= assembler directive, 260 68000, 269 68XXX, 697 80-column color text mode, 284 8-bit adapters, 263 8-bit bus cycle eater, 75-81,83,93,110,113,128,129,699,701,704,705 interaction with DRAM refresh cycle eater, 115 location. 78.83 penalty for word-sized accesses, 79,80,84,110,321,376,662 penalty for word-sized accesses doubles when memory is destination, 321 prefetch queue cycle eater as manifestation of, 83,84 what to do about, 80-83 with multiple word-sized accesses, 79 8-bit data bus, 69,71,76,78,263,525,697 address lines of, 117,121 80186, 71,698 80188.71.698 80286, 71,142,156,160,169,184,211,263,266,306,390,537,696-707,709-722,727 bug in popf, 145,721-723,725-727 handles pushing SP differently than 8088, 141 imbalance between processing speed and memory speed,72 80287, 728, 729 80386, 30, 63, 71, 108, 142, 156, 160, 169, 185, 211, 266, 269, 306, 390, 696-705, 707, 708, 711-718,720,721 imbalance between processing speed and memory speed,72 80386SX, 63,71,698,699 80387, 728, 729 80486, 696 8080, 69,71,134,155,266-272,285,289,290,294,295 8080 legacy, 266,269 8080-specific instructions, 270 8085, 71, 266, 267 8086, 69,71,72,76,78-80,263,266,390,525,616,696-699,731 8087, 291, 728-731 can coprocess with the 8088, 730,731 ensuring synchronization with 8088, 730,731 keep variables in data registers as much as possible, 729,730 8088, 5,6,8,11,13,14,25,26,63,65,69-73,75,76,78-80,117,118,123,169,266-272, 274,281,289-291,295,297,304-306,309,312,316,326,332,344,346,390,396, 508,509,514,517,519,524,535,560,592,616,694,696-701,703-705,708, 712-721,727-731,733

16-bit processor that often performs like an 8-bit processor, 76 16-bit processor with an 8-bit data bus, 133,134 architecture, 266, 267, 295 bug in disabling of interrupts while loading segment registers, 144 can address no more than four 64-Kb blocks at any one time, 134 capable of addressing 1 Mb of memory, 133,134,152,154-156,160 clock speed in PC is slow, 134 compared to 8086, 69,71,72,78,80,84 data lines of, 117,121 derivation from 8086, 69,72,134 display memory access, restricted, 102,103 effect on performance, 62 externally an 8-bit processor, 67,76,78 fairly low-performance processor that's hard to program, 134 handles pushing SP differently than 80286, 141 hodgepodge of a processor, 134 influenced by 8080, 134 instruction execution and memory access relatively slow, 134,158,346 instruction set. < see instruction set> internal parallelism (internal coprocessing), 65-68,85,92,119,122,124,125 internally a 16-bit processor, 67,75-78,83 memory architecture, 152,154-156,167 minimum memory access time, 82,130 mismatched internal and external bus sizes, 69,71,72,76,78,80,701 programming interface, 63,133 register space is limited, 134 resources, 133,135 rests on PC's hardware, 64,65,73 sets tone for PC, 133 speed of accessing the second byte of a word-sized operand, 82,219,384 two processors in one, 65,66 8237 DMA controller chip documentation, 52 DRAM refresh, 95 8253 timer chip, 8,14,23,24,25,28,37 accuracy, 30 configuration in the PC, 24 counting rate, 30 counting resolution, 30 documentation, 52 in PS/2 computers, 36,37 interrupts, 25,27 latching a timer count, 28,36

mode 2, divide-by-N mode, 23,25,26 mode 3, square wave mode, 25,26 modes, 25 programmability, 23-26,36 stopping a timer, 25,28,36 8259 interrupt controller chip, 25 configuration in the PC. 26 documentation, 52 edge triggering, 25,26 timer interrupt, 27 aaa instruction, 139,147,333,335,339-342 aad instruction, 139,333,335-337 aam instruction, 139,333,335-337 aas instruction, 139,147,333,335,339,341,342 accumulator, 138,139,267,270,275-277,290,298,302,351,359,412,436,444 and in and out, 138,261 multiplication and division, 138 sign extension, 139,312 string instructions, 139 accumulator-specific, 278,284 AX-specific form of xchq, <see xchq> direct-addressing form of mov, 219,231,271-280,282,298,299,302,343, 344.648.670 immediate-addressing form of test, 286 immediate-addressing instructions, 231,271,281-283,285,342,344 instructions, 139,270,284,285 adc instruction, 281-283,309,320,343,560,563 add instruction, 147,222,281-283,294,305,306,309,320,334,342,343,643, 712 addressing modes, <see memory addressing modes> AF (auxiliary carry flag), 144,145,147,329,330,334,340-342,354 AH register, 137,138,289-291,294,307,312,315,335,341,362,440,449 not an accumulator, 138,275,276 AL register, 137,138,159,261,298,301,307,312,315,322,334,335,337,339,341,342, 343,347,351,352,354,355,359,405,407,440,449 8-bit accumulator, 138,275-277 algorithms, 59,131,482,734 and instruction, 146,148,229,281-285,301,302,320,335,343,561,563,643 animation, 109,404,489-492,496-499,504,505,594,596,598,668,734 block-move animation, 497-499,504,505,596 xor animation. 489-492.496-499.504.505.594.594 ANSI.SYS device driver, poor performance of, 61 Apple II, 135, 136, 497

Apple Macintosh, 697 application programs, 60,63 arg directive, 244 arithmetic logic unit (ALU), 65,66 arrays, comparing, 359,371,457,458,462,482,483,485 arrays, copying, 351,404,406,407 arrays, searching, 354,400,430,432,433,439,454,471-473,479,482,572,601,656 arrays, setting, 375,376,590,602,608 ASCII, 246,335,336,338,340,672,673 ASCII adjust, 333-335,340,341 ASCII arithmetic, 139,147,333,339,340 assembler code advantages of mixing with high level languages, 241 and stack frames, 240-242 no complete solution to writing, 114 versus compiled code, 10,174,240 assembler programmer can think more flexibly than high level language, 174,400,533 knows exactly what code must do, 164,166,167 knows more about what code must do than high level language, 174,542 assembler programming, 560,589 high-performance must be intuitive art, 131,505,560,589,604,649,694 no hard and fast rules, 316,560 science of, 113 assemblers, 645,646,693 and precalculation, 249,251,258,260 manuals, importance of reading, 192 relationship to machine language, 7,8 assembly language, 4-9,13,166,589,623,624,650,731,733 bad code, 10 complete control over segments, 163,623,624 difficulty of learning, 7.8 excellent data-definition capabilities, 258,260 framework, 11 good at handling multiple segments & larger than 64 KB blocks, 155,163,164, 167,173,179-181,191 good code, 10 hardware, 8 high-performance programming, 64,73,110,505,510,530,531,560,589,593,597, 601-604,611,649 lack of transformation loss. 7 low-level control, 8 need for forethought and planning, 10

