVDDUP	xmm,xmm	1	0	2	1	2	1	mmx	shift	sse3	
MOVSHDUP											
MOVSLDUP	xmm,xmm	1	0	4	1	2	1	mmx	shift	sse3	
PACKSSWB/DW											
PACKUSWB	mm,r/m	1	0	2	1	2	1	mmx	shift	mmx	a
PACKSSWB/DW											
PACKUSWB	xmm,r/m	1	0	4	1	4	1	mmx	shift	mmx	a
PUNPCKH/LBW/WD/ DQ	mm,r/m	1	0	2	1	2	1	mmx	shift	mmx	a
PUNPCKHBW/WD/DQ/ QDQ	xmm,r/m	1	0	4	1	4	1	mmx	shift	sse2	a
PUNPCKLBW/WD/DQ/Q DQ	xmm,r/m	1	0	2	1	2	1	mmx	shift	sse2	a
PSHUFD	xmm,xmm,i	1	0	4	1	2	1	mmx	shift	sse2	
PSHUFL/HW	xmm,xmm,i	1	0	2	1	2	1	mmx	shift	sse	
PSHUFW	mm,mm,i	1	0	2	1	1	1	mmx	shift	sse	
MASKMOVQ	mm,mm	1	4			10	0	mov		sse	
MASKMOVDQU	xmm,xmm	1	6			12	0	mov		sse2	
PMOVMSKB	r32,r	2	0	7		3	0,1	mmx-alu0	sse		
PEXTRW	r32,mm,i	2	0	7		2	1	mmx-int	sse		
PEXTRW	r32,xmm,i	2	0	7		3	1	mmx-int	sse2		
PINSRW	r,r32,i	2	0	4		2	1	int-mmx	sse		
<b>Arithmetic instructions</b>											
PADDB/W/D											
PADD(U)SB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PSUBB/W/D											
PSUB(U)SB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PADDQ, PSUBQ	mm,r/m	1	0	2	1	1	1	mmx	alu	sse2	a
PADDQ, PSUBQ	xmm,r/m	1	0	5	1	2	1	fp	add	sse2	a
PCMPEQB/W/D											
PCMPGTB/W/D	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PMULLW PMULHW	r,r/m	1	0	7	1	1,2	1	fp	mul	mmx	a,j
PMULHUW	r,r/m	1	0	7	1	1,2	1	fp	mul	sse	a,j
PMADDWD	r,r/m	1	0	7	1	1,2	1	fp	mul	mmx	a,j
PMULUDQ	r,r/m	1	0	7	1	1,2	1	fp	mul	sse2	a,j
PAVGB/W	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j
PMIN/MAXUB	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j
PMIN/MAXSW	r,r/m	1	0	2	1	1,2	1	mmx	alu	sse	a,j
PSADBW	r,r/m	1	0	4	1	1,2	1	mmx	alu	sse	a,j
<b>Logic</b>											
PAND, PANDN	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
POR, PXOR	r,r/m	1	0	2	1	1,2	1	mmx	alu	mmx	a,j
PSLL/RLW/D/Q, PSRAW/D	r,i/r/m	1	0	2	1	1,2	1	mmx	shift	mmx	a,j
PSLLDQ, PSRLDQ	xmm,i	1	0	4	1	2	1	mmx	shift	sse2	

<b>Other</b>										
EMMS		10	10			12	0			mmx

**Notes:**

- a) Add 1  $\mu$ op if source is a memory operand.
- j) Reciprocal throughput is 1 for 64 bit operands, and 2 for 128 bit operands.
- k) It may be advantageous to replace this instruction by two 64-bit moves or LD-DQU.

**Floating point XMM instructions**

Instruction	Operands	$\mu$ ops	Microcode	Latency	Additional latency	Reciprocal throughput	Port	Execution unit	Subunit	Instruction set	Notes
<b>Move instructions</b>											
MOVAPS/D	r,r	1	0	7	0	1	0	mov		sse	
MOVAPS/D	r,m	1	0		0	1	2			sse	
MOVAPS/D	m,r	2	0			2	0			sse	
MOVUPS/D	r,r	1	0	7	0	1	0	mov		sse	
MOVUPS/D	r,m	4	0			2	2			sse	k
MOVUPS/D	m,r	4	2			8	0			sse	k
MOVSS	r,r	1	0	2	1	2	1	mmx	shift	sse	
MOVSD	r,r	1	0	4	1	2	1	mmx	shift	sse	
MOVSS, MOVSD	r,m	1	0		0	1	2			sse	
MOVSS, MOVSD	m,r	2	0			2	0			sse	
MOVHPS	r,r	1	0	4	1	2	1	mmx	shift	sse	
MOVLHPS	r,r	1	0	2	1	2	1	mmx	shift	sse	
MOVHPS/D, MOVLPS/D	r,m	2	0			2	2			sse	
MOVHPS/D, MOVLPS/D	m,r	2	0			2	0			sse	
MOVSH/LDUP	r,r	1	0	4	1	2	1			sse3	
MOVDDUP	r,r	1	0	2	1	2	1			sse3	
MOVNTPS/D	m,r	2	0			4	0			sse	
MOVMSKPS/D	r32,r	2	0	5	1	3	1	fp		sse	
SHUFPS/D	r,r/m,i	1	0	4	1	2	1	mmx	shift	sse	
UNPCKHPS/D	r,r/m	2	0	4	1	2	1	mmx	shift	sse	
UNPCKLPS/D	r,r/m	1	0	2	1	2	1	mmx	shift	sse	
<b>Conversion</b>											
CVTTPS2PD	r,r/m	1	0	4	1	4	1	mmx	shift	sse2	a
CVTPD2PS	r,r/m	2	0	10	1	2	1	fp-mmx	sse2	a	
CVTSD2SS	r,r/m	3	0	14	1	6	1	mmx	shift	sse2	a
CVTSS2SD	r,r/m	2	0	8	1	6	1	mmx	shift	sse2	a
CVTDQ2PS	r,r/m	1	0	5	1	2	1	fp		sse2	a
CVTDQ2PD	r,r/m	3	0	10	1	4	1	mmx-fp	sse2	a	
CVT(T)PS2DQ	r,r/m	1	0	5	1	2	1	fp		sse2	a
CVT(T)PD2DQ	r,r/m	2	0	11	1	2	1	fp-mmx	sse2	a	
CVTPI2PS	xmm,mm	4	0	12	1	6	1	mmx		sse	a

Prescott

CVTPI2PD	xmm,mm	4	0	12	1	5	1	fp-mmx	sse2	a	
CVT(T)PS2PI	mm,xmm	3	0	8	0	2	0,1	fp-mmx	sse	a	
CVT(T)PD2PI	mm,xmm	4	0	12	1	3	0,1	fp-mmx	sse2	a	
CVTSS2SS	xmm,r32	3	0	20	1	4	1	fp-mmx	sse	a	
CVTSS2SD	xmm,r32	4	0	20	1	5	1	fp-mmx	sse2	a	
CVT(T)SD2SI	r32,xmm	2	0	12	1	4	1	fp		sse2	a
CVT(T)SS2SI	r32,xmm	2	0	17	1	4	1	fp		sse	a
<b>Arithmetic</b>											
ADDPS/D ADDSS/D	r,r/m	1	0	5	1	2	1	fp	add	sse	a
SUBPS/D SUBSS/D	r,r/m	1	0	5	1	2	1	fp	add	sse	a
ADDSUBPS/D	r,r/m	1	0	5	1	2	1	fp	add	sse3	a
HADDPS/D HSUBPS/D	r,r/m	3	0	13	1	5-6	1	fp	add	sse3	a
MULPS/D MULSS/D	r,r/m	1	0	7	1	2	1	fp	mul	sse	a
DIVSS	r,r/m	1	0	32	1	23	1	fp	div	sse	a,h
DIVPS	r,r/m	1	0	41	1	41	1	fp	div	sse	a,h
DIVSD	r,r/m	1	0	40	1	40	1	fp	div	sse2	a,h
DIVPD	r,r/m	1	0	71	1	71	1	fp	div	sse2	a,h
RCPSS RCPSS	r,r/m	2	0	6	1	4	1	mmx		sse	a
MAXPS/D MAXSS/DMINPS/D MINSS/D	r,r/m	1	0	5	1	2	1	fp	add	sse	a
CMPccPS/D CMPccSS/D	r,r/m	1	0	5	1	2	1	fp	add	sse	a
COMISS/D UCOMISS/D	r,r/m	2	0	6	1	3	1	fp	add	sse	a
<b>Logic</b>											
ANDPS/D ANDNPS/D ORPS/D XORPS/D	r,r/m	1	0	2	1	2	1	mmx	alu	sse	a
<b>Math</b>											
SQRTSS	r,r/m	1	0	32	1	32	1	fp	div	sse	a,h
SQRTPS	r,r/m	1	0	41	1	41	1	fp	div	sse	a,h
SQRTSD	r,r/m	1	0	40	1	40	1	fp	div	sse2	a,h
SQRTPD	r,r/m	1	0	71	1	71	1	fp	div	sse2	a,h
RSQRTSS	r,r/m	2	0	5	1	3	1	mmx		sse	a
RSQRTPS	r,r/m	2	0	6	1	4	1	mmx		sse	a
<b>Other</b>											
LDMXCSR	m	2	11			13	1			sse	
STMXCSR	m	3	0			3	1			sse	

**Notes:**

- a) Add 1  $\mu$ op if source is a memory operand.
- h) Throughput of FP-MUL unit is reduced during the use of the FP-DIV unit.
- k) It may be advantageous to replace this instruction by two 64-bit moves or LDDQU.

**Intel Atom****List of instruction timings and  $\mu$ ops breakdown***Explanation of column headings:*

<b>Instruction:</b>	Instruction name. cc means any condition code. For example, Jcc can be JB, JNE, etc.
<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops:</b>	The number of $\mu$ ops from the decoder or ROM.
<b>Unit:</b>	Tells which execution unit is used. Instructions that use the same unit cannot execute simultaneously. ALU0 and ALU1 means integer unit 0 or 1, respectively. ALU0/1 means that either unit can be used. ALU0+1 means that both units are used. Mem means memory in/out unit. FP0 means floating point unit 0 (includes multiply, divide and other SIMD instructions). FP1 means floating point unit 1 (adder). MUL means multiplier, shared between FP and integer units. DIV means divider, shared between FP and integer units. np means not pairable: Cannot execute simultaneously with any other instruction.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.
<b>Reciprocal throughput:</b>	The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

**Integer instructions**

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1	ALU0/1	1	1/2	
MOV	r,i	1	ALU0/1	1	1/2	
MOV	r,m	1	ALU0, Mem	1-3	1	All addr. modes
MOV	m,r	1	ALU0, Mem	1	1	All addr. modes
MOV	m,i	1	ALU0, Mem		1	
MOV	r,sr	1		1	1	
MOV	m,sr	2			5	
MOV	sr,r	7			21	
MOV	sr,m	8			26	
MOVNTI	m,r	1	ALU0, Mem		2,5	
MOVSX MOVZX MOVSD	r,r/m	1	ALU0	1	1	
CMOVcc	r,r	1	ALU0+1	2	2	
CMOVcc	r,m	1			3	
XCHG	r,r	3		6	6	
XCHG	r,m	4		6	6	Implicit lock

## Atom

XLAT		3		6	6	
PUSH	r	1	np	1	1	
PUSH	i	1	np		1	
PUSH	m	2			5	
PUSH	sr	3			6	
PUSHF(D/Q)		14			12	
PUSHA(D)		9			11	Not in x64 mode
POP	r	1	np	1	1	
POP	(E/R)SP	1	np	1	1	
POP	m	3			6	
POP	sr	7			31	
POPF(D/Q)		19			28	
POPA(D)		16			12	Not in x64 mode
LAHF		1	ALU0+1	2	2	
SAHF		1	ALU0/1	1	1/2	
SALC		2		7	5	Not in x64 mode
LEA	r,m	1	AGU1	1-4	1	4 clock latency on input register
BSWAP	r	1	ALU0	1	1	
LDS LES LFS LGS LSS	m	10		30	30	
PREFETCHNTA	m	1	Mem		1	
PREFETCHT0/1/2	m	1	Mem		1	
LFENCE		1			1/2	
MFENCE		1			1	
SFENCE		1			1	
<b>Arithmetic instructions</b>						
ADD SUB	r,r/i	1	ALU0/1	1	1/2	
ADD SUB	r,m	1	ALU0/1, Mem		1	
ADD SUB	m,r/i	1		2	1	
ADC SBB	r,r/i	1		2	2	
ADC SBB	r,m	1		2	2	
ADC SBB	m,r/i	1		2	2	
CMP	r,r/i	1	ALU0/1	1	1/2	
CMP	m,r/i	1			1	
INC DEC NEG NOT	r	1	ALU0/1	1	1/2	
INC DEC NEG NOT	m	1		1		
AAA		13		16		Not in x64 mode
AAS		13		12		Not in x64 mode
DAA		20		20		Not in x64 mode
DAS		21		25		Not in x64 mode
AAD		4		7		Not in x64 mode
AAM		10		24		Not in x64 mode
MUL IMUL	r8	3	ALU0, Mul	7	7	
MUL IMUL	r16	4	ALU0, Mul	6	6	
MUL IMUL	r32	3	ALU0, Mul	6	6	
MUL IMUL	r64	8	ALU0, Mul	14	14	
IMUL	r16,r16	2	ALU0, Mul	6	5	
IMUL	r32,r32	1	ALU0, Mul	5	2	
IMUL	r64,r64	6	ALU0, Mul	13	11	
IMUL	r16,r16,i	2	ALU0, Mul	5	5	

## Atom

IMUL	r32,r32,i	1	ALU0, Mul	5	2	
IMUL	r64,r64,i	7	ALU0, Mul	14	14	
MUL IMUL	m8	3	ALU0, Mul	6		
MUL IMUL	m16	5	ALU0, Mul	7		
MUL IMUL	m32	4	ALU0, Mul	7		
MUL IMUL	m64	8	ALU0, Mul	14		
DIV	r/m8	9	ALU0, Div	22	22	
DIV	r/m16	12	ALU0, Div	33	33	
DIV	r/m32	12	ALU0, Div	49	49	
DIV	r/m 64	38	ALU0, Div	183	183	
IDIV	r/m8	26	ALU0, Div	38	38	
IDIV	r/m16	29	ALU0, Div	45	45	
IDIV	r/m32	29	ALU0, Div	61	61	
IDIV	r/m64	60	ALU0, Div	207	207	
CBW		2	ALU0	5		
CWDE		1	ALU0	1		
CDQE		1	ALU0	1		
CWD		2	ALU0	5		
CDQ		1	ALU0	1		
CQO		1	ALU0	1		
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1	ALU0/1	1	1/2	
AND OR XOR	r,m	1	ALU0/1, Mem		1	
AND OR XOR	m,r/i	1	ALU0/1, Me	1	1	
TEST	r,r/i	1	ALU0/1	1	1/2	
TEST	m,r/i	1	ALU0/1, Mem		1	
SHR SHL SAR	r,i/cl	1	ALU0	1	1	
SHR SHL SAR	m,i/cl	1	ALU0	1	1	
ROR ROL	r,i/cl	1	ALU0	1	1	
ROR ROL	m,i/cl	1	ALU0	1	1	
RCR	r,1	5	ALU0	7		
RCL	r,1	2	ALU0	1		
RCR	r/m,i/cl	12-17	ALU0	12-15		
RCL	r/m,i/cl	14-20	ALU0	14-18		
SHLD	r16,r16,i	10	ALU0	10		1-2 more if mem
SHLD	r32,r32,i	2	ALU0	5		1-2 more if mem
SHLD	r64,r64,i	10	ALU0	11		1-2 more if mem
SHLD	r16,r16,cl	9	ALU0	9		1-2 more if mem
SHLD	r32,r32,cl	2	ALU0	5		1-2 more if mem
SHLD	r64,r64,cl	9	ALU0	10		1-2 more if mem
SHRD	r16,r16,i	8	ALU0	8		1-2 more if mem
SHRD	r32,r32,i	2	ALU0	5		1-2 more if mem
SHRD	r64,r64,i	10	ALU0	9		1-2 more if mem
SHRD	r16,r16,cl	7	ALU0	8		1-2 more if mem
SHRD	r32,r32,cl	2	ALU0	5		1-2 more if mem
SHRD	r64,r64,cl	9	ALU0	9		1-2 more if mem
BT	r,r/i	1	ALU1	1	1	
BT	m,r	9		10		
BT	m,i	2		5		



## Atom

BTR BTS BTC	r,r/i	1	ALU1	1	1	
BTR BTS BTC	m,r	10	ALU1	11		
BTR BTS BTC	m,i	3	ALU1	6		
BSF BSR	r,r/m	10		16		
SETcc	r	1	ALU0+1	2	2	
SETcc	m	2			5	
CLC STC		1	ALU0/1		1/2	
CMC		1		2	2	
CLD		5			7	
STD		6			25	
<b>Control transfer instructions</b>						
JMP	short/near	1	ALU1		2	
JMP	far	29			66	Not in x64 mode
JMP	r	1			4	
JMP	m(near)	2			7	
JMP	m(far)	30			78	
Conditional jump	short/near	1	ALU1		2	
J(E/R)CXZ	short	3			7	
LOOP	short	8			8	
LOOP(N)E	short	8			8	
CALL	near	1			3	
CALL	far	37			65	Not in x64 mode
CALL	r	1			18	
CALL	m(near)	2			20	
CALL	m(far)	38			64	
RETN		1	np		6	
RETN	i	1	np		6	
RETF		36			80	
RETF	i	36			80	
BOUND	r,m	11			10	Not in x64 mode
INTO		4			6	Not in x64 mode
<b>String instructions</b>						
LODS		3		6		
REP LODS		5n+11		3n+50		
STOS		2		5		
REP STOS		3n+10		2n+4		
MOVS		4		6		
REP MOVS		4n+11		2n - 4n		fastest for high n
SCAS		3		6		
REP SCAS		5n+16		3n+60		
CMPS		5		7		
REP CMPS		6n+16		4n+40		
Other						
NOP (90)		1	ALU0/1		1/2	
Long NOP (0F 1F)		1	ALU0/1		1/2	
PAUSE		5		24		
ENTER	a,0	14		23		

## Atom

ENTER	a,b	20+6b			
LEAVE		4			6
CPUID		40-80		100-170	
RDTSC		16		29	
RDPMSR		24		48	

## Floating point x87 instructions

	Operands	µops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
FLD	r	1		1	1	
FLD	m32/m64	1		3	1	
FLD	m80	4		9	10	
FBLD	m80	52		92	92	
FST(P)	r	1		1	1	
FST(P)	m32/m64	3		7	9	
FSTP	m80	8		12	13	
FBSTP	m80	189		221	221	
FXCH	r	1		1	1	
FILD	m	1		7	6	
FIST(P)	m	3		11	9	
FISTTP	m	3		11	9	SSE3
FLDZ		1			1	
FLD1		2			8	
FLDPI FLDL2E etc.		2			10	
FCMOVcc	r	3		9	9	
FNSTSW	AX	4			10	
FNSTSW	m16	4			10	
FLDCW	m16	2			8	
FNSTCW	m16	3			9	
FINCSTP FDECSTP		1		1	1	
FFREE(P)		1			1	
FNSAVE	m	166		321	321	
FRSTOR	m	83		177	177	
<b>Arithmetic instructions</b>						
FADD(P) FSUB(R)(P)	r/m	1		5	1	
FMUL(P)	r/m	1	Mul	5	2	
FDIV(R)(P)	r/m	1	Div	71	71	
FABS		1		1	1	
FCHS		1		1	1	
FCOM(P) FUCOM	r/m	1		1	1	
FCOMPP FUCOMPP		1		1	1	
FCOMI(P) FUCOMI(P)	r	5			10	
FIADD FISUB(R)	m	3			9	
FIMUL	m	3	Mul		9	
FIDIV(R)	m	3	Div		73	
FICOM(P)	m	3			9	
FTST		1		1	1	