objectives of good programming, 9 objectives of high-performance programming, 9 optimization, 10 performance, 10 porting 8080 code, 267,269,270,272 potential of, 5 produces best code, 10,241 programmers, 8,58 programmers and responsibility for code quality, 8 superior information and adaptability, 10 traditional programming model, 59,60 versus high level languages, 10,163,164,167,173,174,191,240,246,258,400,488, 533,542,560,729,730 when to use, 10 assume directive, 168,196,393 and segment override prefixes, 196,197 assume nothing, 13,250,344 assuming and related problems, 13 automatic (dynamic) variables, 233,240 AUX device driver for reporting timer results, 29 auxiliary carry flag, <see AF> AX register, 137,138,261,267,275,298,307,312,314,315,335,337,339,343,347,351, 352,354,355,359,405,407,449,680 16-bit accumulator, 138 accessible as AH and AL, 138 barrel shifter of the 80386, 720 base addressing, 207,209,211,213,214,218,219,221 base addressing component, 200,202,207 base+displacement, 214,220,255 base+index addressing, 213,214,255 base+index+displacement addressing, 200,202,207,214,718 based relative addressing, 206 BASIC, 166 BC register pair of 8080, 267 BCD arithmetic, 139,147,334,335 beneath the programming interface, importance of understanding, 75,701 best code, rarely such a beast, 174,257 BH register, 137,139 not used as memory-addressing register, 139 BIOS, 8,25,28,35,59-61,75,133,152,194,363,637,653,712,722 adapter-select bits, 284 as an assembly-language program, 61 documentation, 52

equipment flag, 284 inadequacy of some services, 61 interrupt 17h, printer control, 29 time of day count, <see time of day count> bit doubling, 250-254,256,257,332 BL register, 137,139 not used as memory-addressing register, 139 blocks of data, comparing, 359,457,458 blocks of data, copying, 351,413,414,416-420,424 blocks of data, setting, 365-367,384,389 Borland, 645 bound instruction, 715 BP register, 137,140,159,193,239,245,643 base addressing component, 207 no addressing mode that uses only BP, 207,643 normally addresses the stack segment, 140,143,192 specializes as stack frame-addressing register, 140,208,239,240,245 used as memory-addressing register, 140,200,208,223,233,239,245,246,309 branched-to in-line code, 598,599,601,602,604,607,608,679,688 branched-to partial in-line code, 605,606,608 branches, 150,192,297,346,366,471,508,509,512,517,519,521-525,527-531,533, 534.537-540.542.543.545.555-557.560-562.564.565.569.571.572.574.577. 579,581,582,586,587,589-594,596,599,601,602,604-608,610,611,615, 619-621,627,631,632,636,637,649-653,657,658,661,662,668,670,672,674, 678,679,686,688,693,701,702,705,708,710,711,717,723 absolute, 510,511 desirability of eliminating, 251,368,440,444,479,499,508,509,514,530,531, 555,560,574,577,579,582,586,592-594,596,601,602,611,619-621,658,699, 702,705,717 empty the prefetch queue, 66,67,86,294,518,519,522-525,527,528,530,531,539, 556.582.589.590.601.616.619.620.636.637.652.701.702.704.705 first prefetch after is included in execution time, 523-525,527,530 not-branching, <see not-branching> relative, 510-515,565 bus, 62,63,65,68,70,71 bug in splitting 16-bit accesses to 8-bit adapters in certain computers, 263 effect on performance, 62,64,72,77-80,83,84 maximum data transfer rate, 67,70,73,77,78,84 sizes in 8086 family, 69 splits 16-bit accesses to 8-bit adapters with some processors, 263 transparency to programs, 62 bus interface unit (BIU), 65-72,78,158,520,524-529,616,699,701 bottleneck, 70-72,78

can coprocess with EU, 66-68,85,92,119,122,124,519,520 converts 16-bit memory accesses into 8-bit accesses, 69,78,263 features contained within, 67 inability to fetch instruction bytes as fast as EU can execute them, 75,77, 84,85,130,699 interleaves instruction fetches with memory operand accesses, 125 minimum transfer time for bytes from the prefetch queue to the EU, 130 path for all memory and I/O accesses, including instruction fetches, 69 performs all memory and I/O accesses, 66,67 potentially greatest cycle eater of all, 69 prefetches, 66,67,85,519-521,523,616,699 provides instruction bytes for EU, 66,67 provides only 8-bit access to bus, 67,78 BX register, 137,139,159,267,643 accessible as BH and BL, 139 base addressing component, 207 normally addresses the data segment, 140 used as memory-addressing register, 139,200,208,223,246,309,316 <I>Byte<i> magazine, 52 byte-sized accesses, desirability of, 80,81,110 byte-sized versus word-sized operations, 80-83 byte-to-word conversion, 312,313 bytes versus cycles, 9,160,249,255,257,471,537,554,581,588-590,592,596, 602-604,610,617,637,649,651,674,694,711 C, 6,58,166,233,240,433,488,542,589,619,623,624,715 switch, 303,646,670 cache memory, 698,702,703 call instruction, 141-144,517,568,582,584,620,627,630,631,633,635-627, 670,712,726 call tables, <see jump tables> calls, subroutine, 508,517,526,581,582,584,586,588,589,592,627,628,670 direct, 620,622,626,637 far, <see far calls> indirect, 187,620,622,623,626,670,671 moving called code into loop, 582,584,586 near, <see near calls> replacing with macros, 582,584,630 carry flag, <see CF> carrying results along in a flag, 310-312 cbw instruction. 139.140.312.313.315 CF (carry flag), 144-147, 309, 310, 322, 323, 327-330, 332, 341, 354, 488, 547, 560, 562, 563,564,655,716

can sometimes be used to avoid branching, 561-564 CGA, <see Color/Graphics Adapter> CH register, 137,139 not used as counting register, 139 "Chips in Transition," 721 CL register, 137,139,324-327,329,331 used as counting register, 139 clc instruction, 146 cld instruction, 149,362,363,420 clearing the screen, 58 cli instruction, 149 cmc instruction, 146 cmp instruction, 277,278,281-283,301-304,321,343,354,356,359,436,444, 540.643 cmps instruction, 140,359-361,368,371,372,377,381,391,393,457,462,466, 471,482,483,485,499 repeated, <see repz cmps and repnz cmps> cmpsb, <see cmps> cmpsw, <see cmps> COBOL, 166,589 code as data that 8088 interprets as instructions, 65,68-70,73,615,617 desirability of keeping short, <see shorter is better> equivalence with data, 65 seemingly similar sequences can perform guite differently, 289 code maintenance, 9 code segment, <see CS register> Codeview run from a remote terminal, 29 cold boot and system clock, 26,27 Color/Graphics Adapter (CGA), 14,106,262 and display adapter cycle eater, 105 Commodore Amiga, 697 common exit code, <see sharing code> compilers, 6,240-242,362,400,533,542,623 as data transformation programs, 65,533 information available to, 10,542 <I>Complete Turbo Pascal<i>, 735 conditional jumps, <see jumps, conditional> constants, handling efficiently, 297,298 context, 58,85,91,92,116,129,130,174,517,542,554,563 coprocessors, 728,731 CP/M, 266

CS register, 137,142,158,159,169,192,193,396,509-512,514,619,620,625,626,636, 722.725 can't be used for temporary storage, 170 default access to, 142,159 must be loaded, together with IP, in a single instruction, 142,170 CS: segment override prefix, 193 cursor. 58 cwd instruction, 139,312-314,338 CX register, 137,139,267,363,364,371,373-375,377,378,382,452 accessible as CH and CL, 139 used as counting register, 139,316 cycle counting, 14 cycle eaters, 62-64,70,75-77,110,111,504,510,517,530,597,701,717 8-bit bus <see 8-bit bus cycle eater> assembler programming can't be reduced to a science because of, 113 can't be eliminated, 111 cause performance to vary with context and time, 116,119,126,130,517,697 display adapter <see display adapter cycle eater> don't change the effects of code, but do change performance, 129 dynamic RAM (DRAM) refresh, <see dynamic RAM refresh cycle eater> foundation of Zen of assembler, 131 importance, 62,63,65 interaction between. 111.114-116.122 interaction with instruction execution, 117,123,128 live outside execution unit, 75 locations in PCs, 77 must understand to be able to interpret Zen timer results, 110 no compiler can deal with as well as good assembler programmer, 116 no need to understand all interactions between, 115 part of knowledge aspect of Zen of assembly language, 131 prefetch queue, <see prefetch queue cycle eater> underlie programming interface, 131,701 wait state, <see wait state cycle eater> cycles versus bytes, <see bytes versus cycles> daa instruction, 139,147,333,334,341,344 das instruction, 139,147,333,334,341 data, equivalence with code, 65,615,617 data alignment, 696,699,705-711 code, 708-711,717,721 doubleword, 390,711 word. 390.525.705-707.709-711.717.721 data alignment cycle eater, 699,701,705-707,711,717 dealing with, 707,708,710,711,717,721

data bus, <see bus> data segment, <see DS register> Date command, 25,35 db directive, 168 DE register pair of 8080, 267 debugger, 28 using to see actual code generated, 197,208,244,284,693,709 dec instruction, 5,80,81,147,303,304-309,318,342,590,597,662 16-bit register-only form, 305-308,342,662 doesn't affect CF, 309 decimal adjust, 333,334 development environment, 9 device drivers, 59-61 extending DOS's capabilities, 61 poor performance of, 61 DF (direction flag), 144,145,149,291,294,347,348,351-355,359,360,362,363,379, 416-425,427,445 must be in a known state before using string instructions, 362 DH register, 137 DI register, 137,140,149,159,351-356,358-360,380,643 index addressing component, 207 specializes as memory-addressing register for string instructions, 140,192, 193,351,354,359 used as memory-addressing register, 140,200,208,223,246,309,391,396 direct addressing, 207,208,213,218,219,270,272,274-277,280,298,302,343,648 accumulator-specific, <see accumulator-specific direct-addressing> always uses a 16-bit displacement, 208,271 direct indexed addressing, 206 direct memory access, <see DMA> direction flag, <see DF> directives, 168 disk. 60.64.133 disk-backup software, 61 displacements, branch/call/jump, 510,512-515,517,522,531,564,565,601,615,616, 629,643,646,679-680,683,688 forward references, 643-645 displacements, memory addressing, 187,200,202,205,208,213,255,271,643-645 and addressing mode naming, 207 can always reach anywhere in a segment, 224 forward references, 643-645 impact on size and performance, 205,206,209,214,218,264,643 must be numbers or symbols equated to numbers in order to sign extend, 206 negative, 224

sign extension, 205,206,231,643 use 1-byte displacements whenever possible, 214,243,263,601,628 display adapter, 8,29,60,64,133,136,669,713,714 8088 may get as little as 10 percent of display memory accesses, 102,103 allows same access speed regardless of speed of computer, 104,108,713,714 may stretch out access time based on pixel clock, 102,104 must guarantee video circuitry all needed accesses, 102 not very fast compared to system memory, 105 provides memory accesses only at certain intervals, 102,104,713,714 serves two masters, 101 slows up CPU, 101-105 usually 8-bit devices, 713 video circuitry may take up to 90 percent of display memory accesses, 102, 103 "Display Adapter Bottleneck" 110 display adapter cycle eater, 62,76,77,101,110,113,114,122,129,499,597,703,704, 712-714 can more than double the execution time of 8088 code, 107,110 effect on performance, 105-110 effect on performance varies with display mode, 105 effect on performance varies with type of adapter, 105 effects tend to even out over time, 129 impact is proportional to time spent accessing display memory, 107 impact varies with intensity of access to display memory, 108-110 impact varies with time, 114,128 in text mode, 106 interaction with prefetch queue cycle eater, 115 makes exclusive-or animation less-than-ideal, 109,499 matters most in high-resolution EGA and VGA graphics modes, 106 much worse on ATs and 80386 machines, 108 rarely a factor in text mode, 105 what to do about, 108,109 worst with EGA and VGA, 105,106 display memory, 107,152,401,489,491,496-498,594,597,713,714 access as little as possible, 108-110,594,714,717 access speed in the EGA's high-resolution graphics mode, 107 and word-sized string instructions, 390,391,392 avoid read/modify/write accesses to, 109 compared to system memory, 107 don't put code in, 105,115 perform multiple accesses to very rapidly, 109 performance of, 63 set all pixels in a byte at once for speed, 109