## Atom

FXAM	1		1	1
FPREM	26		~110	
FPREM1	37		~130	
FRNDINT	19		48	
<b>Math</b>				
FSCALE	30		56	
FEXTRACT	15		24	
FSQRT	1	Div	71	
FSIN FCOS	9		~260	
FSINCOS	112		~260	
F2XM1	25		~100	
FYL2X FYL2XP1	63		~220	
FPTAN	100		~300	
FPATAN	91		~300	
<b>Other</b>				
FNOP	1			1
WAIT	2		5	5
FNCLEX	4			26
FNINIT	23		74	

## Integer MMX and XMM instructions

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD	r32/64,(x)mm	1		4	2	
MOVD	m32/64,(x)mm	1	Mem	5	1	
MOVD	(x)mm,r32/64	1		3	1	
MOVD	(x)mm,m32/64	1	Mem	4	1	
MOVQ	(x)mm, (x)mm	1	FP0/1	1	1/2	
MOVQ	(x)mm,m64	1	Mem	4	1	
MOVQ	m64, (x)mm	1	Mem	5	1	
MOVDQA	xmm, xmm	1	FP0/1	1	1/2	
MOVDQA	xmm, m128	1	Mem	4	1	
MOVDQA	m128, xmm	1	Mem	5	1	
MOVDQU	m128, xmm	3	Mem	6	6	
MOVDQU	xmm, m128	4	Mem	6	6	
LDDQU	xmm, m128	4	Mem	6	6	
MOVDQ2Q	mm, xmm	1		1	1	
MOVQ2DQ	xmm,mm	1		1	1	
MOVNTQ	m64,mm	1	Mem	~400	1	
MOVNTDQ	m128,xmm	1	Mem	~450	3	
PACKSSWB/DW						
PACKUSWB	(x)mm, (x)mm	1	FP0	1	1	
PUNPCKH/LBW/WD/DQ	(x)mm, (x)mm	1	FP0	1	1	
PUNPCKH/LQDQ	(x)mm, (x)mm	1	FP0	1	1	

## Atom

PSHUFB	mm,mm	1	FP0	1	1
PSHUFB	xmm,xmm	4		6	6
PSHUFW	mm,mm,i	1	FP0	1	1
PSHUFL/HW	xmm,xmm,i	1	FP0	1	1
PSHUFD	xmm,xmm,i	1	FP0	1	1
PALIGNR	xmm, xmm,i	1	FP0	1	1
MASKMOVQ	mm,mm	1	Mem		2
MASKMOVDQU	xmm,xmm	2	Mem		7
PMOVMSKB	r32,(x)mm	1		4	2
PINSRW	(x)mm,r32,i	1		3	1
PEXTRW	r32,(x)mm,i	2		5	5
<b>Arithmetic instructions</b>					
PADD/SUB(U)(S)B/W/D	(x)mm, (x)mm	1	FP0/1	1	1/2
PADDQ PSUBQ	(x)mm, (x)mm	2		5	5
PHADD(S)W PHSUB(S)W	(x)mm, (x)mm	7		8	8
PHADD PHSUBD	(x)mm, (x)mm	3		6	
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	FP0/1	1	1/2
PMULL/HW PMULHUW	mm,mm	1	FP0, Mul	4	1
PMULL/HW PMULHUW	xmm,xmm	1	FP0, Mul	5	2
PMULHRSW	mm,mm	1	FP0, Mul	4	1
PMULHRSW	xmm,xmm	1	FP0, Mul	5	2
PMULUDQ	mm,mm	1	FP0, Mul	4	1
PMULUDQ	xmm,xmm	1	FP0, Mul	5	2
PMADDWD	mm,mm	1	FP0, Mul	4	1
PMADDWD	xmm,xmm	1	FP0, Mul	5	2
PMADDUBSW	mm,mm	1	FP0, Mul	4	1
PMADDUBSW	xmm,xmm	1	FP0, Mul	5	2
PSADBW	mm,mm	1	FP0, Mul	4	1
PSADBW	xmm,xmm	1	FP0, Mul	5	2
PAVGB/W	(x)mm,(x)mm	1	FP0/1	1	1/2
PMIN/MAXUB	(x)mm,(x)mm	1	FP0/1	1	1/2
PMIN/MAXSW	(x)mm,(x)mm	1	FP0/1	1	1/2
PABSB PABSW PABSD	(x)mm,(x)mm	1	FP0/1	1	1/2
PSIGNB PSIGNW PSIGND	(x)mm,(x)mm	1	FP0/1	1	1/2
<b>Logic instructions</b>					
PAND(N) POR PXOR	(x)mm,(x)mm	1	FP0/1	1	1/2
PSLL/RL/RAW/D/Q	(x)mm,(x)mm	2	FP0	5	5
PSLL/RL/RAW/D/Q	(x)xmm,i	1	FP0	1	1
PSLL/RLDQ	xmm,i	1	FP0	1	1
<b>Other</b>					
EMMS		9			9

**Floating point XMM instructions**

	Operands	μops	Unit	Latency	Reciprocal throughput	Remarks
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## Atom

<b>Move instructions</b>					
MOVAPS/D	xmm,xmm	1	FP0/1	1	1/2
MOVAPS/D	xmm,m128	1	Mem	4	1
MOVAPS/D	m128,xmm	1	Mem	5	1
MOVUPS/D	xmm,m128	4	Mem	6	6
MOVUPS/D	m128,xmm	3	Mem	6	6
MOVSS/D	xmm,xmm	1	FP0/1	1	1/2
MOVSS/D	xmm,m32/64	1	Mem	4	1
MOVSS/D	m32/64,xmm	1	Mem	5	1
MOVHPS/D MOVLPS/D	xmm,m64	1	Mem	5	1
MOVHPS/D	m64,xmm	1	Mem	4	1
MOVLPS/D	m64,xmm	1	Mem	4	1
MOVLHPS MOVHLPS	xmm,xmm	1	FP0	1	1
MOVMSKPS/D	r32,xmm	1		4	2
MOVNTPS/D	m128,xmm	1	Mem	~500	3
SHUFPS	xmm,xmm,i	1	FP0	1	1
SHUFPD	xmm,xmm,i	1	FP0	1	1
MOVDDUP	xmm,xmm	1	FP0	1	1
MOVSH/LDUP	xmm,xmm	1	FP0	1	1
UNPCKH/LPS	xmm,xmm	1	FP0	1	1
UNPCKH/LPD	xmm,xmm	1	FP0	1	
<b>Conversion</b>					
CVTPD2PS	xmm,xmm	4		11	11
CVTSD2SS	xmm,xmm	3		10	10
CVTSS2PD	xmm,xmm	4		7	6
CVTSS2SD	xmm,xmm	3		6	6
CVTDQ2PS	xmm,xmm	3		6	6
CVT(T) PS2DQ	xmm,xmm	3		6	6
CVTDQ2PD	xmm,xmm	3		7	6
CVT(T)PD2DQ	xmm,xmm	3		6	6
CVTPI2PS	xmm,mm	1		6	5
CVT(T)PS2PI	mm,xmm	1		4	1
CVTPI2PD	xmm,mm	3		7	6
CVT(T) PD2PI	mm,xmm	4		7	7
CVTSI2SS	xmm,r32	3		7	6
CVT(T)SS2SI	r32,xmm	3		10	8
CVTSI2SD	xmm,r32	3		8	6
CVT(T)SD2SI	r32,xmm	3		10	8
<b>Arithmetic</b>					
ADDSS SUBSS	xmm,xmm	1	FP1	5	1
ADDSD SUBSD	xmm,xmm	1	FP1	5	1
ADDPS SUBPS	xmm,xmm	1	FP1	5	1
ADDPD SUBPD	xmm,xmm	3	FP1	6	6
ADDSUBPS	xmm,xmm	1	FP1	5	1
ADDSUBPD	xmm,xmm	3	FP1	6	6
HADDPS HSUBPS	xmm,xmm	5	FP0+1	8	7
HADDPD HSUBPD	xmm,xmm	5	FP0+1	8	7
MULSS	xmm,xmm	1	FP0, Mul	4	1

## Atom

MULSD	xmm,xmm	1	FP0, Mul	5	2
MULPS	xmm,xmm	1	FP0, Mul	5	2
MULPD	xmm,xmm	6	FP0, Mul	9	9
DIVSS	xmm,xmm	3	FP0, Div	31	31
DIVSD	xmm,xmm	3	FP0, Div	60	60
DIVPS	xmm,xmm	6	FP0, Div	64	64
DIVPD	xmm,xmm	6	FP0, Div	122	122
RCPSS	xmm,xmm	1		4	1
RCPPS	xmm,xmm	5		9	8
CMPccSS/D	xmm,xmm	1	FP0	5	1
CMPccPS/D	xmm,xmm	3	FP0	6	6
COMISS/D UCOMISS/D	xmm,xmm	4	FP0	9	9
MAXSS/D MINSS/D	xmm,xmm	1	FP0	5	1
MAXPS/D MINPS/D	xmm,xmm	3	FP0	6	6
<b>Math</b>					
SQRTSS	xmm,xmm	3	FP0, Div	31	31
SQRTPS	xmm,xmm	5	FP0, Div	63	63
SQRTSD	xmm,xmm	3	FP0, Div	60	60
SQRTPD	xmm,xmm	5	FP0, Div	121	121
RSQRTSS	xmm,xmm	1	FP0	4	1
RSQRTPS	xmm,xmm	5	FP0	9	8
<b>Logic</b>					
ANDPS/D	xmm,xmm	1	FP0/1	1	1/2
ANDNPS/D	xmm,xmm	1	FP0/1	1	1/2
ORPS/D	xmm,xmm	1	FP0/1	1	1/2
XORPS/D	xmm,xmm	1	FP0/1	1	1/2
<b>Other</b>					
LDMXCSR	m32	4		5	6
STMXCSR	m32	4		14	15
FXSAVE	m4096	121		142	144
FXRSTOR	m4096	116		149	150

## Intel Silvermont

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Name of instruction. Multiple names mean that these instructions have the same data. Instructions with or without V name prefix behave the same unless otherwise noted.
<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, m = memory, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops:</b>	The number of $\mu$ ops from the decoder or ROM. A $\mu$ op that goes to multiple units is counted as one.
<b>Unit:</b>	Tells which execution unit is used. Instructions that use the same unit cannot execute simultaneously. IP0 and IP1 means integer port 0 or 1 and their associated pipelines IP0/1 means that either integer unit can be used. IP0+1 means that the $\mu$ op is split in two, using both units. Mem means memory execution cluster FP0 means floating point port 0 (includes multiply, divide, convert and shuffle). FP1 means floating point port 1 (adder).
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.
<b>Reciprocal throughput:</b>	The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread. Delays in the decoders are included in the latency and throughput timings. Values of 4 or more are often caused by bottlenecks in the decoders and microcode ROM rather than the execution units.

### Integer instructions

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1	IP0/1	1	0.5	
MOV	r,i	1	IP0/1	1	0.5	
MOV	r,m	1	Mem	4	1	All addr. modes
MOV	m,r	1	Mem	3	1	All addr. modes
MOV	m,i	1	Mem		1	
MOVNTI	m,r	1	Mem		2	
MOVSX MOVZX MOVSSD	r16,r8	2	IP0		4	
MOVSX MOVZX MOVSSD	r16,m8	3	IP0		10	
MOVSX MOVZX MOVSSD	r32/64,r/m	1	IP0	1	1	
CMOVcc	r,r	1	IP0/1	2	1	
CMOVcc	r,m	1			1	
XCHG	r,r	3	IP0/1	8	8	
XCHG	r,m	3		24	24	Implicit lock
XLAT		4		8	8	

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PUSH	r	1	IP0+1		1	
PUSH	i	1	IP0+1		1	
PUSH	m	3	IP0+1		5	
PUSHF(D/Q)		18	IP0+1		29	
PUSHA(D)		10			10	Not in x64 mode
POP	r	2			1	
POP	(E/R)SP	2			3	
POP	m	6			6	
POPF(D/Q)		21			47	
POPA(D)		17			14	Not in x64 mode
LAHF		1		1	1	
SAHF		1	IP0	2	1	
SALC		2		6	4	Not in x64 mode
LEA	r,[r+d]	1	IP0/1	1	1	
LEA	r,[r+r*s]	1	IP1	1	1	
LEA	r,[r+r*s+d]	1	IP0+1	2	2	
LEA	r,[rip+d]	1	IP0/1		0.5	
LEA	r16,[m]	2		4	4	
BSWAP	r	1	IP0	1	1	
MOVBE	r16,m16	1			2	
MOVBE	r32/64,m32/64	1			1	
MOVBE	m,r	1			1	
PREFETCHNTA	m	1			1	
PREFETCHT0/1/2	m	1			1	
PREFETCHNTW	m	1			1	
LFENCE		2			8	
MFENCE		2			14	
SFENCE		1			7	
<b>Arithmetic instructions</b>						
ADD SUB	r,r/i	1	IP0/1	1	0.5	
ADD SUB	r,m	1	IP0/1, Mem		1	
ADD SUB	m,r/i	1	IP0/1, Mem	6	1	
ADC SBB	r,r/i	1	IP0/1	2	2	
ADC SBB	r,m	1			2	
ADC SBB	m,r/i	1		6	2	
ADCX	r32,r32	1	IP0+1	2	2	
ADCX	r64,r64	1	IP0+1	6	6	
ADOX	r32,r32	1		2	2	
ADOX	r64,r64	1		6	6	
CMP	r,r/i	1	IP0/1	1	0.5	
CMP	m,r/i	1			1	
INC DEC	r	1	IP0/1	1	1	latency to flag=2
NEG NOT	r	1	IP0/1	1	0.5	
INC DEC NEG NOT	m	1		6	1	
AAA		13		12		Not in x64 mode
AAS		13		12		Not in x64 mode
DAA		20		16		Not in x64 mode
DAS		21		16		Not in x64 mode
AAD		4		5		Not in x64 mode
AAM		11		24	16	Not in x64 mode
MUL IMUL	r8	3	IP0	5	5	
MUL IMUL	r16	4	IP0	5	5	



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MUL IMUL	r32	3	IP0	5	5	
MUL IMUL	r64	3	IP0	7	7	
IMUL	r16,r16	2	IP0	4	4	
IMUL	r32,r32	1	IP0	3	1	
IMUL	r64,r64	1	IP0	5	2	
IMUL	r16,r16,i	2	IP0	4	4	
IMUL	r32,r32,i	1	IP0	3	1	
IMUL	r64,r64,i	1	IP0	5	2	
MUL IMUL	m8	3	IP0			
MUL IMUL	m16	5	IP0			
MUL IMUL	m32	4	IP0			
MUL IMUL	m64	4	IP0	14		
MULX	r,r,r	3-4	IP0	8	8	
MULX	r,r,m	4	IP0		8-10	
DIV	r/m8	9	IP0, FP0	24	19	
DIV	r/m16	12	IP0, FP0	25-29	19-23	
DIV	r/m32	12	IP0, FP0	25-39	19-31	
DIV	r/m 64	23	IP0, FP0	34-94	25-94	
IDIV	r/m8	26	IP0, FP0	24-35	25	
IDIV	r/m16	29	IP0, FP0	37-41	30-32	
IDIV	r/m32	29	IP0, FP0	29-46	29-38	
IDIV	r/m64	44	IP0, FP0	47-107	47-107	
CBW		2	IP0	4		
CWDE		1	IP0	1		
CDQE		1	IP0	1		
CWD		2	IP0	4		
CDQ		1	IP0	1		
CQO		1	IP0	1		
POPCNT	r16,r16	2		4	4	
POPCNT	r32,r32	1		3	1	
POPCNT	r64,r64	1		3	1	
CRC32	r32,r8	2		4	4	
CRC32	r32,r16	1		6	6	
CRC32	r32,r32	1		3	1	
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1	IP0/1	1	0.5	
AND OR XOR	r,m	1	IP0/1, Mem		1	
AND OR XOR	m,r/i	1	IP0/1, Mem	6	1	
TEST	r,r/i	1	IP0/1	1	0.5	
TEST	m,r/i	1	IP0/1, Mem		1	
SHR SHL SAR	r,i/cl	1	IP0	1	1	
SHR SHL SAR	m,i/cl	1	IP0		1	
ROR ROL	r,i/cl	1	IP0	1	1	
ROR ROL	m,i/cl	1	IP0		1	
RCR	r,1	7	IP0	9		
RCL	r,1	1	IP0	2	2	
RCR	r,i/cl	11	IP0	12		
RCR	m,i/cl	14	IP0	13		
RCL	r,i/cl	13	IP0	12		
RCL	m,i/cl	16	IP0	14		
SHLD	r16,r16,i	10	IP0	10		2 more if mem
SHLD	r32,r32,i	1	IP0	2		4 more if mem

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SHLD	r64,r64,i	10	IP0	10		2 more if mem
SHLD	r16,r16,cl	9	IP0	10		2 more if mem
SHLD	r32,r32,cl	2	IP0	4		2 more if mem
SHLD	r64,r64,cl	9	IP0	10		2 more if mem
SHRD	r16,r16,i	8	IP0	10		3 more if mem
SHRD	r32,r32,i	2	IP0	4		4 more if mem
SHRD	r64,r64,i	8-10	IP0	10		3 more if mem
SHRD	r16,r16,cl	7	IP0	10		2 more if mem
SHRD	r32,r32,cl	2	IP0	4		2 more if mem
SHRD	r64,r64,cl	2	IP0	4		2 more if mem
BT	r,r/i	1	IP0+1	1	1	
BT	m,r	7		9		
BT	m,i	1		1		
BTR BTS BTC	r,r/i	1	IP0+1	1	1	
BTR BTS BTC	m,r	8			10	
BTR BTS BTC	m,i	1	IP0+1		1	
BSF BSR	r,r/m	10	IP0+1	10	10	
SETcc	r/m	1	IP0+1	2	1	
CLC STC		1	IP0/1		1	
CMC		1		1	1	
CLD		4	IP0+1		7	
STD		5	IP0+1		35	
<b>Control transfer instructions</b>						
JMP	short/near	1	IP1		2	
JMP	r	1			2	
JMP	m(near)	1			2	
Conditional jump	short/near	1	IP1		1-2	
J(E/R)CXZ	short	2			2-15	
LOOP	short	7			10-20	
LOOP(N)E	short	8				
CALL	near	1			2	
CALL	r	1			9	
CALL	m	3			14	
RET		1			3	
RET	i	1			3	
BOUND	r,m	10			10	Not in x64 mode
INTO		4			7	Not in x64 mode
<b>String instructions</b>						
LODS		3		5		
REP LODS		~4n		~2n		
STOS		2		4		
REP STOS		~0.12B		~0.1B		per byte, best case
MOVS		5		6		
REP MOVS		~0.2B		~0.15B		per byte, best case
SCAS		3		5		
REP SCAS		~5n		~3n		
CMPS		6		6		
REP CMPS		~6n		~3n		