display memory wait states, 85,100-104,106,107,109 div instruction, 335-339,720 divide-by-0 interrupt, 339 division, 138,140,312,329-331,335,336,338-340,620,668 effect on EU/BIU coprocessing, 68 rounding with sar, 331 DL register. 137 DMA, 8,24,95 <l>Doctor Dobb's lournal<i> magazine, 344 documentation, 8 don't assume intended instruction uses are always best, 304,315,333 don't jump, 508,530,531,693,705 DOS, 25,59-61,75,133,169,363,637,638,641,642,700,712,717,721 as an assembly-language program, 61 calls part of programming interface, 131 file system, 59 function 4, auxiliary output, 29 function 5, printer output, 29 function 9, print string, 28 functions 2Ah to 2Dh, time and date, 25,35 inadequacy of some services, 61 interrupts, use to obtain blocks, not single characters, 582,637,638,641-643 dot operator, 245 double duty from a single instruction, 656 doubleword alignment, <see data alignment> doublewords, loading, 184,185,189,700 DS register, 137,142,143,158,159,173,192,193,347,351,358,359,396,400 can be used for temporary storage when free, 171 default access to, 142,143,159,208,239,246,247,347,351,359,381,391,395 loading with lds, 176,177 DS: seament override prefix, 193 dual 8/16-bit registers, 137 Duntemann, leff, 135,635,735 duplicating code, 568-572,574,579,588 dw directive, 168 DX register, 137,139,267,312,314,315,337,338 accessible as DH and DL, 139 least specialized general-purpose register, 139 used as I/O-addressing register, 261 dynamic RAM (DRAM), 94 dynamic RAM (DRAM) refresh, 24,25,75,76,83,85,94,95,113,114,251,294,368,531, 703,707,712 act of God, 94,99

can scarcely be addressed at all, 111 can't make less frequent, 99,712 code can't directly control, 94 doesn't necessarily stop 8088, 97 holds up PC via READY line, 117 in PC, 95,96 lowest level, 93,94 dynamic RAM (DRAM) refresh cycle eater, 62,76,77,79,87,110,122,275,316,517, 530.712 affects high-performance assembler code most, 98 affects performance of every program, 93 affects slower instructions least, 99 can cause fractional Zen timer counts, 99 can't structure code to avoid, 99 effect on performance, 95-98,110,123 effect on Zen timer accuracy, 30 effects tend to even out over time, 129 external to 8088.94 impact varies with time, 114,126,128 interaction with 8-bit bus cycle eater, 115 what to do about, 98-99 EA calculations. < see effective address calculations> EAX, 716 EBCDIC, 248 EBX. 716 effective address (EA) calculations, 210-214,219-221,531,645,676,718,720 only <1>mod-reg-rm<i> memory operands require, 212,217 EGA. < see Enhanced Graphics Adapter> ends directive, 168 Enhanced Graphics Adapter (EGA), 62,262,263,492,499,713,714 and display adapter cycle eater, 105,713 and word-sized string instructions, 390-392 enter instruction, 715 ES register, 137,142,143,158,159,173,192,193,351,354,358,359,396,400,401 and loading doublewords, 184 can be used for temporary storage, 171-173 default access to, 143,159,351,354,359,381,391,393,396 loading with les, 176,177,737 ES: segment override prefix, 193 even directive, 707,710 event timeline, 118 execution

as two parallel chains of execution, 122,124 as three interleaved streams of events, 119,122,123,125,126 execution unit (EU), 65-70,72,75,77,78,117,520,522,524,525,527,528,530,699, 701 ability to execute instruction bytes faster than BIU can fetch them, 75,77, 704 can coprocess with BIU, 66-68,85,92,119,122,124,519,520 can process during DRAM refresh unless bus access needed, 97 can process while wait states are inserted unless bus access needed, 101 does not perform direct memory and I/O accesses, 65-67 don't double-count execution time overlapped with instruction fetching, 92, 124 execution times, 85,210,251,279,325,364,619,652,699,718,720 features contained within, 65 fully 16-bit, 67 gets instruction bytes from BIU, 66,67,519-521,523 minimum transfer time for bytes from the prefetch queue to the EU, 130 transfers to from prefetch queue, 118 usually stopped by wait states, 101 extra segment, <see ES register> far calls, 187,517,619-621,623-626,636,670,723,725,726 emulating, 625,725 far data, 397,398,400,413 far jumps, 514,517,619-621,623-626,670 ending subroutines with, 567,568 far pointers, organization in memory, 187 far returns, 568,619-621,623-627,722 filling the screen, <see screen filling> flags, 65, 66, 145, 289-291, 293, 294, 298, 307, 310, 359, 372, 375, 378, 380, 432, 448, 449, 482,488,560,627,636,653,654,657,722,723 double duty, 656 multiple tests, 619,653-655 used by interrupt handler, 318 flags register, 137,144,145,267,289,310,322,636,657,722 flexible mind, 9-12,109,131,471,504,506,508,635,733-735,741,742 developing skill, 10 for statement, 58 Forth, 712 forward references, 244,643-645,646,692,693 front-end entry points, <see multiple entry points> further reading, 52,53 Geary, Michael, 129

84,85,130,702-

general-purpose registers, 136-138,170,270,316,343,349 and <l>mod-reg-rm<i> byte, 204,205 loading segment registers via, 174 use as operands, 138 global variables, 193 graphics support by DOS and BIOS, 61 group directive, 199 hardware, 8,59,60,62,133 documentation, 52 foundation for 8088, 63,65 independence, 59 transparency to programs, 62 Heinlein, Robert, 380 Hercules Graphics Card (HGC), and display adapter cycle eater, 105 hexadecimal, 8,156-158 high level languages, 6,9,10,58,163,164,167,173,179,191,193,240,241,244,258, 400,488,535,542,560,622,623,651,729,730 advantages of mixing with assembler, 241 and segment sharing, 192,199,623 interfacing assembler to, 241,242,623 limitations, 10 low-level control, 8 transformation inefficiencies, 6.10 HL register pair of 8080, 267 horizontal retrace, 106 Hoyt, Michael, 249-251 IBM, 72,154,269,637 AT, 30,53,63,101,108,616,698,702-704,707,708,712-714,717-719 Model 30, 30,53 Models 50 and 60, 53 Model 80, 53,616 PC. 5.8.9.53.58.72.101.113.114.152-155.489.616.694.697.698.704.712-714.717. 719-721,733,734 PC<I>jr<i>, all memory was display memory, 105 PS/2 computers, 30,37 technical reference manuals, 53 XT, 30,53 idiv instruction, 338 IF (interrupt flag), 143-145,148,149,291,294,636,721,723 if directive, 680,692,693 if...then...else. 560 Illowsky, Dan, 332,497,545 immediate addressing, 208,224,226-232,281,284,298,302,343

forward references, 645 no sign extension for mov, 231,232,299 sign extension, 231,282-284,643 sign extension of operands to logical instructions, 284 implementation, <see program implementation> implied addressing, 206 imul instruction. 146.337 in instruction, 138,140,261,262 in-line assembler (in high level language), 241,242 in-line code, 5,155,160,440,471,504,535,572,589,592-596,598,599,601-605,607, 608,613-615,679-680,683,685,688,692,693 branched-to, <see branched-to in-line code> handling blocks of varying size, 679-680,683,688 labels in, <see labels in in-line code> partial, <see partial in-line code> pure, <see pure in-line code> inc instruction, 145,147,182,226,302,304-310,340,342,349,356,366,547, 556.563.699.712 16-bit register-only form, 231,305-307,342 and byte order in memory, 190 doesn't affect CF, 309 incrementing 32-bit values, 652 index addressing, 209.212-214.218.221 index addressing component, 200,202,207 index registers, 137 index+displacement addressing, 207,214 indirect addressing, 208 indirect branching, 208 indivisible doubleword reads, 185,186,700 input/output (I/O) not performed directly by EU, 65,66 performed directly by BIU. 66 input/output (I/O) addressing, 140,261,262 input/output (I/O) instructions, 261,262 input/output (I/O) ports, 62,261 input/output to the real world needed by all useful programs, 61 ins instruction. 715 instruction execution time, 13,279 assumes instruction already prefetched, 68,85 inaccuracy due to prefetch queue cycle eater, 84,85 individual instruction times less useful than overall performance, 129 minimum of 4 cycles times the number of all memory accesses, 90,92,175,471

must be measured for working code sequences, not individual instructions, 91 no exact interval during which one and only one instruction executes, 92, 122-124 no such beast as true, 86,90,91,116,126 only meaningful in context, 91,92,129,130,517 shown in an event timeline, 126 varies depending on preceding code, 85,86,90 working definition of, 92,123,126,523 instruction fetch time, 13,251,517,524 benefits of using short instructions, <see shorter is better> controls execution time when prefetch queue is empty, 68,300,719,720 counts as part of execution time when not overlapped with execution, 68 determines maximum execution speed, 84,369,719,720 don't double-count when overlapped with EU execution time, 92 varies depending on context, 85,524 instruction fetching, 14,53,84,346,519-525,528,529,538,557,589,601,702,703, 708-710,718 can proceed during shifts and rotates by CL, 325,538 effect on performance, 85,88-90,209,210,213,214,251,369,444,471,479,701,719, 720 maximum rate, 84 often subject to wait states in AT. 101 rarely subject to wait states in PC, 101 subject to cycle eaters, 69,70,75,77 instruction mix, effect on performance, 68,85,88-90,542 instruction pointer, <see IP register> instruction prefetch queue, <see prefetch queue> instruction prefetching, 75,262,519-521,523,703 determines execution time of sequence of register-only instructions, 88 most important coprocessing BIU performs, 68 instruction set, 8.59.75.76.134.150.169.263.266.269.270.274.285.295.297.344. 346,535,563,616,617,627,630,635,670,694,717,727,733 view as capable of being used, not as intended to be used, 304,315,333,449, 733,740 instructions, 297,305 desirability of keeping short, <see shorter is better> instruction selection often matters, 289 part of programming interface, 131 int 0, 339 int 1. 149 int 4, 148 int instruction, 141-145,149,636,637,641,657,712

flags affected by, 657 Intel, 13,23,25,34,156,187,190,267,295,363,519,524,721 <I>Microsystem Components Handbook<i>, 52 interleaved memory, 698,702,703 interleaving of memory accesses and instruction execution, 119 interrupt flag, <see IF> interrupt handlers, 193,318,363,626,637 interrupt vectors, 187,636,637 interrupts, 148,319,401,508,517,581,622,636,641,653,657,712,721-723 can use the stack at any time, 237,238 disabling, 143,144,149,319,401 divide-by-0, 339 don't change the effects of code, but do change performance, 129 flush the prefetch queue and change execution patterns, 129 loading vectors is only memory access that doesn't involve a segment, 159 should be disabled for as short a time as possible, 149,401 into instruction, 148 INTR pin, 148 IP register (instruction pointer), 66,67,137,142,144,226,227,509-511,513-515, 517,519,531,582,619,620,625,626,635,636,722 complications arising from prefetching handled internally by 8088, 144 iret instruction, 141-145,362,401,627,636,641,712,722-724,726 all flags are affected by, 657 IRO0, 24-26 ja instruction, 146 jae instruction, 146 jb instruction, 146 ibe instruction. 146 jc instruction, 146 jcxz instruction, 139,374,432,448,449,462,543,544,608,657,668,669 doesn't affect any flags, 657 je instruction, 147 iq instruction, 147,148 jge instruction, 148 il instruction, 148 jle instruction, 148 jmp instruction, 142,144,509-511,513,514,517-519,524-529,531,568-570, 572,582,598,615,627,630-633,643,645,680 short. 509,512,522,525,569,570,572,628,630,643-645,648,679,726 ina imp instruction. 146 inae instruction, 146 inbinstruction, 146

inbe instruction, 146 inc instruction, 146,552 jne instruction, 147 jng instruction, 147,483 inge instruction, 148 inl instruction, 148 inle instruction, 148 ino instruction, 148 inp instruction, 147 ins instruction, 148,563 inz instruction, 5,147,309,318,567,590,597,662,680 jo instruction, 148 ip instruction, 147 jpe instruction, 147 $\langle B \rangle$ instruction, 147 js instruction, 148 jump tables, 193,194,257,450,452,607,619,620,623,625,630,670-676,678,679, 683-686.688 letting assembler do the work of creating, 685 partial jump tables, <see partial jump tables> pure jump tables, <see pure jump tables> jumps. 508-514.563.565.581.615.616.627-629.632.635.644.646.670 around jumps, 457, 563, 567, 611, 672, 679, 683, 688 backward references, 643,646 conditional, 510,512,539-541,545,560,562-565,567,569,577,586,601,610,611, 646,652,672,679-680,683,688,692 direct, 619,630 far, <see far jumps> forward references, 643-646 indirect, 619,623,626,670,671 near. < see near iumps> short, <see jmp short> replacing calls, 628 to other subroutines in place of ret, 567,568,630,633 unconditional, 563, 565, 567-569, 572, 611, 679, 688, 693 jz instruction, 147,540,565,567,660,680 keyboard, 8,35,59,60,64,129,401,675,676,712 interrupt, 136,149 macro software, 61 knowledge, 8,9,11,58,59,131,471,504,508,733,734,741,742 labels in in-line code, 613,614,684 lahf instruction, 139,145,267,289-291,294,309,312,727