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<b>Synchronization instructions</b>					
XADD	m,r	6		6	
LOCK XADD	m,r	4		10	
LOCK ADD	m,r	1		10	
CMPXCHG	m,r	8		10	
LOCK CMPXCHG	m,r	6		11	
CMPXCHG8B	m,r	13		14	
LOCK CMPXCHG8B	m,r	11		14	
CMPXCHG16B	m,r	19		24	
LOCK CMPXCHG16B	m,r	17		27	
<b>Other</b>					
NOP (90)		1	IP0/1		0.5
Long NOP (0F 1F)		1	IP0/1		0.5
PAUSE		6		24	
ENTER	a,0	15		14	
ENTER	a,b	19+6b		59+5b	
LEAVE		4			5
CPUID		31-80		54-108	
RDTSC		13		29	
RDTSCP		15		25	
RDPMC		19		19	
RDRAND	r	15			~1472

**Floating point x87 instructions**

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
FLD	r	1		1	0.5	
FLD	m32/m64	1		4	1	
FLD	m80	5		9	8	
FBLD	m80	59		68	68	
FST(P)	r	1		1	0.5	
FST(P)	m32/m64	1		3	2	
FSTP	m80	8		9	9	
FBSTP	m80	204		239	239	
FXCH	r	2	FP0+1	1	1	
FILD	m	1		6	2	
FIST(P)	m	6		9	9	
FISTTP	m	7		6	13	
FLDZ		1			1	
FLD1		1			7	
FLDPI FLDL2E etc.		2			7	
FCMOVcc	r	3		6	6	
FNSTSW	AX	2		~9	9	
FNSTSW	m16	4			11	
FLDCW	m16	2		~6	4	
FNSTCW	m16	4		~5	5	
FINCSTP FDECSTP		1		1	0.5	
FFREE(P)		1			0.5	
FNSAVE	m	166		240	240	

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FRSTOR	m	82		174	174	
<b>Arithmetic instructions</b>						
FADD(P) FSUB(R)(P)	r/m	1	FP1	3	1	
FMUL(P)	r/m	1	FP0	5	2	
FDIV(R)(P)	r/m	1	FP0	39	37	
FABS		1		1	1	
FCHS		1		1	1	
FCOM(P) FUCOM	r/m	1		5	1	
FCOMPP FUCOMPP		1		5	1	
FCOMI(P) FUCOMI(P)	r	1		5	1	
FIADD FISUB(R)	m	3			5	
FIMUL	m	3			6	
FIDIV(R)	m	3			39	
FICOM(P)	m	3			5	
FTST		1		6	1	
FXAM		1		7	1	
FPREM		27		32-57	32-57	
FPREM1		27		32-57	32-57	
FRNDINT		18		26	26	
<b>Math</b>						
FSCALE		27			66	
FEXTRACT		15		20	20	
FSQRT		1		13-40	13-40	
FSIN FCOS		18		40-170	40-170	
FSINCOS		110		40-170		
F2XM1		9		39-90		
FYL2X		34		80-140		
FYL2XP1		61		154		
FPTAN		101		45-200		
FPATAN		63		85-190		
<b>Other</b>						
FNOP		1			0.5	
WAIT		2			4	
FNCLEX		4			24	
FNINIT		19			65	

**Integer MMX and XMM instructions**

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD MOVQ	r32/64,(x)mm	1		4	1	
MOVD MOVQ	m,(x)mm	1	Mem	3	1	
MOVD MOVQ	(x)mm,r32/64	1		3	1	
MOVD MOVQ	(x)mm,m	1	Mem	4	1	
MOVQ	(x)mm, (x)mm	1	FP0/1	1	0.5	
MOVDQA	x, x	1	FP0/1	1	0.5	
MOVDQA MOVDQU	x, m128	1	Mem	4	1	

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MOVDQA MOVDQU	m128, x	1	Mem	3	1	
LDDQU	x, m128	1	Mem	4	1	
MOVDQ2Q	mm, x	1		1	1	
MOVQ2DQ	x,mm	1		1	1	
MOVNTQ	m64,mm	1	Mem	~370	1	
MOVNTDQ	m128,x	1	Mem	~370	1	
MOVNTDQA	x, m128	1		4	1	
PACKSSWB/DW						
PACKUSWB	(x)mm, (x)mm	1	FP0	1	1	
PACKUSDW	x,x	1	FP0	1	1	
PUNPCKH/LBW/WD/DQ	(x)mm, (x)mm	1	FP0	1	1	
PUNPCKH/LQDQ	(x)mm, (x)mm	1	FP0	1	1	
PMOVX/ZX BW BD BQ DW DQ	x,x	1		1	1	
PMOVX/ZX BW BD BQ DW DQ	x,m	1		1	1	
PSHUFB	mm,mm	1	FP0	1	1	
PSHUFB	x,x	4	FP0	5	5	
PSHUFW	mm,mm,i	1	FP0	1	1	
PSHUFL/HW	x,x,i	1	FP0	1	1	
PSHUFD	x,x,i	1	FP0	1	1	
PALIGNR	x,x,i	1	FP0	1	1	
PBLENDVB	x,x,xmm0	2	FP0	4	4	
PBLENDVB	x,m,xmm0	3	FP0		5	
PBLENDW	x,x/m,i	1	FP0	1	1	
MASKMOVQ	mm,mm	1	Mem	~370	1	
MASKMOVDQU	x,x	3	Mem	~370	5	
PMOVMSKB	r32,(x)mm	1		4	1	
PINSRW	(x)mm,r32,i	1		3	1	
PINSRB/D/Q	x,r32,i	1		3	1	
PINSRB/D/Q	x,m8,i	1			1	
PEXTRW	r32,(x)mm,i	2		5	4	
PEXTRB/W	r32,x,i	2		5	4	
PEXTRQ	r64,x,i	2		7	7	
PEXTRB/W	m8/16,x,i	5			6	
PEXTRD	m32,x,i	4			5	
PEXTRQ	m64,x,i	4			8	
<b>Arithmetic instructions</b>						
PADD/SUB(U)(S)B/W/D	(x)mm, (x)mm	1	FP0/1	1	0.5	
PADDQ PSUBQ	(x)mm, (x)mm	2		4	4	
PADDQ PSUBQ	(x)mm, m	3			5	
PHADD(S)W PHSUB(S)W	mm, mm	5		6	6	
PHADD(S)W PHSUB(S)W	x, x/m	7-8		9	9	
PHADDD PHSUBD	(x)mm, (x)mm	3-4		5-6	5-6	
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	FP0/1	1	0.5	
PCMPEQQ	x, x	2		4	4	+1 if mem
PCMPGTQ	x, x	1	FP0	5	2	
PMULL/HW PMULHUW	mm,mm	1	FP0	4	1	
PMULL/HW PMULHUW	x, x	1	FP0	5	2	
PMULHSW	mm,mm	1	FP0	4	1	
PMULHSW	x, x	1	FP0	5	2	
PMULLD	x, x	7	FP0	11	11	+1 if mem

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PMULDQ	x, x	1	FP0	5	2	
PMULUDQ	mm,mm	1	FP0	4	1	
PMULUDQ	x, x	1	FP0	5	2	
PMADDWD	mm,mm	1	FP0	4	1	
PMADDWD	x, x	1	FP0	5	2	
PMADDUBSW	mm,mm	1	FP0	4	1	
PMADDUBSW	x, x	1	FP0	5	2	
PSADBW	mm,mm	1	FP0	4	1	
PSADBW	x, x	1	FP0	5	2	
MPSADBW	x,x,i	3		7	6	
MPSADBW	x,m,i	4			6	
PAVGB/W	(x)mm,(x)mm	1	FP0/1	1	0.5	
PMIN/MAXUB	(x)mm,(x)mm	1	FP0/1	1	0.5	
PMIN/MAXSW	(x)mm,(x)mm	1	FP0/1	1	0.5	
PMIN/PMAX						
SB/SW/SD						
UB/UW/UD	x,x	1		1	1	
PHMINPOSUW	x,x	1	FP0	5	2	
PASB PABSW PABSD	(x)mm,(x)mm	1	FP0/1	1	0.5-1	
PSIGNB PSIGNW PSIGND	(x)mm,(x)mm	1	FP0/1	1	0.5-1	
<b>Logic instructions</b>						
PAND(N) POR PXOR	(x)mm,(x)mm	1	FP0/1	1	0.5	
PTEST	x,x	1		1	1	
PSLL/RL/RAW/D/Q	(x)mm,(x)mm	2	FP0	2	2	
PSLL/RL/RAW/D/Q	(x)mm,i	1	FP0	1	1	
PSLL/RLDQ	x,i	1	FP0	1	1	
<b>String instructions</b>						
PCMPESTRM	x,x,i	9	FP0	21	21	+1 if mem
PCMPESTRM	x,x,i	8	FP0	17	17	+1 if mem
PCMPISTRM	x,x,i	6	FP0	17	17	+1 if mem
PCMPISTRM	x,x,i	5	FP0	13	13	+1 if mem
<b>Encryption instructions</b>						
PCLMULQDQ	x,x,i	8	FP0	10	10	+1 if mem
<b>Other</b>						
EMMS		9			10	

**Floating point XMM instructions**

	Operands	μops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVAPS/D	x, x	1	FP0/1	1	0.5	
MOVAPS/D	x,m128	1	Mem	4	1	
MOVAPS/D	m128,x	1	Mem	3	1	
MOVUPS/D	x,m128	1	Mem	4	1	
MOVUPS/D	m128,x	1	Mem	3	1	
MOVSS/D	x, x	1	FP0/1	1	0.5	
MOVSS/D	x,m32/64	1	Mem	4	1	

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MOVSS/D	m32/64,x	1	Mem	3	1	
MOVHPS/D MOVLPS/D	x,m64	1	Mem	4	1	
MOVHPS/D MOVLPS/D	m64,x	1	Mem	3	1	
MOVLHPS MOVHLPS	x,x	1	FP0	1	1	
BLENDPS/PD	x,x/m,i	1		1	1	
BLENDVPS/PD	x,x,xmm0	2	FP0+1	4	4	
BLENDVPS/PD	x,m,xmm0	3	FP0+1	5	5	
INSERTPS	x,x,i	1		1	1	
INSERTPS	x,m32,i	3		5	5	
EXTRACTPS	r32,x,i	2			4	
EXTRACTPS	m32,x,i	4		4	5	
MOVMSKPS/D	r32,x	1	FP0	4	1	
MOVNTPS/D	m128,x	1	Mem	~370	1	
SHUFPS	x,x,i	1	FP0	1	1	
SHUFPD	x,x,i	1	FP0	1	1	
MOVDDUP	x, x	1	FP0	1	1	
MOVSH/LDUP	x, x	1	FP0	1	1	
UNPCKH/LPS	x, x	1	FP0	1	1	
UNPCKH/LPD	x, x	1	FP0	1	1	
<b>Conversion</b>						
CVTPD2PS	x, x	1	FP0	5	2	
CVTSD2SS	x, x	1	FP0	4	2	
CVTPS2PD	x, x	1	FP0	5	2	
CVTSS2SD	x, x	1	FP0	4	2	
CVTDQ2PS	x, x	1	FP0	5	2	
CVT(T) PS2DQ	x, x	1	FP0	5	2	
CVTDQ2PD	x, x	1	FP0	5	2	
CVT(T)PD2DQ	x, x	1	FP0	5	2	
CVTPI2PS	x,mm	1	FP0	4	2	
CVT(T)PS2PI	mm,x	1	FP0	4	2	
CVTPI2PD	x,mm	1	FP0	5	2	
CVT(T) PD2PI	mm,x	1	FP0	5	2	
CVTSI2SS	x,r32	1	FP0	5	2	
CVT(T)SS2SI	r32,x	1	FP0	5	1	
CVTSI2SD	xm,r32	1	FP0	5	2	
CVT(T)SD2SI	r32,x	3	FP0	5	1	
<b>Arithmetic</b>						
ADDSS SUBSS	x, x	1	FP1	3	1	
ADDSD SUBSD	x, x	1	FP1	3	1	
ADDPS SUBPS	x, x	1	FP1	3	1	
ADDPD SUBPD	x, x	1	FP1	4	2	
ADDSUBPS	x, x	1	FP1	3	1	
ADDSUBPD	x, x	1	FP1	4	2	
HADDPS HSUBPS	x, x	4		6	6	+1 if mem
HADDPD HSUBPD	x, x	4		6	5	+1 if mem
MULSS	x, x	1	FP0	4	1	
MULSD	x, x	1	FP0	5	2	
MULPS	x, x	1	FP0	5	2	
MULPD	x, x	1	FP0	7	4	
DIVSS	x, x	1	FP0	19	17	
DIVSD	x, x	1	FP0	34	32	

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DIVPS	x, x	6	FP0	39	39	
DIVPD	x, x	6	FP0	69	69	
RCPSS	x, x	1	FP0	4	1	
RCPPS	x, x	5	FP0	9	8	
CMPccSS/D PS/D	x, x	1	FP1	3	1	
COMISS/D UCOMISS/D	x, x	1	FP1		1	
MAXSS/D MINSS/D	x, x	1	FP1	3	1	
MAXPS MINPS	x, x	1	FP1	3	1	
MAXPD MINPD	x, x	1	FP1	4	2	
ROUNDSS/D	x,x,i	1	FP0	4	2	
ROUNDPS/D	x,x,i	1	FP0	5	2	
DPPS	x,x,i	9	FP0	15	12	+1 if mem
DPPD	x,x,i	5	FP0	12	8	+1 if mem
<b>Math</b>						
SQRTSS	x, x	1	FP0	20	18	
SQRTPS	x, x	5	FP0	40	40	
SQRTSD	x, x	1	FP0	35	33	
SQRTPD	x, x	5	FP0	70	70	
RSQRTSS	x, x	1	FP0	4	1	
RSQRTPS	x, x	5	FP0	9	8	
<b>Logic</b>						
ANDPS/D	x, x	1	FP0/1	1	0.5	
ANDNPS/D	x, x	1	FP0/1	1	0.5	
ORPS/D	x, x	1	FP0/1	1	0.5	
XORPS/D	x, x	1	FP0/1	1	0.5	
<b>Other</b>						
LDMXCSR	m32	5		10	8	
STMXCSR	m32	4		12	11	
FXSAVE	m4096	115		132	132	32 bit mode
FXSAVE	m4096	123		143	143	64 bit mode
FXRSTOR	m4096	114		118	118	32 bit mode
FXRSTOR	m4096	123		122	122	64 bit mode



## Intel Goldmont

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Name of instruction. Multiple names mean that these instructions have the same data.
<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, v = mmx or xmm vector register, m = memory, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops:</b>	The number of $\mu$ ops from the decoder or ROM. A $\mu$ op that goes to multiple units is counted as one.
<b>Unit:</b>	Tells which execution unit is used. Instructions that use the same unit cannot execute simultaneously.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.

**Reciprocal throughput:** The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread. Delays in the decoders are included in the latency and throughput timings. Values of 4 or more are often caused by bottlenecks in the decoders and microcode ROM rather than the execution units.

### Integer instructions

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1		1	0.33	
MOV	r,i	1		1	0.33	
MOV	r,m	1		3	1	All addr. modes
MOV	m,r	1		2	1	All addr. modes
MOV	m,i	1			1	
MOVNTI	m,r	2		2	2	
MOVSX MOVZX	r16,r8	2			4	
MOVSX MOVZX	r16,m8	3			4	
MOVSX MOVZX MOVSX	r32/64,r	1		1	1	
MOVSX MOVSXD	r32/64,m	1		3	1	
MOVZX	r32/64,m	1		2	1	
CMOVcc	r,r	1		2	1	
CMOVcc	r,m	1			1	
XCHG	r,r	3		4	4	
XCHG	r,m	3		13	13	Implicit lock
XLAT		4		5	5	
PUSH	r	1			1	
PUSH	i	1			1	
PUSH	m	2			1	
PUSH	sp	2			1	
PUSHF(D/Q)		16			26	
PUSHA(D)		10			8	Not in x64 mode
POP	r	1			1	

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POP	m	6		5	
POP	sp	1		2.5	
POPF(D/Q)		22		42	
POPA(D)		17		10	Not in x64 mode
LAHF		1	2	2	
SAHF		1	1	1	
SALC		2	4	4	Not in x64 mode
LEA	r16,[m]	2	5	4	
LEA	r,[r+d]	1	1	1	
LEA	r,[r+r*1]	1	1	1	
LEA	r32,[r+r*s]	1	2	2	
LEA	r64,[r+r*s]	1	1	1	
LEA	r,[r+r*s+d]	1	2	2	
LEA	r,[rip+d]	1		0.5	
BSWAP	r	1	1	1	
MOVBE	r,m	1		1	
MOVBE	m,r	1		1	
PREFETCHNTA	m	1		1	
PREFETCHT0/1/2	m	1		1	
PREFETCHNTW	m	1		1	
LFENCE		3		8	
MFENCE		3		22	
SFENCE		1		2	
CLFLUSH	m	1		165	
CLFLUSHOPT	m	4		165	
<b>Arithmetic instructions</b>					
ADD SUB	r,r/i	1	1	0.33	
ADD SUB	r,m	1		1	
ADD SUB	m,r/i	1	5	1	
ADC SBB	r,r/i	1	2	2	
ADC SBB	r,m	1		2	
ADC SBB	m,r/i	1	6	2	
CMP	r,r/i	1	1	0.33	
CMP	m,r/i	1		1	
INC DEC	r	1	1	1	latency to flag=2
NEG NOT	r	1	1	0.33	
INC DEC NEG NOT	m	1	5	1	
AAA		14	10		Not in x64 mode
AAS		14	10		Not in x64 mode
DAA		21	13		Not in x64 mode
DAS		22	14		Not in x64 mode
AAD		4	5		Not in x64 mode
AAM		5	14	11	Not in x64 mode
MUL IMUL	r8	2	4	4	
MUL IMUL	r16	4	5	5	
MUL IMUL	r32	2	4	2	
MUL IMUL	r64	2	6	2	
IMUL	r16,r16	2	4	4	
IMUL	r32,r32	1	3	1	
IMUL	r64,r64	1	5	2	
IMUL	r16,r16,i	2	4	4	
IMUL	r32,r32,i	1	3	1	

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IMUL	r64,r64,i	1		5	2	
MUL IMUL	m8	3				
MUL IMUL	m16	5				
MUL IMUL	m32	2			1	
MUL IMUL	m64	2			2	
DIV	r8	3		13-14	11-12	
DIV	r16	6		14-19	13-18	
DIV	r32	6		14-27	13-26	
DIV	r64	6		14-43	13-42	
IDIV	r8	3		13-14	11-12	
IDIV	r16	6		14-19	13-18	
IDIV	r32	6		14-27	13-26	
IDIV	r64	6		14-43	13-42	
CBW		2		4		
CWDE		1		1		
CDQE		1		1		
CWD		2		4		
CDQ		1		1		
CQO		1		1		
POPCNT	r16,r16	2		4	4	
POPCNT	r32,r32	1		3	1	
POPCNT	r64,r64	1		3	1	
CRC32	r32,r8	1		3	1	
CRC32	r32,r16	1		3	2	
CRC32	r32,r32	1		3	1	
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1		1	0.33	
AND OR XOR	r,m	1			1	
AND OR XOR	m,r/i	1		5	1	
TEST	r,r/i	1		1	0.33	
TEST	m,r/i	1			1	
SHR SHL SAR	r,i/cl	1		1	1	
SHR SHL SAR	m,i/cl	1			1	
ROR ROL	r,i/cl	1		1	1	
ROR ROL	m,i/cl	1			1	
RCL	r,1	1		2	2	
RCL	r,i	16		14	14	2 more if mem
RCL	r,cl	16		16	16	2 more if mem
RCR	r,1	10		11	11	3 more if mem
RCR	r,i	14		12	12	2 more if mem
RCR	r,cl	14		14	14	2 more if mem
SHLD	r16,r16,i	10		15	15	4 more if mem
SHLD	r32,r32,i	2		2	2	6 more if mem
SHLD	r64,r64,i	13		12	12	2 more if mem
SHLD	r16,r16,cl	10		17	17	4 more if mem
SHLD	r32,r32,cl	2		4	4	6 more if mem
SHLD	r64,r64,cl	12		14	14	2 more if mem
SHRD	r16,r16,i	10		11	11	3 more if mem
SHRD	r32,r32,i	2		2	2	6 more if mem
SHRD	r64,r64,i	13		12	12	2 more if mem
SHRD	r16,r16,cl	10		13	13	2 more if mem
SHRD	r32,r32,cl	2		4	4	6 more if mem