latches, EGA/VGA, 391,392 layered system software, 59,60,63,64 lds instruction, 143,176,177,182 lea instruction, 198,214,221-223 leave instruction, 715 les instruction, 143,170,176-179,182,184,737 and byte order in memory, 189 and loading doublewords, 184-186, 189, 700, 736 and performance, 179 libraries, subroutine and macro, 589 link, 32 listing file, using to see actual code generated, 197,244,284,588,693 local directive, 244,614 bug when used in rept blocks, 614 local variables, 239,240,242-244 lods instruction, 82,139,140,182,288,347-351,357,359,361,377,381,391, 404-407,412,413,420,421,435,436,439,440,442-444,458,464,466,534,610, 613 doesn't affect any flags, 375 repeated, <see rep lods> synergy with other instructions, 404-407,412,413,464,613 lodsb, <see lods> lodsw. <see lods> look-up tables, 14,153,154,160,249-252,254,256-258,260,297,303,332,333,404, 450,452,456,457,468,471,538,539,607,615,626,673,676-678,686,693 loop instruction, 139,179,192,309,310,318,366,368,375,378,483,533,534, 537, 538, 572, 574, 589-592, 594, 597, 598, 601, 604, 608, 657, 658, 660-662, 688, 709 doesn't affect any flags, 310,657 loope instruction, 658 loopne instruction, 658 loopnz instruction, 139.657.658.660 doesn't affect any flags, 657 loops, 508,534,535,537,538,542,565,567,569,572,574,577,579,581,582,586-599, 602-606,608,611,613,632,637,653,656-658,660-662,668,669,685,693,709, 711 loopz instruction, 139,657,658 doesn't affect any flags, 657 lss instruction, doesn't exist, 190 LZTEST.ASM long-period Zen timer test bed program, 49 LZTEST.EXE long-period Zen timer executable program, 50 LZTIME.BAT long-period Zen timer batch file, 50,51,164,639 LZTIMER.ASM long-period Zen timer source code, 37,50

machine language, 6,8,10,645 ultimate form of all source code, 63-65,73 macros, 582,584,586,588,589,615,620,630,646,679-680,683,684,685,688,692,693, 725.727 text substitution, 683,684,685 <I>MAD<i> magazine, 168 many ways to approach any task in assembler, 231,254,257,292,404,448,458,470, 545,554 maskable interrupts, <see interrupts> MASM (Microsoft Macro Assembler), 32,50,52,168,170,190,192,196,197,198,242, 253,284,372,373,393-396,614,645,646,693,730 memory, 8,9,60,64,133,152,219 8-bit as a cycle eater in AT, 62,713 accessed directly by BIU, 66 avoid accessing whenever possible for performance, 92,153,182,210,218,263, 316,440,471,699,705,720 constant access by programs, 62 effect on performance, 62,279 initializing, 258,259,301 initializing when defined (at assembly time), desirability of, 260 is slow, 210,346,697 not accessed directly by EU. 65 part of the PC's hardware, 61 should not be destination operand whenever that can be avoided, 319-321 tradeoff for performance, 160 use to improve performance, 9,154,160 versus processing horsepower, 9 memory accessing instructions, effect on instruction prefetching, 68,90 are slow, 152,158,211,246,704 never faster than register-only instructions, 217 often slower than 4 cycles per memory access, 90 suffer less from the prefetch queue than register-only instructions, 217 memory addresses, calculate outside loops, 214,220-222 memory addressing, 6,59,149,150,154,157,198,263 can only address memory pointed to by at least one segment register, 160,161 difficulty of dealing with blocks larger than 64 Kb, 161,162,167 difficulty of handling blocks that cross a segment boundary, 162,167 part of programming interface, 131 use of square brackets to denote, 154,246 memory addressing modes, 152,153,159,198-200,202,211,212,232,715-717,729 16 completely distinct memory-addressing modes, 205,206,271,349 24 distinct ways to generate a memory offset, 204

immediate addressing, <see immediate addressing> <l>mod-reg-rm<i> addressing, <see <l>mod-reg-rm<i> addressing> naming <I>mod-reg-rm<i> addressing modes, 206,207,209 specifying <I>mod-reg-rm<i> addressing modes, 245 stack addressing, <see stack addressing> memory architecture in 80286- and 80386-based computers, 698,702-704,721 memory resident programs, 254,637 MEMR line, 117,121,123,124 MEMW line, 117,121,123,124 microcode, 211 Microsoft Linker, 29,32,50 Miller, Dave, 129 mini-interpreters, 260,653,734 <l>mod-reg-rm<i> addressing, 199,200,203,205,208,213,218,221,223-226,231-233, 239,245,246,255,272,274-279,281-286,288,306,307,342,343,344,648,676, 740 allow only word-sized registers to be used to address memory, 248 and code size, 209,210,217,218,234,237 and performance, 209-214,216-218,235,237 avoid whenever possible for performance, 210,263 can be forced to access any segment, 208 can select a memory offset or register as an operand in any of 16 ways, 205, 271,349 can specify 256 possible source/destination combinations, 203,204 defaults to accessing DS except when BP is used, 208,239 direct addressing as anomaly, 207 doesn't work with all instructions, 209 has two performance components, 211 naming modes, 206,207,209 no addressing mode that uses only BP, 207,208,245 no inherent support for constant operands, 205 slow, but less slow than you might think relative to registers, 216 some instructions can only use <1>mod-reg-rm<i> addressing, 210 specifying, 245,246 suffer less from the prefetch queue than register-only instructions, 217 use displacement-free modes whenever you can, 214 used by many register-only instructions, 210 varies in performance due to EA calculation time, 211-213 very flexible, 203,205,209,224 workhorse memory addressing mode of the 8088, 210,224 <l>mod-reg-rm<i> bytes, 199,201-204,207,208,213,224,226,227,245,270,271,343, 393,511,643 time required to calculate addresses from (EA calculation time), 209,210,

219,220 with one-operand instructions, 200,204 Mode command, 29 Monochrome Display Adapter (MDA), and display adapter cycle eater, 105 "More optimizing for Speed," 251 mouse, 35, 49, 129, 401, 712 mov instruction, 34,143,145,170,182,221,226,232,272-277,282,285,298, 299,300,311,315,342-344,347,349-351,366,367,413,468,631,644,648,670 accumulator-specific direct-addressing form, <see accumulator-specific> and byte order in memory, 187,188,190 and segment copying, 174 byte versus word, 79,81,84 doesn't affect any flags, 311 doesn't sign extend immediate operands, 231 no non-<l>mod-reg-rm<i> memory immediate form, 344 non-<l>mod-reg-rm<i> register immediate form, 231,232,343,344 movs instruction, 140,173,351,353,359,377,380,381,391,393,405,413,414, 420.428.497.499.581 doesn't affect any flags, 375 repeated, <see rep movs> movsb, <see movs> movsd, 716 movsw, <see movs> MS DOS, <see DOS> mul instruction, 146,205,336,337,598,607,679,720 doesn't suffer from DRAM refresh, 97 effect on prefetch queue, 87,89,90 multi-bit shifts and rotates, 324,325,538,715 multi-byte values, storage organization in memory, 186-190,379 multi-word shifts and rotates, 328 multi-word values, addition and subtraction of, 309.310 multiple entry points, 650 front-end entry points, 650,651 multiple tests from a single instruction, 619,653-655 multiplication, 138,140,146,329,335,336,607,673 effect on EU/BIU coprocessing, 68 Navas, John, 244 near calls, 192,517,619,620,623-626,670,723,725 near jumps, 514,517,619,620,623-625,670 ending subroutines with, 567,568 near keyword in C. 623 near returns, 568,619,620,623-625 NEC, 267

neg instruction, 147,321-324,546-549,716 negating 32-bit values, 322,323,544-552,554,555,652,716 negation, 322,323,544-552,554,555 NMI pin, 149 <l>non-mod-reg-rm addressing, 199,208,214,218,224,225,231,343 generally faster than <1>mod-reg-rm<i> addressing, 210,224,225 generally less flexible than <1> mod-reg-rm<i> addressing, 210,224 requires no EA calculation time, 224 nonmaskable interrupts, 136,149 nop instruction, 569,644,707.710 not instruction, 321-323,546,547,552 doesn't affect any flags, 322 not-branching, 533,535,537,617,619,651,658,662 OF (overflow flag), 144-148,291,294,329-331,354 official execution times, 252,257,514,524,530,539 can't simply add up times for individual instructions, 91 inaccuracy of, 84-86,91,106,111,324,325 offset operator, 198,199 and segment groups, 199 offsets, 155-159, 198, 510, 511, 513, 514, 564, 607, 631, 671, 679, 686, 723 24 distinct ways to generate, 204 calculating, 159, 198, 199, 200, 208-210, 245-248, 607 just 16-bit numbers, 222,223 loading, 198,221,736 loading for a variable in a segment group, 199 offsets greater than 16 bits wrap around to 0, 162,223-225,382,383,385,420 use in addressing memory, 198 very flexible portion of memory addressing, 198,203 OmniLab electronic test instrument, 117 "On Graphics," 244 operating system, 8.60 OPTASM, 645 optimization, 4,59,81,292,542,550,554,579,581,693,694,696-700,708,711,717,718, 721,729,733,736,741,742 8088 is best place to focus efforts, 696-699,715-717,731 8088 optimizations serve well on other processors, 698,699,717,720,721 concentrate on loops and time-critical code, 153,166,182,186,214,218,219, 227,240,241,264,538,554,572,574,579,581,582,588,589,617,619,632,637, 653,656,660,694,711 detailed 80286/80386 optimization, 718-721 don't become fixated on a particular trick, 288,315 don't use nifty tricks for their own sake, 279 for space (size), 653,662,693,736

optimize for the common case, 449,539-545,551,552,559,560 understand conditions under which it will run, 541,542,554,688 worst-case, 541,542 "Optimizing for Speed," 249 or instruction, 146,148,229,281-284,301,302,320,343,412 OS/2, 696,697,700 out instruction. 138.140.261.262 desirability of byte-sized, 263 hazards of word-sized, 262,263 outs instruction, 715 overflow, 148 overflow flag, <see OF> packed BCD, 334 paired-byte initialization, 300,301 paired jumps, <see jumps around jumps> parameter passing, 233,239-241,244,576,650,651,675,740,741 macro parameters, 684 parity, 147 parity errors, 136 parity flag, <see PF> partial in-line code, 537,602-606,608,610,611,613,688,693 partial jump tables, 673,674,678 Pascal, 6,242,589,623,624,635,715 Paterson, Tim, 344 PC data bus, <see bus> <I>PC Tech Journal<i> magazine, 110,721 peripherals, 728,731 performance, 9,542,588,592,593,601-604,611,617,623,632,633,645,662,668,693, 697,698,700,710,717,733,736 can only be improved by reducing code's limiting factor, 91 can only know by measuring, 91-93,109,113,116,128,131,164,275,293,294,316, 351,517,555 can vary by up to 8.33 percent from DRAM refresh, 99 controlled by instruction fetch time, EU execution time, or both, 90 how to measure, 14 importance of measuring, 13,14 may vary for same code sequence over time because of cycle eaters, 113,114, 119,122,127,697 must be measured for working code sequences, not individual instructions, 91 pointlessness of trying to understand exactly, 113,114,116,117,121,126,128, 130,294,530 traditional assembler programming model, 60

true nature of, 131 true performance, 8,13,14 perspective, 5,315 PF (parity flag>, 144,147,329,330,354 plus operator, 246 pop instruction, 141,143,170,211,234-240,289,306,317,343,712,740 and segment copying, 173, 174 non-<l>mod-rea-rm<i> register form, 234,237 psw on 8088, 290 popa instruction, 715 popf instruction, 145,291,294,309,312,362,721-723,725-727 80286 bug and workaround for, 721-727 portability, 60 precalculation, desirability of, 249,253,258,260,539,610 prefetch queue, 14,66,68,71,106,300,326,368,518-525,527,528,530,531,538,539, 542,556,582,589,590,601,616,619,620,636,637,652,701,702,709,718,720 allowed to fill by mul, 89,90 and performance of <I>mod-reg-rm<i> instructions, 216 can add as much as 4 cycles per byte to instruction execution time, 91 drained by register-only instruction, 88,90 drained by short instructions, 93 effect on Zen timer accuracy, 30,53,86 emptied by branches, 66.67 located in BIU, 67 size, 67,69,616,701 state varies with code mix, 85 transfers from to EU, 118 prefetch gueue cycle eater, 62,69,72,76,77,79,83,93,110,113,122,126,205,217, 227,250-252,258,275,281,305,313,316,325,326,455,499,517,523,525, 527-531,538,552,601,699,701-705,717 as manifestation of 8-bit bus cycle eater, 83 effect on performance, 84,85,110,123,214 effect on register-only code, 88 interaction with display adapter cycle eater, 115 looms over the performance of all 8088 code, 93 minimum transfer time for bytes from the prefetch queue to the EU, 130 observed, 130 undocumented and unpredictable, 84 variation during different executions of same code sequence, 85,93 what to do about, 92,93 prefetching, <see instruction prefetching> prefix bytes, 363,401 avoid multiple, 149,401