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SHRD	r64,r64,cl	12		14	14	2 more if mem
BT	r,r/i	1		1	1	
BT	m,r	10			12	
BT	m,i	1			1	
BTR BTS BTC	r,r/i	1		1	1	
BTR BTS BTC	m,r	10		12	10	
BTR BTS BTC	m,i	1			2	
BSF BSR	r,r/m	11		10	8	
SETcc	r/m	1		2	1	
CLC STC		1			1	
CMC		1		1	1	
CLD		3			7	
STD		4			35	
<b>Control transfer instructions</b>						
JMP	short/near	1			2	
JMP	r	1			2	
JMP	m(near)	1			2	
Conditional jump	short/near	1			1-2	
J(E/R)CXZ	short	2			4-18	
LOOP	short	9			10-23	
LOOP(N)E	short	9			12-24	
CALL	near	1			2	
CALL	r	1			8	
CALL	m	3			11	
RET		1			2-3	
RET	i	2			2	
BOUND	r,m	9			9	Not in x64 mode
INTO		4			7	Not in x64 mode
<b>String instructions</b>						
LODS		3		4		
REP LODS		~5n		~2n		
STOS		2		4		
REP STOS		~0.13B		~0.07B		per byte, best case
MOVS		5		5		
REP MOVS		~ 0.2B		~0.07B		per byte, best case
SCAS		3		4		
REP SCAS		~6n		~2n		
CMPS		6		4		
REP CMPS		~8n		~3n		
<b>Synchronization instructions</b>						
XADD	m,r	6		5		
LOCK XADD	m,r	6		13		
LOCK ADD	m,r	1		13		
CMPXCHG	m,r	8		8		
LOCK CMPXCHG	m,r	8		14		
CMPXCHG8B	m,r	14		9		
LOCK CMPXCHG8B	m,r	14		16		
CMPXCHG16B	m,r	19		23		

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LOCK CMPXCHG16B	m,r	19		30	
<b>Other</b>					
NOP (90)		1			0.33
Long NOP (0F 1F)		1			1
PAUSE		3		147	
ENTER	a,0	14		10	
ENTER	a,b	17+6b		~75+3b	
LEAVE		2			3
CPUID		37-78		69-2800	
RDTSC		19			20
RDTSCP		22			31
RDPMC		13			9
RDRAND	r	17			~3100
RDSEED	r	17			~3100

**Floating point x87 instructions**

	Operands	µops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
FLD	r	1		1	0.5	
FLD	m32/m64	1		3	1	
FLD	m80	1		3	1	
FBLD	m80	54		56	50	
FST(P)	r	1		1	0.5	
FST(P)	m32/m64	1		3	2	
FSTP	m80	1		3	2	
FBSTP	m80	195		190	190	
FXCH	r	2		1	1	
FILD	m	1		7	1	
FIST(P)	m	8		6	10	
FISTTP	m	8		6	13	
FLDZ		1			1	
FLD1		2			6	
FLDPI FLDL2E etc.		2			3	
FCMOVcc	r	4		5	5	
FNSTSW	AX	2			10	
FNSTSW	m16	3			11	
FLDCW	m16	4			15	
FNSTCW	m16	3			4	
FINCSTP FDECSTP		1		1	0.5	
FFREE(P)		1			0.5	
FNSAVE	m	151		173	173	
FRSTOR	m	85		155	155	
<b>Arithmetic instructions</b>						
FADD(P) FSUB(R)(P)	r	1		3	1	
FADD(P) FSUB(R)(P)	m	2			2	
FMUL(P)	r	1		5	2	
FMUL(P)	m	2			2	
FDIV(R)(P)	r	1		39	38	
FDIV(R)(P)	m	2			38	

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FABS		1		1	1	
FCHS		1		1	1	
FCOM(P) FUCOM	r/m	1			1	
FCOMPP FUCOMPP		1			1	
FCOMI(P) FUCOMI(P)	r	1			1	
FIADD FISUB(R)	m	3			5	
FIMUL	m	3			5	
FIDIV(R)	m	4			38	
FICOM(P)	m	3			4	
FTST		1			1	
FXAM		1			1	
FPREM		29		37-42	37-42	
FPREM1		29		37-42	37-42	
FRNDINT		19		41	41	
<b>Math</b>						
FSCALE		30		32	32	
FEXTRACT		16		22	22	
FSQRT		1		10-40	40-40	
FSIN FCOS		17-100		45-150	45-150	
FSINCOS		17-110		48-135	48-135	
F2XM1		9-27		40-90	40-90	
FYL2X		34-61		88-130	88-130	
FYL2XP1		61		140	140	
FPTAN		16-100		45-180	45-180	
FPATAN		33-65		85-190	85-190	
<b>Other</b>						
FNOP		1			0.5	
WAIT		2			6	
FNCLEX		4			24	
FNINIT		14			49	

**Integer MMX and XMM instructions**

	Operands	µops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD MOVQ	r32/64,v	1		4	1	
MOVD MOVQ	m,v	1		3	1	
MOVD MOVQ	v,r32/64	1		4	1	
MOVD MOVQ	v,m	1		3	1	
MOVQ	v,v	1		1	0.5	
MOVDQA	x, x	1		1	0.5	
MOVDQA MOVDQU	x, m128	1		3	1	
MOVDQA MOVDQU	m128, x	1		3	1	
LDDQU	x, m128	1		3	1	
MOVDQ2Q	mm, x	1		1	0.5	
MOVQ2DQ	x,mm	1		1	0.5	
MOVNTQ	m64,mm	1		3	1	
MOVNTDQ	m128,x	1		3	1	

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MOVNTDQA	x, m128	1		3	1	
PACKSSWB/DW						
PACKUSWB	v,v	1		1	0.5	
PACKUSDW	x,x	1		1	0.5	
PUNPCKH/LBW/WD/DQ	v,v	1		1	0.5	
PUNPCKH/LQDQ	v,v	1		1	0.5	
PMOVSX/ZX BW BD BQ DW DQ	x,x	1		1	0.5	
PMOVSX/ZX BW BD BQ DW DQ	x,m	1		1	1	
PSHUFB	mm,mm	1		1	0.5	
PSHUFB	x,x	1		1	1	
PSHUFW	mm,mm,i	1		1	0.5	
PSHUFL/HW	x,x,i	1		1	0.5	
PSHUFD	x,x,i	1		1	0.5	
PALIGNR	x,x,i	1		1	0.5	
PBLENDVB	x,x,xmm0	2		4	4	
PBLENDVB	x,m,xmm0	3			4	
PBLENDW	x,x/m,i	1		1	0.5	
MASKMOVQ	mm,mm	1		~350	1	
MASKMOVDQU	x,x	3		~360	1	
PMOVMASKB	r32,v	1		4	1	
PINSRW	v,r32,i	1		4	1	
PINSRB/D/Q	x,r32,i	1		4	1	
PINSRB/D/Q	x,m8,i	1			1	
PEXTRB/W/D/Q	r,v,i	1		4	1	
PEXTRB/W/D/Q	m,v,i	4			4	
<b>Arithmetic instructions</b>						
PADD/SUB(U)(S)B/W/D	v,v	1		1	0.5	
PADDQ PSUBQ	v,v	1		2	1	
PHADD(S)W PHSUB(S)W	mm, mm	5		7	7	
PHADD(S)W PHSUB(S)W	x, x/m	7		6	6	+1 if mem
PHADDD PHSUBD	v,v	3		4	4	+1 if mem
PCMPEQ/GTB/W/D	v,v	1		1	0.5	
PCMPEQQ	x, x	1		2	1	
PCMPGTQ	x, x	1		2	1	
PMULL/HW PMULHUW	v,v	1		4	1	
PMULHRSW	v,v	1		4	1	
PMULLD	x, x	1		5	2	
PMULDQ	x, x	1		4	1	
PMULUDQ	v,v	1		4	1	
PMADDWD	v,v	1		4	1	
PMADDUBSW	v,v	1		4	1	
PSADBW	v,v	1		4	1	
MPSADBW	x,x,i	3		5	4	+1 if mem
PAVGB/W	v,v	1		1	0.5	
PMIN/MAXUB	v,v	1		1	0.5	
PMIN/PMAX SB/SW/SD						
UB/UW/UD	x,x	1		1	0.5	
PHMINPOSUW	x,x	1		5	2	
PASB PABSW PABSD	v,v	1		1	0.5	

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PSIGNB PSIGNW PSIGND	v,v	1		1	0.5	
<b>Logic instructions</b>						
PAND(N) POR PXOR	v,v	1		1	0.5	
PTEST	x,x	1		1	1	
PSLL/RL/RAW/D/Q	v,v	1		2	1	
PSLL/RL/RAW/D/Q	v,i	1		1	0.5	
PSLL/RLDQ	x,i	1		1	0.5	
<b>String instructions</b>						
PCMPESTRI	x,x,i	10		13	13	+1 if mem
PCMPESTRM	x,x,i	9		14	14	+1 if mem
PCMPISTRI	x,x,i	6		8	8	+1 if mem
PCMPISTRM	x,x,i	5		12	12	+1 if mem
<b>Encryption instructions</b>						
PCLMULQDQ	x,x,i	3		6	4	
AESDEC	x,x	1		6	2	+1 if mem
AESDECLAST	x,x	1		6	2	+1 if mem
AESENC	x,x	1		6	2	+1 if mem
AESENCLAST	x,x	1		6	2	+1 if mem
AESIMC	x,x	1		5	2	
AESKEYGENASSIST	x,x,i	1		5	2	
SHA1RNDS4	x,x,i	1		5	2	
SHA1NEXTE	x,x	1		3	1	
SHA1MSG1	x,x	1		3	1	
SHA1MSG2	x,x	1		3	1	
SHA256RNDS2	x,x	3		8	4	
SHA256MSG1	x,x	1		3	1	
SHA256MSG2	x,x	1		3	1	
<b>Other</b>						
EMMS		13			23	

**Floating point XMM instructions**

	Operands	μops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVAPS/D	x, x	1		0-1	0.5	
MOVAPS/D	x,m128	1		3	1	
MOVAPS/D	m128,x	1		3	1	
MOVUPS/D	x,m128	1		3	1	
MOVUPS/D	m128,x	1		3	1	
MOVSS/D	x, x	1		1	0.5	
MOVSS/D	x,m32/64	1		3	1	
MOVSS/D	m32/64,x	1		3	1	
MOVHPS/D MOVLPS/D	x,m64	1		4	1	
MOVHPS/D MOVLPS/D	m64,x	1		3	1	
MOVLHPS MOVHLPS	x,x	1		1	0.5	
BLENDPS/PD	x,x/m,i	1		1	0.5	
BLENDVPS/PD	x,x,xmm0	2		4	4	+1 if mem



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INSERTPS	x,x,i	1	1	0.5	
INSERTPS	x,m32,i	3	4	4	
EXTRACTPS	r32,x,i	1	4	1	
EXTRACTPS	m32,x,i	1	4	2	
MOVMSKPS/D	r32,x	1	4	1	
MOVNTPS/D	m128,x	1	3	1	
SHUFPS	x,x,i	1	1	0.5	
SHUFPD	x,x,i	1	1	0.5	
MOVDDUP	x, x	1	1	0.5	
MOVSH/LDUP	x, x	1	1	0.5	
UNPCKH/LPS/PD	x, x	1	1	0.5	
<b>Conversion</b>					
CVTPD2PS	x, x	1	4	1	
CVTPS2PD	x, x	1	4	1	
CVTSD2SS	x, x	1	4	2	
CVTSS2SD	x, x	1	4	2	
CVTDQ2PS	x, x	1	4	1	
CVT(T) PS2DQ	x, x	1	4	1	
CVTDQ2PD	x, x	1	4	1	
CVT(T)PD2DQ	x, x	1	4	1	
CVTPI2PS	x,mm	1	4	2	
CVT(T)PS2PI	mm,x	1	4	1	
CVTPI2PD	x,mm	1	4	1	
CVT(T) PD2PI	mm,x	1	4	1	
CVTSI2SS	x,r32	1	6	2	
CVT(T)SS2SI	r32,x	1	5	1	
CVTSI2SD	xm,r32	1	6	2	
CVT(T)SD2SI	r32,x	1	5	1	
<b>Arithmetic</b>					
ADDSS/SD/PS/PD	x, x	1	3	1	
SUBSS/SD/PS/PD	x, x	1	3	1	
ADDSUBPS/PD	x, x	1	3	1	
HADDPS HSUBPS	x, x	4	6	6	+1 if mem
HADDPD HSUBPD	x, x	4	5	5	+1 if mem
MULSS/SD/PS/PD	x, x	1	4	1	
DIVSS	x, x	1	19	18	
DIVSD	x, x	1	34	33	
DIVPS	x, x	1	36	35	
DIVPD	x, x	1	66	65	
RCPSS	x, x	1	4	1	
RCPPS	x, x	5	9	6	+1 if mem
CMPccSS/SD/PS/PD	x, x	1	3	1	
(U)COMISS/SD	x, x	1	4	1	
MAXSS/SD/PS/PD	x, x	1	3	1	
MINSS/SD/PS/PD	x, x	1	3	1	
ROUNDSS/SD/PS/PD	x,x,i	1	4	1	
DPPS	x,x,i	9	14	10	+1 if mem
DPPD	x,x,i	10	8	8	+1 if mem
<b>Math</b>					
SQRTSS	x, x	1	20	19	

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SQRTPS	x, x	1		38	37	
SQRTSD	x, x	1		35	34	
SQRTPD	x, x	1		68	67	
RSQRTSS	x, x	1		4	1	
RSQRTPS	x, x	5		9	6	
<b>Logic</b>						
ANDPS/D	x, x	1		1	0.5	
ANDNPS/D	x, x	1	FP0/1	1	0.5	
ORPS/D	x, x	1		1	0.5	
XORPS/D	x, x	1		1	0.5	
<b>Other</b>						
LDMXCSR	m32	6		18	18	
STMXCSR	m32	3		12	12	
FXSAVE	m4096	202		130	130	32 bit mode
FXSAVE	m4096	123		143	143	64 bit mode
FXRSTOR	m4096	160		218	218	32 bit mode
FXRSTOR	m4096	128		155	155	64 bit mode
XSAVEC	m	241		160	160	
XSAVEOPT	m	227		144	144	

## Intel Knights Landing

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

<b>Instruction:</b>	Name of instruction. Multiple names mean that these instructions have the same data. Instructions with or without V name prefix behave the same unless otherwise noted.
<b>Operands:</b>	i = immediate data, r = register, mm = 64 bit mmx register, x = 128 bit xmm register, (x)mm = mmx or xmm register, y = 256 bit ymm register, z = 512 bit zmm register, v = any vector register (mmx, xmm, ymm, zmm), k = mask register. same = same register for both operands. m = memory operand, m32 = 32-bit memory operand, etc.
<b><math>\mu</math>ops:</b>	The number of $\mu$ ops from the decoder or ROM. A $\mu$ op that goes to multiple units is counted as one.
<b>Unit:</b>	Tells which execution unit is used. Instructions that use the same unit cannot execute simultaneously. IP0 and IP1 means integer port 0 or 1 and their associated pipelines IP0/1 means that either integer unit can be used. IP0+1 means that the $\mu$ op is split in two, using both units. Mem means memory execution cluster FP0 means floating point port 0 (includes multiply, divide, convert and shuffle).  FP1 means floating point port 1.
<b>Latency:</b>	This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.  Some instructions have a range of latencies. For example VPSHUFD has a latency of 3-6. The short latency is measured in a chain of similar instructions. The long latency is measured when the input comes from an instruction of a different type and the output goes to an instruction of a different type, for example a move instruction. The long latency will apply in most cases. Division and some square root instructions have latencies that depend on the values of the operands.
<b>Reciprocal throughput:</b>	The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread. Delays in the decoders are included in the latency and throughput timings. Values of 4 or more are often caused by bottlenecks in the decoders and microcode ROM rather than the execution units.

### Integer instructions

	Operands	$\mu$ ops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1	IP0/1	1	0.5	
MOV	r,i	1	IP0/1	1	0.5	
MOV	r,m	1	Mem	4	1	All addr. modes
MOV	m,r	1	Mem	3	1	All addr. modes
MOV	m,i	1	Mem		1	
MOVNTI	m,r	1	Mem		2	

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MOVSX MOVZX MOVSD	r16,r8	2	IP0	7	7	
MOVSX MOVZX MOVSD	r16,m8	3	IP0	7	8	
MOVSX MOVZX MOVSD	r32/64,r	1	IP0	1	1	
MOVSX MOVZX MOVSD	r32/64,m	1	IP0	4	1	
CMOVcc	r,r	1	IP0/1	2	1	
CMOVcc	r,m	1			1	
XCHG	r,r	3	IP0/1	8	8	
XCHG	r,m	3		24	24	Implicit lock
XLAT		4		8		
PUSH	r	1			1	
PUSH	i	1	IP0+1		1	
PUSH	m	3	IP0+1		8	
PUSHF(D/Q)		18	IP0+1		28	
PUSHA(D)		10			10	Not in x64 mode
POP	r	2			1	
POP	(E/R)SP	2			4	
POP	m	6			9	
POPF(D/Q)		21			48	
POPA(D)		17			15	Not in x64 mode
LAHF		1	IP0	1	1	
SAHF		1	IP0	2	1	
SALC		2		9	7	Not in x64 mode
LEA	r,[r+d]	1	IP0/1	1	0.5	
LEA	r,[r+r*s]	1	IP1	1	1	
LEA	r,[r+r*s+d]	1	IP0+1	2	1	
LEA	r,[rip+d]	1	IP0/1		0.5	
LEA	r16,[m]	2		7		
BSWAP	r	1	IP0	1	1	
MOVBE	r16,m16	1			1	
MOVBE	r/m32/64	1			1	
MOVBE	m,r	1			1	
PREFETCHNTA	m	1			0.5	
PREFETCH0/1/2	m	1			0.5	
PREFETCHNTW	m	1			0.5	
LFENCE		2			8	
MFENCE		2			17	
SFENCE		1			10	
<b>Arithmetic instructions</b>						
ADD SUB	r,r/i	1	IP0/1	1	0.5	
ADD SUB	r,m	1	IP0/1, Mem		1	
ADD SUB	m,r/i	1	IP0/1, Mem	7	1	
ADC SBB	r,r/i	1	IP0+1	2	2	
ADC SBB	r,m	1			2	
ADC SBB	m,r/i	1		7	2	
ADCX ADOX	r32,r32	1	IP0+1	2	2	
ADCX ADOX	r64,r64	1	IP0+1	2	6	due to decoder
CMP	r,r/i	1	IP0/1	1	0.5	
CMP	m,r/i	1			1	
INC DEC	r	1	IP0/1	1-2	1	
NEG NOT	r	1	IP0/1	1	0.5	
INC DEC NEG NOT	m	1		7	1	
AAA AAS		13		13		Not in x64 mode

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DAA		20		17		Not in x64 mode
DAS		21		17		Not in x64 mode
AAD		4		8		Not in x64 mode
AAM		10		30	14	Not in x64 mode
MUL IMUL	r8	3	IP0	8		
MUL IMUL	r16	4	IP0	8		
MUL IMUL	r32	3	IP0	8		
MUL IMUL	r64	3	IP0	8		
IMUL	r16,r16	2	IP0	7	7	
IMUL	r32,r32	1	IP0	3	1	
IMUL	r64,r64	1	IP0	5	2	
IMUL	r16,r16,i	2	IP0	7	7	
IMUL	r32,r32,i	1	IP0	3	1	
IMUL	r64,r64,i	1	IP0	5	2	
MUL IMUL	m8	3	IP0			
MUL IMUL	m16	3	IP0			
MUL IMUL	m32	4	IP0			
MUL IMUL	m64	3	IP0			
DIV	r/m8	9	IP0, FP0	30	12	
DIV	r/m16	12	IP0, FP0	30-35	13-15	
DIV	r/m32	12	IP0, FP0	29-42	13-23	
DIV	r/m 64	23	IP0, FP0	39-95	22-95	
IDIV	r/m8	26	IP0, FP0	39	20	
IDIV	r/m16	29	IP0, FP0	38-42	22	
IDIV	r/m32	29	IP0, FP0	37-49	22-26	
IDIV	r/m64	44	IP0, FP0	53-108	36-107	
CBW		2	IP0	7		
CWDE		1	IP0	1		
CDQE		1	IP0	1		
CWD		2	IP0	7		
CDQ		1	IP0	1		
CQO		1	IP0	1		
POPCNT	r16,r16	2		7	7	
POPCNT	r32,r32	1		3	1	
POPCNT	r64,r64	1		3	1	
CRC32	r32,r8	2		7	2	
CRC32	r32,r16	1		6	6	
CRC32	r32,r32	1		3	1	
CRC32	r64,r64	1		6	1	
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1	IP0/1	1	0.5	
AND OR XOR	r,m	1	IP0/1, Mem		1	
AND OR XOR	m,r/i	1	IP0/1, Mem	6	1	
TEST	r,r/i	1	IP0/1	1	0.5	
TEST	m,r/i	1	IP0/1, Mem		1	
SHR SHL SAR	r,i/cl	1	IP0	1	1	
SHR SHL SAR	m,i/cl	1	IP0		1	
ROR ROL	r,i/cl	1	IP0	1	1	
ROR ROL	m,i/cl	1	IP0		1	
RCR	r,1	7	IP0	10	10	
RCL	r,1	1	IP0	2	2	
RCR	r,i/cl	11	IP0	13	13	

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RCR	m,i/cl	14	IP0	13	
RCL	r,i/cl	13	IP0	13	13
RCL	m,i/cl	16	IP0	16	16
SHLD	r16,r16,i	10	IP0	11	11
SHLD	r16,m16,i	13	IP0	13	13
SHLD	r32,r32,i	1	IP0	2	2
SHLD	r32,m32,i	6	IP0	9	9
SHLD	r64,r64,i	10	IP0	11	11
SHLD	r64,m64,i	13	IP0	13	13
SHLD	r16,r16,cl	9	IP0	11	11
SHLD	r16,m16,cl	12	IP0	13	13
SHLD	r32,r32,cl	2	IP0	7	7
SHLD	r32,m32,cl	6	IP0	9	9
SHLD	r64,r64,cl	9	IP0	11	11
SHLD	r64,m64,cl	12	IP0	13	13
SHRD	r16,r16,i	8	IP0	11	11
SHRD	r16,m16,i	11	IP0	12	12
SHRD	r32,r32,i	2	IP0	7	7
SHRD	r32,m32,i	6	IP0	9	9
SHRD	r64,r64,i	10	IP0	11	11
SHRD	r64,m64,i	13	IP0	15	15
SHRD	r16,r16,cl	7	IP0	11	11
SHRD	r16,m16,cl	10	IP0	12	12
SHRD	r32,r32,cl	2	IP0	7	7
SHRD	r32,r32,cl	6	IP0	9	9
SHRD	r64,r64,cl	9	IP0	11	11
SHRD	r64,m64,cl	12	IP0	14	14
SHLX SHRX SARX	r,r,r	1	IP0	2	1
RORX	r,r,i	1	IP0	1	1
BT	r,r/i	1	IP0+1	1	1
BT	m,r	7		10	10
BT	m,i	1		1	1
BTR BTS BTC	r,r/i	1	IP0+1	1	1
BTR BTS BTC	m,r	8		11	11
BTR BTS BTC	m,i	1	IP0+1	1	1
BSF BSR	r,r/m	10	IP0/1	11	11
SETcc	r/m	1	IP0+1	2	1
CLC STC		1	IP0		1
CMC		1	IP0	1	1
CLD		4	IP0/1		8
STD		5	IP0/1		36
LZCNT	r,r/m	1		3	1
TZCNT	r,r/m	1		3	1
ANDN	r,r,r	1		1	0.5
ANDN	r,r,m	1		1	1
BLSI BLSMSK BLSR	r,r/m	1		1	1
BEXTR	r,r,r	2		7	7
BEXTR	r,r,m	3			8
BZHI	r,r,r	1		3	1
PDEP	r,r,r	1		3	1
PEXT	r,r,r	1		3	1
<b>Control transfer instructions</b>					

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JMP	short/near	1	IP1	2	
JMP	r	1	IP1	2	
JMP	m(near)	1	IP1	2	
Conditional jump	short/near	1	IP1	1-2	
J(E/R)CXZ	short	2		7-18	
LOOP	short	7		14-23	
LOOP(N)E	short	8		14-23	
CALL	near	1		2	
CALL	r	1		2	
CALL	m	3		14	
RET		1		2	
RET	i	1		2	
BOUND	r,m	10		11	Not in x64 mode
INTO		4		8	Not in x64 mode
<b>String instructions</b>					
LODS		3		8	
REP LODS		~4n		~2n	
STOS		2		7	
REP STOS		~0.07B		~0.054B	per byte, best case
MOVS		5		9	
REP MOVS		~ 0.1B		~0.08B	per byte, best case
SCAS		3		8	
REP SCAS		~5n		~3n	
CMPS		6		9	
REP CMPS		~6n		~3n	
<b>Synchronization instructions</b>					
XADD	m,r	6		9	
LOCK XADD	m,r	4		24	
LOCK ADD	m,r	1		13	
CMPXCHG	m,r	8		11	
LOCK CMPXCHG	m,r	6		26	
CMPXCHG8B	m,r	13		15	
LOCK CMPXCHG8B	m,r	11		29	
CMPXCHG16B	m,r	19		31	
LOCK CMPXCHG16B	m,r	17		48	
<b>Other</b>					
NOP (90)		1	IP0/1	0.5	
Long NOP (0F 1F)		1	IP0/1	0.5	
PAUSE		6		25	
ENTER	a,0	15		14	
ENTER	a,b	19+6b		66+4b	
LEAVE		4		8	5
XGETBV		7			14
CPUID		40-83		63-270	
RDTSC		15		30	
RDTSCP		17		36	
RDPMC		19		20	
RDRAND	r	17			200
RDSEED	r	17			200

**Floating point x87 instructions**

	Operands	µops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
FLD	r	1		2	1	
FLD	m32/m64	1		8	1	
FLD	m80	5		9	12	
FBLD	m80	52			66	
FST(P)	r	1		2	1	
FST	m32/m64	5		14	13	
FSTP	m32/m64	6		14	13	
FSTP	m80	8		11	14	
FBSTP	m80	189			264	
FXCH	r	3	FP0+1	9	9	
FILD	m	1		5	2	
FIST(P)	m	6		18	12	
FISTTP	m	6			14	
FLDZ		1			1	
FLD1		2			10	
FLDPI FLDL2E etc.		2			10	
FCMOVcc	r	3		9		
FNSTSW	AX	3			12	
FNSTSW	m16	4			13	
FLDCW	m16	3			15	
FNSTCW	m16	5			15	
FINCSTP FDECSTP		1		1	1	
FFREE(P)		1			1	
<b>Arithmetic instructions</b>						
FADD(P) FSUB(R)(P)	r	1	FP0	6	1.5	
FADD(P) FSUB(R)(P)	m	1	FP0		12	
FMUL(P)	r	1	FP0	7	2	
FMUL(P)	m	1	FP0	7	12	
FDIV(R)(P)	r	1	FP0	41	37	
FDIV(R)(P)	m	1	FP0	41	44	
FABS		1		2		
FCHS		1		2		
FCOM(P) FUCOM	r	1			1	
FCOM(P) FUCOM	m	1			2	
FCOMPP FUCOMPP		1			1	
FCOMI(P) FUCOMI(P)	r	3			9	
FIADD FISUB(R)	m	3			17	
FIMUL	m	3			17	
FIDIV(R)	m	3			41	
FICOM(P)	m	3			8	
FTST		1			1	
FXAM		1			1	
FPREM		27		26-47	25-32	
FPREM1		27		33-72	25-32	
FRNDINT		18		36	36	



Knights Landing

<b>Math</b>						
FSCALE		30		31		
FEXTRACT		15		19	18	
FSQRT		1		15-42	11-38	
FSIN FCOS		16-100		40-250	40-250	
FSINCOS		17-110		50-250	50-250	
F2XM1		9-24		100-400		
FYL2X		34-61		126-190	98-190	
FYL2XP1		61		190	190	
FPTAN		17-100		50-280	50-280	
FPATAN		33-63		125-265	125-265	
<b>Other</b>						
FNOP		1			1	
WAIT		2			7	
FNCLEX		5			26	
FNINIT		15			63	

**Integer MMX and XMM instructions**

	Operands	µops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD MOVQ	r32/64,(x)mm	1		4	1	
MOVD MOVQ	(x)mm,r32/64	1		5	1	
MOVD MOVQ	m32/64,(x)mm	1	Mem	5	1	
MOVD MOVQ	(x)mm,m32/64	1	Mem	5	0.5	
MOVQ	(x)mm, (x)mm	1	FP0/1	2	0.5	
(V)MOVDQA/U	v,v	1	FP0/1	2	0.5	
(V)MOVDQA/U	v,m	1	Mem	5	0.5	
VMOVDQA/U	v{k},m	1	Mem	7	0.5	
(V)MOVDQA/U	m,v	1	Mem	5	1	
VMOVDQA/U	m{k},v	1	Mem	9	1	
LDDQU	x, m128	1	Mem	5	0.5	
MOVDQ2Q	mm, x	1	FP0/1	2	0.5	
MOVQ2DQ	x,mm	1	FP0/1	2	0.5	
MOVNTQ	m64,mm	1	Mem	~650	1	
MOVNTDQ	m128,x	1	Mem	~550	1	
(V)MOVNTDQA	v, m	1	Mem	5	0.5	
MASKMOVQ	mm,mm	6	Mem	~550	12	
MASKMOVDQU	x,x	6	Mem	~550	12	
VPMASKMOVD/Q	v,v,m	5	Mem	7	9	
VPMASKMOVD/Q	m,v,v	4	Mem	6	8	
VPACKSSWB/DW						
VPACKUSWB/DW	(x)mm, (x)mm	1	FP0	2-6	1	
VPACKSSWB/DW						
VPACKUSWB/DW	y/z,y/z,y/z	5		11-14	9	
VPACKSSWB/DW						
VPACKUSWB/DW	y/z,y/z,m	6			9	
PUNPCKH/LBW/WD/DQ	(x)mm, (x)mm	1	FP0	2-6	1	
VPUNPCKH/LBW/WD	y/z,y/z,y/z	5		11-14	9	
VPUNPCKH/LBW/WD	y/z,y/z,m	6			9	

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PUNPCKH/LQDQ	(x)mm, (x)mm	1	FP0	2-6	1
VPUNPCKH/L(Q)DQ	y/z,y/z,y/z	1	FP0	4-7	2
(V)PMOV SX BW BD BQ DW DQ	v,v	2		8	7-8
(V)PMOV ZX BW BD BQ DW DQ	v,v	1		3	2
VPMOV QB QW QD DB DW	v,v	1	FP0	3	1
VPMOV(U)S QB QW QD DB DW	v,v	2		8	7
PSHUFB	mm,mm	1	FP0	2-6	1
PSHUFB	x,x	5	FP0	11-13	10
PSHUFB	x,m	6	FP0		10
VPSHUFB	y,y,y	12	FP0	23-25	12
VPSHUFB	y,y,m	13	FP0		13
PSHUFW	mm,mm,i	1	FP0	2-6	1
PSHUFL/HW	x,x,i	1	FP0	2-6	1
VPSHUFL/HW	y,y,i	4	FP0	11-14	8
VPSHUFL/HW	y,m,i	5	FP0		9
(V)PSHUFD	v,v,i	1	FP0	3-6	1
PALIGNR	mm,mm,i	1	FP0	2-6	1
PALIGNR	x,x,i	1	FP0	2-6	2
VPALIGNR	y,y,y,i	5	FP0	11-14	9
VPALIGNR	y,y,m,i	6	FP0		9
VALIGND/Q	z,z,z,i	1	FP0	3-6	1
VPCOMPRESSD/Q	z{k},z	1		3-6	3
VPEXPANDD/Q	z{k},z	1		3-6	3
PBLENDVB	x,x,xmm0	5	FP0	9-10	9
PBLENDVB	x,m,xmm0	6	FP0		9
VPBLENDVB	v,v,v,v	4		8-10	8
PBLENDW	x,x/m,i	1		2	2
VPBLENDW	y,y,y/m,i	1		2	0.5
VPBLEND	v,v,v/m,i	1	FP0/1	2	0.5
VPBLENDMD/Q	z{k},z,z	1	FP0/1	2	0.5
VPERMD	v,v,v	1	FP0	3-6	1
VPERMQ	v,v,i	1	FP0	3-6	1
VPERM2I128	v,v,v,i	1	FP0	4-7	2
VPERM2D VPERM2D	v,v,v	1	FP0	4-7	2
VPERM2Q VPERM2Q	v,v,v	1	FP0	4-7	2
VSHUFI32X4	z,z,z,i	1	FP0	4-7	2
VSHUFI64X2	z,z,z,i	1	FP0	4-7	2
PMOVMSKB	r32,mm	4		14	8
PMOVMSKB	r32,x	5		19	8
PMOVMSKB	r32,y	12		26	12
PEXTRB/W/D	r32,x,i	2		8	7
PEXTRQ	r64,x,i	2		8	10
VEEXTRACTI128	x,y,i	1	FP0	3-6	1
VEEXTRACTI128	m128,y,i	4		7	8
PINSRB/W	x,r32,i	1	FP0	5	1
PINSRD	x,r32,i	1	FP0	4	1.5
PINSRQ	x,r64,i	1	FP0	4	6
VINSERTI128	y,y,x,i	1	FP0	3-6	1
VINSERTI32X4	z,z,x,i	1	FP0	3-6	1
VINSERTI64X4	z,z,y,i	1	FP0	3-6	1
VPBROADCASTB/W	v,x	2		8	7
VPBROADCASTD/Q	v,x	1	FP0	3	1
VBROADCASTI128	y,m128	1		5	0.5

Knights Landing

VBROADCASTI32X4	z,m128	1		5	0.5
VBROADCASTI64X4	z,m256	1		5	0.5
<b>Gather and scatter</b>					
VPGATHERDD	x,[r+s*x],x	6			12
VPGATHERDD	y,[r+s*y],y	6			12
VPGATHERDD	z,[r+s*z],z	1			11
VPGATHERQD	x,[r+s*x],x	6			12
VPGATHERQD	x,[r+s*y],x	6			12
VPGATHERQD	y,[r+s*z],y	1			7
VPGATHERDQ	x,[r+s*x],x	6			12
VPGATHERDQ	y,[r+s*x],y	6			12
VPGATHERDQ	z,[r+s*y],z	1			7
VPGATHERQQ	x,[r+s*x],x	6			12
VPGATHERQQ	y,[r+s*y],y	6			12
VPGATHERQQ	z,[r+s*z],z	1			7
VPSCATTERDD	z,[r+s*z],z	4			17
VPSCATTERQD	y,[r+s*z],y	4			11
VPSCATTERDQ	z,[r+s*y],z	4			11
VPSCATTERQQ	z,[r+s*z],z	4			11
<b>Arithmetic instructions</b>					
PADD/SUB(U,S)B/W/D/Q	(x)mm, (x)mm	1	FP0/1	2	0.5
VPADD/SUB(U,S)B/W/D/Q	v,v,v	1	FP0/1	2	0.5
PHADD(S)W PHSUB(S)W	mm, mm	5		18	9
PHADD(S)W PHSUB(S)W	x, x	6	FP0	28	28
PHADD(S)W PHSUB(S)W	x, m	7			28
PHADD(S)W PHSUB(S)W	y, y	7	FP0	23	9
PHADDD PHSUBD	mm, mm	4		14	8
PHADDD PHSUBD	x, x	3		11	9
VPHADDD VPHSUBD	y,y,y	3		11	8
PCMPEQ/GTB/W/D	(x)mm,(x)mm	1	FP0/1	2	0.5
VPCMPEQ/GTB/W/D	y,y,y	1	FP0/1	2	0.5
PCMPEQ/GTQ	x, x	1		2	2
VPCMPEQQ	y,y,y	1	FP0/1	2	0.5
VPCMP(U)D/Q	k,z,z,i	1	FP0/1	2	0.5
VPTSTMD/Q	k,z,z	1	FP0/1	2	0.5
PMULL/HW PMULHUW	mm,mm	1	FP0	6	1
PMULL/HW PMULHUW	x, x	1	FP0	7	2
VPMULL/HW VPMULHUW	y,y,y	5	FP0	16	9
PMULHRSW	mm,mm	1	FP0		1
PMULHRSW	x, x	1	FP0	7	2
PMULLD	x, x	1	FP0	7	2
VPMULLD	v,v,v	1	FP0	7	1
PMULDQ	x, x	1	FP0	6	2
VPMULDQ	v,v,v	1	FP0/1	6	0.5
PMULUDQ	(x)mm,(x)mm	1	FP0/1	6	0.5
VPMULUDQ	v,v,v	1	FP0/1	6	0.5
PMADDWD	mm,mm	1	FP0	6	1
PMADDWD	x, x	1	FP0	7	2
PMADDUBSW	mm,mm	1	FP0	6	1
PMADDUBSW	x, x	1	FP0	7	2
PMADDUBSW	y,y,y	5	FP0	16	9

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PSADBW	mm,mm	1	FP0	6	1	
PSADBW	x, x	1	FP0	7	2	
PSADBW	y,y,y	5	FP0	16	9	
MPSADBW	x,x,i	3		9	9	
VMPSADBW	y,y,y,i	9		19	13	
PAVGB/W	(x)mm,(x)mm	1	FP0/1	2	0.5	
PAVGB/W	y,y,y	1	FP0/1	2	0.5	
PMIN/MAXUB/SW	(x)mm,(x)mm	1	FP0/1	2	2	
VPMIN/MAXUB/SW/D/Q	y,y,y	1	FP0/1	2	0.5	
PHMINPOSUW	x,x	1	FP0	3	2	
PABSB/W/D	mm,mm	1	FP0/1	2	0.5	
PABSB/W/D	x,x	1	FP0/1	2	2	
VPABSB/W/D/Q	y,y	1	FP0/1	2	0.5	
PSIGNB/W/D	mm,mm	1	FP0/1	2	0.5	
PSIGNB/W/D	x,x	1	FP0/1	2	2	
VPSIGNB/W/D	y,y	1	FP0/1	2	0.5	
<b>Logic instructions</b>						
PAND(N)/OR/XOR	(x)mm,(x)mm	1	FP0/1	2	0.5	
VPAND(N)/OR/XOR	y,y,y	1	FP0/1	2	0.5	
VPAND(N)/OR/XORD/Q	z,z,z	1	FP0/1	2	0.5	
VPTERNLOGD/Q	z,z,z,i	1	FP0+1	2	1	
PTEST	x,x	4		9	9	
VPTEST(N)MD/Q	k,z,z	1	FP0/1	2	0.5	
VPTEST	y,y	4		9	8	
PSLL/RL/RAW/D/Q	mm,mm	1	FP0	2	1	
PSLL/RL/RAW/D/Q	x,x	2	FP0	13	13	
PSLL/RL/RAW/D/Q	(x)mm,i	1	FP0	2	1	
VPSLL/RL/RAW/D/Q	y,y,i	4	FP0	11	8	
VPSLL/RA/RLVD/Q	z,z,z	1	FP0	2	1	
VPROL/RD/Q	z,z,i	1	FP0	2	1	
VPROL/RVD/Q	z,z,z	1	FP0	2	1	
VPLZCNTD/Q	z,z	1	FP0	2	1	
VPCONFLICTD/Q	z,z	1	FP0	3	1	
<b>String instructions</b>						
PCMPESTRI	x,x,i	9	FP0	21	21	+1 if mem
PCMPESTRM	x,x,i	8	FP0	17	17	+1 if mem
PCMPISTRI	x,x,i	6	FP0	17	17	+1 if mem
PCMPISTRM	x,x,i	5	FP0	13	13	+1 if mem
<b>Encryption instructions</b>						
PCLMULQDQ	x,x,i	1	FP0	3-6	2	+1 if mem
AESDEC, AESDECLAST, AESENC, AESENCLAST, AESIMC, AESKEYGENASSIST	x,x	1		3-6	2	
<b>Other</b>						
EMMS		10			13	

**Floating point XMM instructions**

## Knights Landing

	Operands	μops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
(V)MOVAPS/D	v,v	1	FP0/1	2	0.5	
(V)MOVAPS/D	v,m	1	Mem	5	0.5	
(V)MOVAPS/D	m,v	1	Mem	5	1	
(V)MOVUPS/D	v,m	1	Mem	5	0.5	
(V)MOVUPS/D	m,v	1	Mem	5	1	
VMOVAPS/D VMOVUPS/D	z{k},m	1	Mem	7	0.5	
VMOVAPS/D VMOVUPS/D	m{k},z	1	Mem	9	1	
MOVSS/D	x, x	1	FP0/1	2	0.5	
MOVSS/D	x,m	1	Mem	5	0.5	
MOVSS/D	m,x	1	Mem	5	1	
MOVHPS/D	x,m64	1	Mem	6	1.5	
MOVHPS/D	m64,x	4	Mem	9	1	
MOVLPS/D	x,m64	1	Mem	6	1.5	
MOVLPS/D	m64,x	1	Mem	6	1	
(V)MOVNTPS/D	m,v	1	Mem	~500		
MOVMSKPS/D	r32,x	2	FP0	6	7	
MOVLHPS MOVHLPS	x,x	1	FP0	3-6	1	
MOVDDUP	x,x	1	FP0	3-6	1	
MOVDDUP	x,m	1		14		
VMOVDDUP	v,v	1		3-6	1	
(V)MOVSH/LDUP	v,v	1	FP0	3-6	1	
VBROADCASTSS/D	v,x	1		3-6	1	
VBROADCASTSS/D	v,m	1		5	0.5	
VBROADCASTF128	y,m128	1		5	0.5	
VBROADCASTF32X4	v,m128	1		5	0.5	
VBROADCASTF64X4	z,m256	1		5	0.5	
UNPCKH/LPS/D	x,x	1	FP0	2	2	
VUNPCKH/LPS/D	v,v,v	1	FP0	4-7	2	
INSERTPS	x,x,i	2		8	7	
INSERTPS	x,m32,i	4		17	8	
INSERTF128	y,x	1		3-6	1	
INSERTF128	y,m128	1		7	1	
VINSERTF32X4	z,z,x	1		3-6	1	
VINSERTF32X4	z,z,m128	1		7	1	
VINSERTF64X4	z,z,y	1		3-6	1	
VINSERTF64X4	z,z,m256	1		7	1	
EXTRACTPS	r32,x,i	2		8	7	
EXTRACTPS	m32,x,i	4		7	8	
VEXTRACTF128	x,y,i	1		3-6	1	
VEXTRACTF128	m128,y	4		7	8	
VEXTRACTF32X4	x,z	1		3-6	1	
VEXTRACTF32X4	m128,z	4		7	8	
VEXTRACTF64X4	y,z	1		3-6	1	
VEXTRACTF64X4	m256,z	4		7	8	
BLENDPS/PD	x,x/m,i	1	FP0/1	2	2	
VBLENDPS/PD	v,v,v,i	1	FP0/1	2	0.5	
(V)BLENDVPS/PD	v,v,v	2		7	7	
BLENDVPS/PD	x,m,xmm0	3			8	
VBLENDMPS/D	z{k},z,z	1	FP0/1	2	0.5	
SHUFPS/D	x,x,i	1	FP0	4	2	

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VSHUFFS/D	v,v,v,i	1	FP0	4-7	2
VSHUFF32X4	z,z,z,i	1	FP0	4-7	2
VSHUFF64X2	z,z,z,i	1	FP0	4-7	2
VPERMILPS/PD	v,v/m,i	1	FP0	3-6	1
VPERMILPS/PD	v,v,v/m	1	FP0	3-6	1
VPERM2F128	y,y,y/m,i	1	FP0	4-7	2
VPERMPS/PD	v,v,v/m	1	FP0	3-6	1
VPERMI2PS/PD	z,z,z/m	1	FP0	4-7	2
VCOMPRESSPS/D	z{k},z	1		3-6	3
VEXPANDPS/D	z{k},z	1		3-6	3
<b>Gather and scatter</b>					
VPGATHERDPS	x,[r+s*x],x	6			12
VPGATHERDPS	y,[r+s*y],y	6			12
VPGATHERDPS	z,[r+s*z],z	1			11
VPGATHERQPS	x,[r+s*x],x	6			12
VPGATHERQPS	x,[r+s*y],x	6			12
VPGATHERQPS	y,[r+s*z],y	1			7
VPGATHERDPD	x,[r+s*x],x	6			12
VPGATHERDPD	y,[r+s*x],y	6			12
VPGATHERDPD	z,[r+s*y],z	1			7
VPGATHERQPD	x,[r+s*x],x	6			12
VPGATHERQPD	y,[r+s*y],y	6			12
VPGATHERQPD	z,[r+s*z],z	1			7
VGATHERPF0DPS	z,[r+s*z],z	1			~200
VGATHERPF0QPS	y,[r+s*z],y	1			~100
VGATHERPF0DPD	z,[r+s*y],z	1			~100
VGATHERPF0QPD	z,[r+s*z],z	1			~100
VGATHERPF1DPS	z,[r+s*z],z	1			~200
VGATHERPF1QPS	y,[r+s*z],y	1			~100
VGATHERPF1DPD	z,[r+s*y],z	1			~100
VGATHERPF1QPD	z,[r+s*z],z	1			~100
VPSCATTERDPS	z,[r+s*z],z	4			17
VPSCATTERQPS	y,[r+s*z],y	4			11
VPSCATTERDPD	z,[r+s*y],z	4			11
VPSCATTERQPD	z,[r+s*z],z	4			11
VSCATTERPF0DPS	z,[r+s*z],z	1			~200
VSCATTERPF0QPS	y,[r+s*z],y	1			~100
VSCATTERPF0DPD	z,[r+s*y],z	1			~100
VSCATTERPF0QPD	z,[r+s*z],z	1			~100
VSCATTERPF1DPS	z,[r+s*z],z	1			~200
VSCATTERPF1QPS	y,[r+s*z],y	1			~100
VSCATTERPF1DPD	z,[r+s*y],z	1			~100
VSCATTERPF1QPD	z,[r+s*z],z	1			~100
<b>Conversion</b>					
(V)CVTSD2SS	x,x	1	FP0	2	1
(V)CVTSS2SD	x,x	1	FP0	2	1
(V)CVTPD2PS	v,v	2	FP0	7	7
(V)CVTPS2PD	v,v	2	FP0	7	7
VCVTPS2PH	v,v	2		7	7
VCVTPS2PH	m,v	5			9
VCVTPH2PS	v,v	2		7	7

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VCVTPH2PS	v,m	3			8
(V)CVT(T)SS2(U)SI	r32/64,x	2	FP0	6	7
(V)CVT(U)SI2SS	x,r32/64	1	FP0	5	1
(V)CVT(T)SD2(U)SI	r32/64,x	2	FP0	6	7
(V)CVT(U)SI2SD	x,r32/64	1	FP0	5	1
CVT(T)PS2PI	mm,x	1	FP0	3	1
CVTPI2PS	x,mm	2	FP0	7	7
CVT(T) PD2PI	mm,x	2	FP0	7	7
CVTPI2PD	x,mm	2	FP0	7	7
(V)CVT(T) PS2DQ	v,v	1	FP0	2	1
(V)CVTDQ2PS	v,v	1	FP0	2	1
(V)CVT(T)PD2DQ	v,v	2	FP0	7	7
(V)CVTDQ2PD	v,v	2	FP0	7	7
VCVT(T)PS2UDQ	z,z	1	FP0	2	1
VCVTUDQ2PS	z,z	1	FP0	2	1
VCVT(T)PD2UDQ	z,z	2	FP0	7	7
VCVTUDQ2PD	z,z	2	FP0	7	7
<b>Arithmetic</b>					
ADDSS SUBSS	x,x	1	FP0/1	6	0.5
ADDSD SUBSD	x,x	1	FP0/1	6	0.5
ADDPSS SUBPSS	x,x	1	FP0/1	6	0.5
VADDPSS VSUBPSS	v,v,v	1	FP0/1	6	0.5
ADDPD SUBPD	x,x	1	FP0/1	6	0.5
VADDPD VSUBPD	v,v,v	1	FP0/1	6	0.5
ADDSUBPS/D	x,x	1	FP0/1	6	0.5
VADDSUBPS/D	v,v,v	1	FP0/1	6	0.5
HADDPSS/D HSUBPSS/D	x,x	3		15	8
VHADDPSS/D VHSUBPSS/D	yy,y,	3		15	8
MULSS/D	x,x	1	FP0/1	6	0.5
MULPS/D	x,x	1	FP0/1	6	0.5
VMULPS/D	v,v,v	1	FP0/1	6	0.5
DIVSS	x,x	3	FP0	27	17
DIVSD	x,x	3	FP0	42	42
DIVPSS	x,x	18	FP0	32	20
VDIVPSS	v,v,v	18	FP0	32	32
DIVPD	x,x	18	FP0	32	20
VDIVPD	v,v,v	18	FP0	32	32
RCPSS	x,x	1	FP0	7	2
(V)RCPPS	v,v	1	FP0	8	3
VRCP14SS	x,x,x	1	FP0	7	2
VRCP14PS	v,v	1	FP0	8	3
VRCP28SS	x,x,x	1	FP0	7	2
VRCP28PS	v,v	1	FP0	8	3
VRCP28SD	x,x,x	1	FP0	7	2
VRCP28PD	v,v	1	FP0	7	2
CMPccSS/D PS/D	x,x	1	FP0/1	2	0.5
VCMPccPS/D	k,z,z	1	FP0/1	2	0.5
COMISS/D UCOMISS/D	x,x	2		7	7
COMISS/D UCOMISS/D	x,m	3			8
MAXSS/D MINSS/D	x,x	1	FP0/1	2	0.5
MAXPS/D MINPS/D	x,x	1	FP0/1	2	0.5
VMAXPS/D VMINPS/D	v,v,v	1	FP0/1	2	0.5

Knights Landing

ROUNDSS/D	x,x,i	1		6	2	
(V)ROUNDPS/D	v,v,i	1		6	0.5	
VRNDSCALESS/D	x,x,x,i	1		6	0.5	
VRNDSCALEPS/D	v,v,i	1		6	0.5	
VSCALEFSS/D	x,x,x	1	FP0/1	6	0.5	
VSCALEFPS/D	z,z,z	1	FP0/1	6	0.5	
DPPS	x,x,i	14		36	14	
VDPPS	y,y,y,i	14		36	13	
DPPD	x,x,i	12		24	13	
VFMADD... (all FMA instr.)	v,v,v	1		6	0.5	
<b>Math</b>						
SQRTSS	x,x	3	FP0	28	18	
SQRTPS	x,x	18	FP0	38	16	
VSQRTPS	v,v	18	FP0	38	16	
SQRTSD	x,x	30	FP0	43	35	
SQRTPD	x,x	18	FP0	37	16	
VSQRTPD	v,v	18	FP0	37	16	
RSQRTSS	x,x	1	FP0	7	2	
RSQRTPS	x,x	1	FP0	8	3	
VRSQRTPS	v,v	1	FP0	7	3	
VRSQRT14SS	v,v,v	1	FP0	7	2	
VRSQRT14PS	v,v	1	FP0	7	3	
VRSQRT28SS	v,v,v	1	FP0	7	2	
VRSQRT28PS	v,v	1	FP0	7	3	
VRSQRT28SD	v,v,v	1	FP0	7	2	
VRSQRT28PD	v,v	1	FP0	6	2	
VEXP2PS	v,v	2		10	7	
VEXP2PD	v,v	2		9	7	
VFIXUPIMMSS/D/PS/D	v,v,v,i	1	FP0	2	1	
VGETEXPSS/D	v,v,v	1	FP0/1	6	0.5	
VGETEXPPS/D	v,v	1	FP0/1	6	0.5	
VGETMANTSS/D	v,v,v	1	FP0/1	6	0.5	
VGETMANTPS/D	v,v	1	FP0/1	6	0.5	
VFIXUPIMMSS/SD/PS/PD	v,v,v	1	FP0	2	1	
<b>Logic</b>						
ANDPS/D ANDNPS/D	x,x	1	FP0/1	2	0.5	
ORPS/D XORPS/D	x,x	1	FP0/1	2	0.5	
VANDPS/D VANDNPS/D	v,v,v	1	FP0/1	2	0.5	
VORPS/D VXORPS/D	v,v,v	1	FP0/1	2	0.5	
<b>Other</b>						
VZEROUPPER		11			30	32 bit mode
VZEROUPPER		19			36	64 bit mode
VZEROALL		11			30	32 bit mode
VZEROALL		19			36	64 bit mode
LDMXCSR	m32	6			21	
STMXCSR	m32	5			15	
FXSAVE	m	90			113	32 bit mode
FXSAVE	m	98			119	64 bit mode
FXRSTOR	m	98			122	32 bit mode
FXRSTOR	m	114			130	64 bit mode



Knights Landing

FNSAVE	m	135		205	205	
FRSTOR	m	78		191	191	
XSAVE	m	251			396	32 bit mode
XSAVE	m	291			430	64 bit mode
XRSTOR	m	116			231	32 bit mode
XRSTOR	m	157			273	64 bit mode
XSAVEOPT	m	251			396	32 bit mode
XSAVEOPT	m	291			428	64 bit mode

**Mask register instructions**

	Operands	μops	Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
KMOVW	k,k	1	FP0/1	2	0.5	
KMOVW	k,m	1		7	0.5	
KMOVW	m,k	1		7	1	
KMOVW	k,r	1	FP0	5	1	
KMOVW	r,k	1		4	1	
KUNPCKBW	k,k,k	1	FP0/1	2	0.5	
VPBROADCASTMB2Q	v,k	1	FP0	6	1	
VPBROADCASTMW2D	v,k	1	FP0	6	1	
<b>Arithmetic</b>						
KSHIFTLW	k,k,i	1	FP0/1	2	0.5	
KSHIFTRW	k,k,i	1	FP0/1	2	0.5	
<b>Logic</b>						
KANDW KANDNW	k,k,k	1	FP0/1	2	0.5	
KORW KXORW KXNORW	k,k,k	1	FP0/1	2	0.5	
KNOTW	k,k	1	FP0/1	2	0.5	
KORTESTW	k,k	1	FP1	5	1	

## VIA Nano 2000 series

### List of instruction timings and $\mu$ op breakdown

#### Explanation of column headings:

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.

**$\mu$ ops:** The number of micro-operations from the decoder or ROM. Note that the VIA Nano 2000 processor has no reliable performance monitor counter for  $\mu$ ops. Therefore the number of  $\mu$ ops cannot be determined except in simple cases.

**Port:** Tells which execution port or unit is used. Instructions that use the same port cannot execute simultaneously.

**I1:** Integer add, Boolean, shift, etc.

**I2:** Integer add, Boolean, move, jump.

**I12:** Can use either I1 or I2, whichever is vacant first.

**MA:** Multiply, divide and square root on all operand types.

**MB:** Various Integer and floating point SIMD operations.

**MBfadd:** Floating point addition subunit under MB.

**SA:** Memory store address.

**ST:** Memory store.

**LD:** Memory load.

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.

Note: There is an additional latency for moving data from one unit or subunit to another. A table of these latencies is given in manual 3: "The microarchitecture of Intel, AMD and VIA CPUs". These additional latencies are not included in the listings below where the source and destination operands are of the same type.

**Reciprocal throughput:** The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

#### Integer instructions

	Operands	$\mu$ ops	Port	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1	I2	1	1	Latency 4 on pointer register
MOV	r,i	1	I2	1	1	
MOV	r,m	1	LD	2	1	
MOV	m,r	1	SA, ST	2	1,5	
MOV	m,i	1	SA, ST		1,5	
MOV	r,sr				1	
MOV	m,sr				2	
MOV	sr,r			20	20	
MOV	sr,m			20	20	

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MOVNTI	m,r		SA, ST	2	1,5	
MOVSX MOVSXD						
MOVZX	r,r	1	I2	1	1	
MOVSX MOVSXD	r,m	2	LD, I2	3	1	
MOVZX	r,m	1	LD	2	1	
CMOVcc	r,r	2	I1, I2	2	1	
CMOVcc	r,m		LD, I1	5	2	
XCHG	r,r	3	I2	3	3	
XCHG	r,m			20	20	Implicit lock
XLAT	m			6		
PUSH	r		SA, ST		1-2	
PUSH	i		SA, ST		1-2	
PUSH	m		Ld, SA, ST		2	
PUSH	sr				17	
PUSHF(D/Q)				8	8	
PUSHA(D)					15	Not in x64 mode
POP	r		LD		1,25	
POP	(E/R)SP				4	
POP	m				5	
POP	sr				20	
POPF(D/Q)				9	9	
POPA(D)					12	Not in x64 mode
LAHF		1	I1	1	1	
SAHF		1	I1	1	1	
SALC				9	6	Not in x64 mode
LEA	r,m	1	SA	1	1	3 clock latency on input register
BSWAP	r	1	I2	1	1	
LDS LES LFS LGS LSS						
	m			30	30	
PREFETCHNTA	m		LD		1-2	
PREFETCH0/1/2	m		LD		1-2	
LFENCE					14	
MFENCE					14	
SFENCE					14	
<b>Arithmetic instructions</b>						
ADD SUB	r,r/i	1	I12	1	1/2	
ADD SUB	r,m	2	LD I12		1	
ADD SUB	m,r/i	3	LD I12 SA ST	5	2	
ADC SBB	r,r/i	1	I1	1	1	
ADC SBB	r,m	2	LD I1		1	
ADC SBB	m,r/i	3	LD I1 SA ST	5	2	
CMP	r,r/i	1	I12	1	1/2	
CMP	m,r/i	2	LD I12		1	
INC DEC NEG NOT	r	1	I12	1	1/2	
INC DEC NEG NOT	m	3	LD I12 SA ST	5		
AAA					37	Not in x64 mode
AAS					37	Not in x64 mode
DAA					22	Not in x64 mode

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DAS					24	Not in x64 mode
AAD					23	Not in x64 mode
AAM					30	Not in x64 mode
MUL IMUL	r8		MA	7-9		Extra latency to other ports
MUL IMUL	r16		MA	7-9		do.
MUL IMUL	r32		MA	7-9		do.
MUL IMUL	r64		MA	8-10		do.
IMUL	r16,r16		MA	4-6	1	do.
IMUL	r32,r32		MA	4-6	1	do.
IMUL	r64,r64		MA	5-7	2	do.
IMUL	r16,r16,i		MA	4-6	1	do.
IMUL	r32,r32,i		MA	4-6	1	do.
IMUL	r64,r64,i		MA	5-7	2	do.
DIV	r8		MA	26	26	do.
DIV	r16		MA	27-35	27-35	do.
DIV	r32		MA	25-41	25-41	do.
DIV	r64		MA	148-183	148-183	do.
IDIV	r8		MA	26	26	do.
IDIV	r16		MA	27-35	27-35	do.
IDIV	r32		MA	23-39	23-39	do.
IDIV	r64		MA	187-222	187-222	do.
CBW CWDE CDQE		1	I1	1	1	
CWD CDQ CQO		1	I1	1	1	
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1	I12	1	1/2	
AND OR XOR	r,m	2	LD I12		1	
AND OR XOR	m,r/i	3	LD I12 SA ST	5	2	
TEST	r,r/i	1	I12	1	1/2	
TEST	m,r/i	2	LD I12		1	
SHR SHL SAR	r,i/cl	1	I1	1	1	
ROR ROL	r,i/cl	1	I1	1	1	
RCR RCL	r,1	1	I1	1	1	
RCR RCL	r,i/cl		I1	28+3n	28+3n	
SHLD SHRD	r16,r16,i		I1	11	11	
SHLD SHRD	r32,r32,i		I1	7	7	
SHLD	r64,r64,i		I1	33	33	
SHRD	r64,r64,i		I1	43	43	
SHLD SHRD	r16,r16,cl		I1	11	11	
SHLD SHRD	r32,r32,cl		I1	7	7	
SHLD	r64,r64,cl		I1	33	33	
SHRD	r64,r64,cl		I1	43	43	
BT	r,r/i	1	I1	1	1	
BT	m,r		I1		8	
BT	m,i	2	I1		1	
BTR BTS BTC	r,r/i	2	I1	2	2	
BTR BTS BTC	m,r		I1	10	10	
BTR BTS BTC	m,i		I1	8	8	
BSF BSR	r,r		I1	3	2	

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SETcc	r		11	2	1	
SETcc	m				1	
CLC STC CMC			11	3	3	
CLD STD				3	3	
<b>Control transfer instructions</b>						
JMP	short/near	1	12	3	3	8 if >2 jumps in 16 bytes block
JMP	far			58		Not in x64 mode
JMP	r		12	3	3	8 if >2 jumps in 16 bytes block
JMP	m(near)			3	3	do.
JMP	m(far)			55		
Conditional jump	short/near			1-3-8	1-3-8	1 if not jumping. 3 if jumping. 8 if >2 jumps in 16 bytes block
J(E/R)CXZ	short			1-3-8	1-3-8	do.
LOOP	short			1-3-8	1-3-8	do.
LOOP(N)E	short			25	25	
CALL	near			3	3	8 if >2 jumps in 16 bytes block
CALL	far			72	72	Not in x64 mode
CALL	r			3	3	8 if >2 jumps in 16 bytes block
CALL	m(near)			4	3	do.
CALL	m(far)			72	72	
RETN				3	3	8 if >2 jumps in 16 bytes block
RETN	i			3	3	do.
RETF				39	39	
RETF	i			39	39	
BOUND	r,m				13	Not in x64 mode
INTO					7	Not in x64 mode
<b>String instructions</b>						
LODSB/W/D/Q					1	
REP LODSB/W/D/Q					3n+22	
STOSB/W/D/Q					1-2	
REP STOSB/W/D/Q					Small: 2n+2, Big: 6 bytes per clock	
MOVSB/W/D/Q					2	
REP MOVSB/W/D/Q					Small: 2n+45, Big: 6 bytes per clock	
SCASB/W/D/Q					1	
REP SCASB					2.2n	

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REP SCASW/D/Q					Small: 2n+50 Big: 5 bytes per clock	Blocks all ports	
CMPSB/W/D/Q					6		
REP CMPSB/W/D/Q					2.4n+24		
<b>Other</b>							
NOP (90)		1	All		1		
Long NOP (0F 1F)		1	I12		1/2		
PAUSE					25		
ENTER	a,0				23		
ENTER	a,b				52+5b		
LEAVE				4	4		
CPUID				53-173			
RDTSC					39		
RDPMC				40	40		

**Floating point x87 instructions**

	Operands	μops	Port and Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
FLD	r	1	MB	1	1	
FLD	m32/m64	2	LD MB	4	1	
FLD	m80	2	LD MB	4	1	
FBLD	m80			54	54	
FST(P)	r	1	MB	1	1	
FST(P)	m32/m64	3	MB SA ST	5	1-2	
FSTP	m80	3	MB SA ST	5	1-2	
FBSTP	m80			125	125	
FXCH	r	1	I2	0	1	
FILD	m16			7		
FILD	m32			5		
FILD	m64			5		
FIST(T)(P)	m16			6		
FIST(T)(P)	m32			5		
FIST(T)(P)	m64			5		
FLDZ FLD1		1	MB		1	
FLDPI FLDL2E etc.					10	
FCMOVcc	r			2	2	
FNSTSW	AX				5	
FNSTSW	m16				3	
FLDCW	m16			13	13	
FNSTCW	m16				2	
FINCSTP FDECSTP		1	I2	0	1	
FFREE(P)		1	MB		1	
FNSAVE	m			321	321	
FRSTOR	m			195	195	
<b>Arithmetic instructions</b>						

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FADD(P) FSUB(R)(P)	r/m	1	MB	2	1	Lower precision: Lat: 4, Thr: 2	
FMUL(P)	r/m	1	MA	4	2		
FDIV(R)(P)	r/m		MA	15-42	15-42		
FABS		1	MB	1	1		
FCHS		1	MB	1	1		
FCOM(P) FUCOM	r/m	1	MB		1		
FCOMPP FUCOMPP		1	MB		1		
FCOMI(P) FUCOMI(P)	r	1	MB		1		
FIADD FISUB(R)	m		MB		2		
FIMUL	m				4		
FIDIV(R)	m				42		
FICOM(P)	m	1			2		
FTST		1	MB		1		
FXAM					41		
FPREM				151-171			
FPREM1				106-155			
FRNDINT				29			
<b>Math</b>							
FSCALE				39			
EXTRACT				36-57			
FSQRT				73			
FSIN FCOS				51-159			
FSINCOS				270-360			
F2XM1				50-200			
FYL2X				~60			
FYL2XP1				~170			
FPTAN				300-370			
FPATAN				~170			
<b>Other</b>							
FNOP		1	MB		1		
WAIT		1	I12	0	1/2		
FNCLEX					57		
FNINIT					85		

**Integer MMX and XMM instructions**

	Operands	μops	Port and Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD	r32/64,(x)mm	1		3	1	
MOVD	n32/64,(x)mm	1	SA ST	2-3	1-2	
MOVD	(x)mm,r32/64			4	1	
MOVD	x)mm,m32/64	1	LD	2-3	1	
MOVQ	(x)mm, (x)mm	1	MB	1	1	
MOVQ	(x)mm,m64	1	LD	2-3	1	
MOVQ	m64, (x)mm	1	SA ST	2-3	1-2	
MOVDQA	xmm, xmm	1	MB	1	1	
MOVDQA	xmm, m128	1	LD	2-3	1	

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MOVDQA	m128, xmm	1	SA ST	2-3	1-2
MOVDQU	m128, xmm	1	SA ST	2-3	1-2
MOVDQU	xmm, m128	1	LD	2-3	1
LDDQU	xmm, m128	1	LD	2-3	1
MOVDQ2Q	mm, xmm	1	MB	1	1
MOVQ2DQ	xmm,mm	1	MB	1	1
MOVNTQ	m64,mm	3		~300	2
MOVNTDQ	m128,xmm	3		~300	2
PACKSSWB/DW					
PACKUSWB	v,v	1	MB	1	1
PUNPCKH/LBW/WD/ DQ	v,v	1	MB	1	1
PUNPCKH/LQDQ	v,v	1	MB	1	1
PSHUFB	v,v	1	MB	1	1
PSHUFW	mm,mm,i	1	MB	1	1
PSHUFL/HW	x,x,i	1	MB	1	1
PSHUFD	x,x,i	1	MB	1	1
PALIGNR	x,x,i	1	MB	1	1
MASKMOVQ	mm,mm				1-3
MASKMOVDQU	xmm,xmm				1-3
PMOVMSKB	r32,(x)mm			3	1
PEXTRW	r32 ,(x)mm,i			3	1
PINSRW	(x)mm,r32,i			9	9
<b>Arithmetic instructions</b>					
PADD/SUB(U)(S)B/W/D	v,v	1	MB	1	1
PADDQ PSUBQ	v,v	1	MB	1	1
PHADD(S)W					
PHSUB(S)W	v,v	3	MB	3	3
PHADDD PHSUBD	v,v	3	MB	3	3
PCMPEQ/GTB/W/D	v,v	1	MB	1	1
PMULL/HW PMULHUW	v,v	1	MA	3	1
PMULHRSW	v,v	1	MA	3	1
PMULUDQ	v,v	1	MA	3	1
PMADDWD	v,v			4	2
PMADDUBSW	v,v			10	8
PSADBW	v,v		MB	2	1
PAVGB/W	v,v	1	MB	1	1
PMIN/MAXUB	v,v	1	MB	1	1
PMIN/MAXSW	v,v	1	MB	1	1
PABSB PABSW PABSD	v,v	1	MB	1	1
PSIGNB PSIGNW					
PSIGND	v,v	1	MB	1	1
<b>Logic instructions</b>					
PAND(N) POR PXOR	v,v	1	MB	1	1
PSLL/RL/RAW/D/Q	v,v	1	MB	1	1
PSLL/RL/RAW/D/Q	v,i	1	MB	1	1
PSLL/RLDQ	x,i	1	MB	1	1



<b>Other</b>					
EMMS		1	MB		1

**Floating point XMM instructions**

	Operands	μops	Port and Unit	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVAPS/D	xmm,xmm	1	MB	1	1	
MOVAPS/D	xmm,m128	1	LD	2-3	1	
MOVAPS/D	m128,xmm	1	SA ST	2-3	1-2	
MOVUPS/D	xmm,m128	1	LD	2-3	1	
MOVUPS/D	m128,xmm	1	SA ST	2-3	1-2	
MOVSS/D	xmm,xmm	1	MB	1	1	
MOVSS/D	x,m32/64	1	LD	2-3	1	
MOVSS/D	m32/64,x	1	SA ST	2-3	1-2	
MOVHPS/D	xmm,m64			6	1	
MOVLPS/D	xmm,m64			6	1	
MOVHPS/D	m64,xmm			6	1-2	
MOVLPS/D	m64,xmm			2	1-2	
MOVLHPS MOVHLPS	xmm,xmm	1	MB	1	1	
MOVMSKPS/D	r32,xmm			3	1	
MOVNTPS/D	m128,xmm			~300	2,5	
SHUFPS	xmm,xmm,i	1	MB	1	1	
SHUFPD	xmm,xmm,i	1	MB	1	1	
MOVDDUP	xmm,xmm	1	MB	1	1	
MOVSH/LDUP	xmm,xmm	1	MB	1	1	
UNPCKH/LPS	xmm,xmm	1	MB	1	1	
UNPCKH/LPD	xmm,xmm	1	MB	1	1	
<b>Conversion</b>						
CVTPD2PS	xmm,xmm			3-4		
CVTSD2SS	xmm,xmm			15		
CVTPS2PD	xmm,xmm			3-4		
CVTSS2SD	xmm,xmm			15		
CVTDQ2PS	xmm,xmm			3		
CVT(T) PS2DQ	xmm,xmm			2		
CVTDQ2PD	xmm,xmm			4		
CVT(T)PD2DQ	xmm,xmm			3		
CVTPI2PS	xmm,mm			4		
CVT(T)PS2PI	mm,xmm			3		
CVTPI2PD	xmm,mm			4		
CVT(T) PD2PI	mm,xmm			3		
CVTSI2SS	xmm,r32			5		
CVT(T)SS2SI	r32,xmm			4		
CVTSI2SD	xmm,r32			5		
CVT(T)SD2SI	r32,xmm			4		
<b>Arithmetic</b>						
ADDSS SUBSS	xmm,xmm	1	MBfadd	2-3	1	

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ADDSD SUBSD	xmm,xmm	1	MBfadd	2-3	1
ADDPS SUBPS	xmm,xmm	1	MBfadd	2-3	1
ADDPD SUBPD	xmm,xmm	1	MBfadd	2-3	1
ADDSUBPS	xmm,xmm	1	MBfadd	2-3	1
ADDSUBPD	xmm,xmm	1	MBfadd	2-3	1
HADDPS HSUBPS	xmm,xmm		MBfadd	5	3
HADDPD HSUBPD	xmm,xmm		MBfadd	5	3
MULSS	xmm,xmm	1	MA	3	1
MULSD	xmm,xmm	1	MA	4	2
MULPS	xmm,xmm		MA	3	1
MULPD	xmm,xmm		MA	4	2
DIVSS	xmm,xmm		MA	15-22	15-22
DIVSD	xmm,xmm		MA	15-36	15-36
DIVPS	xmm,xmm		MA	42-82	42-82
DIVPD	xmm,xmm		MA	24-70	24-70
RCPSS	xmm,xmm			5	5
RCPPS	xmm,xmm			14	11
CMPccSS/D	xmm,xmm	1	MBfadd	2	1
CMPccPS/D	xmm,xmm	1	MBfadd	2	1
COMISS/D UCOMISS/D	xmm,xmm			3	1
MAXSS/D MINSS/D	xmm,xmm	1	MBfadd	2	1
MAXPS/D MINPS/D	xmm,xmm	1	MBfadd	2	1
<b>Math</b>					
SQRTSS	xmm,xmm		MA	33	33
SQRTPS	xmm,xmm		MA	126	126
SQRTSD	xmm,xmm		MA	62	62
SQRTPD	xmm,xmm		MA	122	122
RSQRTSS	xmm,xmm			5	5
RSQRTPS	xmm,xmm			14	11
<b>Logic</b>					
ANDPS/D	xmm,xmm	1	MB	1	1
ANDNPS/D	xmm,xmm	1	MB	1	1
ORPS/D	xmm,xmm	1	MB	1	1
XORPS/D	xmm,xmm	1	MB	1	1
<b>Other</b>					
LDMXCSR	m32			45	29
STMXCSR	m32			13	13
FXSAVE	m4096			208	208
FXRSTOR	m4096			232	232

**VIA-specific instructions**

Instruction	Conditions	Clock cycles, approximately
XSTORE	Data available	160-400 clock giving 8 bytes
XSTORE	No data available	50-80 clock giving 0 bytes
REP XSTORE	Quality factor = 0	4800 clock per 8 bytes
REP XSTORE	Quality factor > 0	19200 clock per 8 bytes

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REP XCRYPTECB	128 bits key	44 clock per 16 bytes
REP XCRYPTECB	192 bits key	46 clock per 16 bytes
REP XCRYPTECB	256 bits key	48 clock per 16 bytes
REP XCRYPTCBC	128 bits key	54 clock per 16 bytes
REP XCRYPTCBC	192 bits key	59 clock per 16 bytes
REP XCRYPTCBC	256 bits key	63 clock per 16 bytes
REP XCRYPTCTR	128 bits key	43 clock per 16 bytes
REP XCRYPTCTR	192 bits key	46 clock per 16 bytes
REP XCRYPTCTR	256 bits key	48 clock per 16 bytes
REP XCRYPTCFB	128 bits key	54 clock per 16 bytes
REP XCRYPTCFB	192 bits key	59 clock per 16 bytes
REP XCRYPTCFB	256 bits key	63 clock per 16 bytes
REP XCRYPTOFB	128 bits key	54 clock per 16 bytes
REP XCRYPTOFB	192 bits key	59 clock per 16 bytes
REP XCRYPTOFB	256 bits key	63 clock per 16 bytes
REP XSHA1		3 clock per byte
REP XSHA256		4 clock per byte

## VIA Nano 3000 series

### List of instruction timings and $\mu$ ops breakdown

#### Explanation of column headings:

**Operands:** i = immediate data, r = register, mm = 64 bit mmx register, xmm = 128 bit xmm register, (x)mm = mmx or xmm register, sr = segment register, m = memory, m32 = 32-bit memory operand, etc.

**$\mu$ ops:** The number of micro-operations from the decoder or ROM. Note that the VIA Nano 3000 processor has no reliable performance monitor counter for  $\mu$ ops. Therefore the number of  $\mu$ ops cannot be determined except in simple cases.

**Port:** Tells which execution port or unit is used. Instructions that use the same port cannot execute simultaneously.

**I1:** Integer add, Boolean, shift, etc.

**I2:** Integer add, Boolean, move, jump.

**I12:** Can use either I1 or I2, whichever is vacant first.

**MA:** Multiply, divide and square root on all operand types.

**MB:** Various Integer and floating point SIMD operations.

**MBfadd:** Floating point addition subunit under MB.

**SA:** Memory store address.

**ST:** Memory store.

**LD:** Memory load.

**Latency:** This is the delay that the instruction generates in a dependency chain. The numbers are minimum values. Cache misses, misalignment, and exceptions may increase the clock counts considerably. Floating point operands are presumed to be normal numbers. Denormal numbers, NAN's and infinity increase the delays very much, except in XMM move, shuffle and Boolean instructions. Floating point overflow, underflow, denormal or NAN results give a similar delay.

Note: There is an additional latency for moving data from one unit or subunit to another. A table of these latencies is given in manual 3: "The microarchitecture of Intel, AMD and VIA CPUs". These additional latencies are not included in the listings below where the source and destination operands are of the same type.

**Reciprocal throughput:** The average number of clock cycles per instruction for a series of independent instructions of the same kind in the same thread.

### Integer instructions

	Operands	$\mu$ ops	Port	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOV	r,r	1	I2	1	1	Latency 4 on pointer register
MOV	r,i	1	I12	1	1/2	
MOV	r,m	1	LD	2	1	
MOV	m,r	1	SA, ST	2	1,5	
MOV	m,i	1	SA, ST		1,5	
MOV	r,sr		I12		1/2	
MOV	m,sr				1,5	
MOV	sr,r			20	20	

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MOV	sr,m			20	20	
MOVNTI	m,r		SA, ST	2	1,5	
MOVSX MOVZX	r,r	1	I12	1	1/2	
MOVSXD	r64,r32	1		1	1	
MOVSX MOVSXD	r,m	2	LD, I12	3	1	
MOVZX	r,m	1	LD	2	1	
CMOVcc	r,r	1	I12	1	1/2	
CMOVcc	r,m		LD, I12	5	1	
XCHG	r,r	3	I12	3	1,5	
XCHG	r,m			18	18	Implicit lock
XLAT	m	3	LD, I1	6	2	
PUSH	r	1	SA, ST		1-2	
PUSH	i	1	SA, ST		1-2	
PUSH	m		LD, SA, ST		2	
PUSH	sr				6	
PUSHF(D/Q)		3		2	2	
PUSHA(D)		9			15	Not in x64 mode
POP	r	2	LD		1,25	
POP	(E/R)SP				4	
POP	m	3			2	
POP	sr				11	
POPF(D/Q)		3			1	
POPA(D)		16			12	Not in x64 mode
LAHF		1	I1	1	1	
SAHF		1	I1	1	1	
SALC		2		10	6	Not in x64 mode
LEA	r,m	1	SA	1	1	Extra latency to other ports
BSWAP	r	1	I2	1	1	
LDS LES LFS LGS LSS	m	12		28	28	
PREFETCHNTA	m	1	LD		1	
PREFETCHT0/1/2	m	1	LD		1	
LFENCE MFENCE SFENCE					15	
<b>Arithmetic instructions</b>						
ADD SUB	r,r/i	1	I12	1	1/2	
ADD SUB	r,m	2	LD I12		1	
ADD SUB	m,r/i	3	LD I12 SA ST	5	2	
ADC SBB	r,r/i	1	I1	1	1	
ADC SBB	r,m	2	LD I1		1	
ADC SBB	m,r/i	3	LD I1 SA ST	5	2	
CMP	r,r/i	1	I12	1	1/2	
CMP	m,r/i	2	LD I12		1	
INC DEC NEG NOT	r	1	I12	1	1/2	
INC DEC NEG NOT	m	3	LD I12 SA ST	5		
AAA		12			37	Not in x64 mode
AAS		12			22	Not in x64 mode
DAA		14			22	Not in x64 mode

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DAS		14			24	Not in x64 mode
AAD		7			24	Not in x64 mode
AAM		13			31	Not in x64 mode
MUL IMUL	r8	1	I2	2		
MUL IMUL	r16	3	I2	3		
MUL IMUL	r32	3	I2	3		
MUL IMUL	r64	3	MA	8	8	Extra latency to other ports
IMUL	r16,r16	1	I2	2	1	
IMUL	r32,r32	1	I2	2	1	
IMUL	r64,r64	1	MA	5	2	Extra latency to other ports
IMUL	r16,r16,i	1	I2	2	1	
IMUL	r32,r32,i	1	I2	2	1	
IMUL	r64,r64,i	1	MA	5	2	Extra latency to other ports
DIV	r8		MA	22-24	22-24	
DIV	r16		MA	24-28	24-28	
DIV	r32		MA	22-30	22-30	
DIV	r64		MA	145-162	145-162	
IDIV	r8		MA	21-24	21-24	
IDIV	r16		MA	24-28	24-28	
IDIV	r32		MA	18-26	18-26	
IDIV	r64		MA	182-200	182-200	
CBW CWDE CDQE		1	I2	1	1	
CWD CDQ CQO		1	I2	1	1	
<b>Logic instructions</b>						
AND OR XOR	r,r/i	1	I12	1	1/2	
AND OR XOR	r,m	2	LD I12		1	
AND OR XOR	m,r/i	3	LD I12 SA ST	5	2	
TEST	r,r/i	1	I12	1	1/2	
TEST	m,r/i	2	LD I12		1	
SHR SHL SAR	r,i/cl	1	I12	1	1/2	
ROR ROL	r,i/cl	1	I1	1	1	
RCR RCL	r,1	1	I1	1	1	
RCR RCL	r,i/cl	5+2n	I1	28+3n	28+3n	
SHLD SHRD	r16,r16,i/cl	2	I1	2	2	
SHLD SHRD	r32,r32,i/cl	2	I1	2	2	
SHLD	r64,r64,i/cl	16	I1	32	32	
SHRD	r64,r64,i/cl	23	I1	42	42	
BT	r,r/i	1	I1	1	1	
BT	m,r	6	I1		8	
BT	m,i	2	I1		1	
BTR BTS BTC	r,r/i	2	I1	2	2	
BTR BTS BTC	m,r	8	I1	10	10	
BTR BTS BTC	m,i	5	I1	8	8	
BSF BSR	r,r	2	I1	2	2	
SETcc	r8	1	I1	1	1	
SETcc	m	2			2	

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CLC STC CMC		3	11	3	3	
CLD STD		3	11	3	3	
<b>Control transfer instructions</b>						
JMP	short/near	1	12	3	3	8 if >2 jumps in 16 bytes block
JMP	far	14			50	Not in x64 mode
JMP	r	2	12	3	3	8 if >2 jumps in 16 bytes block
JMP	m(near)	2		3	3	do.
JMP	m(far)	17			42	
Conditional jump	short/near	1	12	1-3-8	1-3-8	1 if not jumping. 3 if jumping. 8 if >2 jumps in 16 bytes block
J(E/R)CXZ	short	2		1-3-8	1-3-8	
LOOP	short	2		1-3-8	1-3-8	
LOOP(N)E	short	5		24	24	
CALL	near	2		3	3	8 if >2 jumps in 16 bytes block
CALL	far	17			58	Not in x64 mode
CALL	r	2		3	3	8 if >2 jumps in 16 bytes block
CALL	m(near)	3		4	3	do.
CALL	m(far)	19			54	
RETN		3		3	3	8 if >2 jumps in 16 bytes block
RETN	i	4		3	3	do.
RETF		20			49	
RETF	i	20			49	
BOUND	r,m	9			13	Not in x64 mode
INTO		3			7	Not in x64 mode
<b>String instructions</b>						
LODSB/W/D/Q		2			1	
REP LODSB/W/D/Q		3n			3n+27	
STOSB/W/D/Q		1			1-2	
REP STOSB/W/D/Q					Small: n+40, Big: 6-7 bytes/clock	
MOVSB/W/D/Q		3			2	
REP MOVSB/W/D/Q					Small: 2n+20, Big: 6-7 bytes/clock	
SCASB/W/D/Q		3			1	
REP SCASB					2.4n	
REP SCASW/D/Q					Small: 2n+31, Big: 5 bytes/clock	

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CMPSB/W/D/Q REP CMPSB/W/D/Q		5			6 2.2n+30	
<b>Other</b>						
NOP (90)		0-1	I12	0	1/2	Sometimes fused
long NOP (0F 1F)		0-1	I12	0	1/2	
PAUSE		2			6	
ENTER	a,0	10			21	
ENTER	a,b				52+5b	
LEAVE		3		2	2	
CPUID				55-146		
RDTSC					37	
RDPMC					40	

**Floating point x87 instructions**

	Operands	μops	Port	Latency	Reciprocal through-put	Remarks
<b>Move instructions</b>						
FLD	r	1	MB	1	1	
FLD	m32/m64	2	LD MB	4	1	
FLD	m80	2	LD MB	4	1	
FBLD	m80	36		54	54	
FST(P)	r	1	MB	1	1	
FST(P)	m32/m64	3	MB SA ST	5	1-2	
FSTP	m80	3	MB SA ST	5	1-2	
FBSTP	m80	80		125	125	
FXCH	r	1	I2	0	1	
FILD	m16	3		7		
FILD	m32	2		5		
FILD	m64	2		5		
FIST(T)(P)	m16	3		6		
FIST(T)(P)	m32	3		5		
FIST(T)(P)	m64	3		5		
FLDZ FLD1		1	MB		1	
FLDPI FLDL2E etc.		3			10	
FCMOVcc	r	1	MB	2	2	
FNSTSW	AX	1			1	
FNSTSW	m16	3			2	
FLDCW	m16	5			8	
FNSTCW	m16	3			2	
FINCSTP FDECSTP		1	I2	0	1	
FFREE(P)		1	MB		1	
FNSAVE	m	122		319	319	
FRSTOR	m	115		196	196	
<b>Arithmetic instructions</b>						
FADD(P) FSUB(R)(P)	r/m	1	MB	2	1	



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FMUL(P)	r/m	1	MA	4	2		
FDIV(R)(P)	r/m		MA	14-23	14-23		
FABS		1	MB	1	1		
FCHS		1	MB	1	1		
FCOM(P) FUCOM	r/m	1	MB		1		
FCOMPP FUCOMPP		1	MB		1		
FCOMI(P) FUCOMI(P)	r	1	MB	2	1		
FIADD FISUB(R)	m	3	MB		2		
FIMUL	m	3			4		
FIDIV(R)	m	3			16		
FICOM(P)	m	3			2		
FTST		1	MB	2	1		
FXAM		15		38	38		
FPREM				~130			
FPREM1				~130			
FRNDINT		11		27			
<b>Math</b>							
FSCALE		22		37			
EXTRACT		13		57			
FSQRT				73		Less at lower precision	
FSIN FCOS				~150			
FSINCOS				270-360			
F2XM1				50-200			
FYL2X				~50			
FYL2XP1				~50			
FPTAN				300-370			
FPATAN				~180			
<b>Other</b>							
FNOP		1	MB		1		
WAIT		1	I12	0	1/2		
FNCLEX					59		
FNINIT					84		

**Integer MMX and XMM instructions**

	Operands	μops	Port	Latency	Reciprocal throughput	Remarks
<b>Move instructions</b>						
MOVD	r,(x)mm	1	MB	3	1	
MOVD	m,(x)mm	1	SA ST	2	1-2	
MOVD	(x)mm,r	1	I2	4	1	
MOVD	(x)mm,m	1	LD	2	1	
MOVQ	v,v	1	MB	1	1	
MOVQ	(x)mm,m64	1	LD	2	1	
MOVQ	m64, (x)mm	1	SA ST	2	1-2	
MOVDQA	x,x	1	MB	1	1	

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MOVDQA	x, m128	1	LD	2	1
MOVDQA	m128, x	1	SA ST	2	1-2
MOVDQU	m128, x	1	SA ST	2	1-2
MOVDQU	x, m128	1	LD	2	1
LDDQU	x, m128	1	LD	2	1
MOVDQ2Q	mm, x	1	MB	1	1
MOVQ2DQ	x,mm	1	MB	1	1
MOVNTQ	m64,mm	2		~360	2
MOVNTDQ	m128,x	2		~360	2
MOVNTDQA	x,m128	1		2	1
PACKSSWB/DW					
PACKUSWB	v,v	1	MB	1	1
PACKUSDW	x,x	1	MB	1	1
PUNPCKH/LBW/WD/DQ	v,v	1	MB	1	1
PUNPCKH/LQDQ	v,v	1	MB	1	1
PSHUFB	v,v	1	MB	1	1
PSHUFW	mm,mm,i	1	MB	1	1
PSHUFL/HW	x,x,i	1	MB	1	1
PSHUFD	x,x,i	1	MB	1	1
PBLENDVB	x,x,xmm0	1	MB	2	2
PBLENDW	x,x,i	1	MB	1	1
PALIGNR	x,x,i	1	MB	1	1
MASKMOVQ	mm,mm				1-2
MASKMOVDQU	x,x				1-2
PMOVMSKB	r32,(x)mm			3	1
PEXTRW	r32 ,(x)mm,i	1	MB	3	1
PEXTRB/D/Q	r32/64,x,i	1	MB	3	1
PINSRW	(x)mm,r32,i	2	MB	5	1
PINSRB/D/Q	x,r32/64,i	2	MB	5	1
PMOVSX/ZXBW/BD/ BQ/WD/WQ/DQ	x,x	1	MB	1	1
<b>Arithmetic instructions</b>					
PADD/SUB(U)(S)B/W/D	v,v	1	MB	1	1
PADDQ PSUBQ	v,v	1	MB	1	1
PHADD(S)W					
PHSUB(S)W	v,v	3	MB	3	3
PHADD PHSUBD	v,v	3	MB	3	3
PCMPEQ/GTB/W/D	v,v	1	MB	1	1
PCMPEQQ	x,x	1	MB	1	1
PMULL/HW PMULHUW	v,v	1	MA	3	1
PMULHRSW	v,v	1	MA	3	1
PMULLD	x,x	1	MA	3	1
PMULUDQ	v,v	1	MA	3	1
PMULDQ	x,x	1	MA	3	1
PMADDWD	v,v	1	MA	4	2
PMADDUBSW	v,v	7		10	8
PSADBW	v,v	1	MB	2	1
MPSADBW	x,x,i	1	MB	2	1
PAVGB/W	v,v	1	MB	1	1

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PMIN/MAXSW	v,v	1	MB	1	1
PMIN/MAXUB	v,v	1	MB	1	1
PMIN/MAXSB/D	x,x	1	MB	1	1
PMIN/MAXUW/D	x,x	1	MB	1	1
PHMINPOSUW	x,x	1	MB	2	1
PABSB PABSW PABSD					
	v,v	1	MB	1	1
PSIGNB PSIGNW					
PSIGND	v,v	1	MB	1	1
<b>Logic instructions</b>					
PAND(N) POR PXOR	v,v	1	MB	1	1
PTEST	v,v	1	MB	3	1
PSLL/RL/RAW/D/Q	v,v	1	MB	1	1
PSLL/RL/RAW/D/Q	(x)xmm,i	1	MB	1	1
PSLL/RLDQ	x,i	1	MB	1	1
<b>Other</b>					
EMMS		1	MB		1

**Floating point XMM instructions**

	Operands	μops	Port	Latency	Reciprocal through-put	Remarks
<b>Move instructions</b>						
MOVAPS/D	x,x	1	MB	1	1	
MOVAPS/D	x,m128	1	LD	2	1	
MOVAPS/D	m128,x	1	SA ST	2	1	
MOVUPS/D	x,m128	1	LD	2	1	
MOVUPS/D	m128,x	2	SA ST	2	1	
MOVSS/D	x,x	1	MB	1	1	
MOVSS/D	x,m32/64	1	LD	2-3	1	
MOVSS/D	m32/64,x	2	SA ST	2-3	1-2	
MOVHPS/D	x,m64	2		6	1	
MOVLPS/D	x,m64	2		6	1	
MOVHPS/D	m64,x	3		6	1-2	
MOVLPS/D	m64,x	1		2	1-2	
MOVLHPS MOVHLPS	x,x	1		1	1	
MOVMSKPS/D	r32,x			3	1	
MOVNTPS/D	m128,x	2		~360	1-2	
SHUFPS	x,x,i	1	MB	1	1	
SHUFPD	x,x,i	1	MB	1	1	
MOVDDUP	x,x	1	MB	1	1	
MOVSH/LDUP	x,x	1	MB	1	1	
UNPCKH/LPS	x,x	1	MB	1	1	
UNPCKH/LPD	x,x	1	MB	1	1	
<b>Conversion</b>						
CVTPD2PS	x,x	2		5	2	
CVTSD2SS	x,x	1		2		
CVTSS2PD	x,x	2		5	1	

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CVTSS2SD	x,x	1		2	
CVTDQ2PS	x,x	1	MB	3	1
CVT(T) PS2DQ	x,x	1		2	1
CVTDQ2PD	x,x	2		5	1
CVT(T)PD2DQ	x,x			4	2
CVTPI2PS	x,mm	2		5	2
CVT(T)PS2PI	mm,x	1		4	1
CVTPI2PD	x,mm	2		4	1
CVT(T) PD2PI	mm,x	2		4	2
CVTSI2SS	x,r32	2		5	
CVT(T)SS2SI	r32,x	1		4	1
CVTSI2SD	x,r32	2		5	
CVT(T)SD2SI	r32,x	1		4	1
<b>Arithmetic</b>					
ADDSS SUBSS	x,x	1	MBfadd	2	1
ADDSD SUBSD	x,x	1	MBfadd	2	1
ADDPs SUBPS	x,x	1	MBfadd	2	1
ADDPD SUBPD	x,x	1	MBfadd	2	1
ADDSubPS	x,x	1	MBfadd	2	1
ADDSubPD	x,x	1	MBfadd	2	1
HADDPs HSubPS	x,x	3	MBfadd	5	3
HADDPD HSubPD	x,x	3	MBfadd	5	3
MULSS	x,x	1	MA	3	1
MULSD	x,x	1	MA	4	2
MULPS	x,x	1	MA	3	1
MULPD	x,x	1	MA	4	2
DIVSS	x,x	1	MA	13	13
DIVSD	x,x	1	MA	13-20	13-20
DIVPS	x,x	1	MA	24	24
DIVPD	x,x	1	MA	21-38	21-38
RCPSS	x,x	1	MA	5	5
RCPPS	x,x	3	MA	14	11
CMPccSS/D	x,x	1	MBfadd	2	1
CMPccPS/D	x,x	1	MBfadd	2	1
COMISS/D UCOMISS/D	x,x	1	MBfadd	3	1
MAXSS/D MINSS/D	x,x	1	MBfadd	2	1
MAXPS/D MINPS/D	x,x	1	MBfadd	2	1
<b>Math</b>					
SQRTSS	x,x	1	MA	33	33
SQRTPS	x,x	1	MA	64	64
SQRTSD	x,x	1	MA	62	62
SQRTPD	x,x	1	MA	122	122
RSQRTSS	x,x	1		5	5
RSQRTPS	x,x	3		14	11
<b>Logic</b>					
ANDPS/D	x,x	1	MB	1	1

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ANDNPS/D	x,x	1	MB	1	1
ORPS/D	x,x	1	MB	1	1
XORPS/D	x,x	1	MB	1	1
<b>Other</b>					
LDMXCSR	m32				31
STMXCSR	m32				13
FXSAVE	m4096				97
FXRSTOR	m4096				201

**VIA-specific instructions**

Instruction	Conditions	Clock cycles, approximately
XSTORE	Data available	160-400 clock giving 8 bytes
XSTORE	No data available	50-80 clock giving 0 bytes
REP XSTORE	Quality factor = 0	1300 clock per 8 bytes
REP XSTORE	Quality factor > 0	5455 clock per 8 bytes
REP XCRYPTECB	128 bits key	15 clock per 16 bytes
REP XCRYPTECB	192 bits key	17 clock per 16 bytes
REP XCRYPTECB	256 bits key	18 clock per 16 bytes
REP XCRYPTCBC	128 bits key	29 clock per 16 bytes
REP XCRYPTCBC	192 bits key	33 clock per 16 bytes
REP XCRYPTCBC	256 bits key	37 clock per 16 bytes
REP XCRYPTCTR	128 bits key	23 clock per 16 bytes
REP XCRYPTCTR	192 bits key	26 clock per 16 bytes
REP XCRYPTCTR	256 bits key	27 clock per 16 bytes
REP XCRYPTCFB	128 bits key	29 clock per 16 bytes
REP XCRYPTCFB	192 bits key	33 clock per 16 bytes
REP XCRYPTCFB	256 bits key	37 clock per 16 bytes
REP XCRYPTOFB	128 bits key	29 clock per 16 bytes
REP XCRYPTOFB	192 bits key	33 clock per 16 bytes
REP XCRYPTOFB	256 bits key	37 clock per 16 bytes
REP XSHA1		5 clock per byte
REP XSHA256		5 clock per byte