preloading values, 555-557,559,560,569,572 printer, 250 printer ports, 8 program commenting, 9 conception, 5 desian. 6.9.59 execution, true nature, 65 implementation, 5,6,131,504,508,733 specification and Zen of assembly language, 9 <I>Programmer's Journal<i> magazine, 244,249,251 "Programming Insight: High-Performance Software Analysis on the IBM PC," 52 programming interface, 59-65,68-70,73 beneath, 75,110,701 component parts, 133 part of knowledge aspect of Zen of assembly language, 131 rests on cycle eaters, 131 protected mode, 142,169,170,184,700,701,711,715-717 PS2 equate for assembling PS/2 version of long-period timer, 36,37 public option to the segment directive, 192 pure in-line code, 598,599,602,603,679,693 pure jump tables, 674,678 push instruction, 141.143.211.234-237.239.240.289.306.317.343.582.626. 711,715 and segment copying, 173,174 non-<l>mod-reg-rm<i> register form, 234,237 psw on 8088, 290 pusha instruction, 715 pushf instruction, 145,291,294,309,312,627,727 PZTEST.ASM precision Zen timer test bed program, 31,32,34 PZTEST.EXE precision Zen timer executable program, 32 PZTIME.BAT precision Zen timer batch file, 32.34 PZTIMER.ASM precision Zen timer source code, 15,32,34 OS0 line, 117,118 QS1 line, 117,118 RAM disk, 154 rcl instruction, 139,328 rcr instruction, 328,560 **READY** line, 117 real mode, 169,170,700,711,715,716,721 ReferenceZTimerOff. 29 ReferenceZTimerOn, 29 register hidden agenda, 135,136

register set, 135-137,149,267-269 register-only instructions, 217,258,263,468,534 effect on instruction prefetching, 68,217,346 many use <I>mod-reg-rm<i> addressing, 210,217 registers, 59,65,66,75,319,412,466,557,559,631,632,716,717 desirability of using as much as possible, 83,93,110,135,153,210,217,218, 227,229,230,232,234,235,237,245,246,263,305,316,321,698,699,705,717, 720 initializing multiple registers to same value, 299,300 initializing two bytes with a single mov, 300,301 irregularity of, 135 part of programming interface, 131 register selection often matters, 289 should be destination operand whenever possible, 319-321 use to store frequently used constants, 298,356,563,594,616,653 use to store variables, 83,305,616,656 rep cmps, 372 rep movs, 79,173,363,373,405,413,416-420,497,596,597,707,713,714 rep prefix, 139,351,361,363-365,372,373,375,378,380,401,404,405,497, 499,537,598,601,613 don't use with segment override prefixes, 401 rep lods, 373 rep scas, 372 rep stos, 58,298,365-368,370,373,376,736 repe prefix, 371 repeated string instructions, 109,139,319,346,354,356,363-365,368,375,377, 381,386,390,405,412,413,471,538,688,717,736 always alter CX, 373,374 don't use with segment override prefixes, 401 execution time, 364 handling 0-byte and 64 K-byte blocks, 377,380,382,384,385,389,432 handling blocks larger than 64 K. 505.506 much less flexible than normal instructions, 368 no branching, 366-368,538,717 no instruction fetching, 364,366-368,370,538,717 operation when CX equals zero, 377,378,380,382,384,432,448,449,462 try to use whenever possible, 368,677 use ZF, not CX, to evaluate comparison results, 371,374,375 word-sized operations, advantages of, 376,384,389,420,449,450,581 word-sized operations, hazards of, 390-392,420,421 repne prefix. 371 repnz cmps, 371-375,378,448,449,482,485 repnz prefix, 368,371,372,433,482

repnz scas, 323,354,356,357,371-375,378,380,430,432-435,439,442-445, 448-450,452,454,456,457,464,471,474,479,482,658,675,677 rept assembler directive, 52,260,592,598,611,614,685 repz cmps, 371-375,378,380,448,449,458,464,471,472,474,479,482,485 repz prefix, 368,371,372,433,482,658 repz scas, 354,356,371-375,378,432-434,442-445,448-450,454,482 ret instruction, 141-144,517,567-569,572,582,584,620,627,630,631,633, 648,670,712 return addresses, organization in memory, 187 returns, subroutine, 508,581,582,584,586,588,589,627,628,631-633,635 far, <see far returns> near, <see near returns> to anywhere, 631,632 rol instruction, 327 ROMable code, 653 ror instruction, 139,327 rotate instruction affect fewer flags than you might think, 329 rotates, multi-bit, <see multi-bit shifts and rotates> sahf instruction, 139,145,267,289,290,291,294,309,312,362,727 shl instruction, 329,563,564,655,699 sar instruction, 257,330-333 sbb instruction. 147.281-283.309.320.323.341.343.548.550-552 scas instruction, 139,140,171,354-356,359,368,371,372,377,381,391,393, 404,430,432,433,440,450,454,457,458,462,464,466,482,581,610,613 repeated, <see repz scas and repnz scas> scasb, <see scas> scasw, <see scas> screen filling, 735-741 seq operator, 190,191,198,358 segment directive, 168,192 segment:offset addressing, 156-159,162,167,198,200,202,514 4096 pairs point to each address, 159 don't count on wrapping back to 0, 160 not particularly fast, 158 offset portion very flexible, 198 sums greater than 20 bits normally wrap around to 0, 160,162 segment: offset pointers loading, 176,198,736 organization in memory, 187,722,723 passing in stack frames, 176 usually loaded with les. 176.737 segment override prefixes, 142,143,171,179,192-196,211,246,347,351,359,361, 363,381,391,394-398,401

and the assume directive, 196,197 don't use with rep, 401 segment registers, 66,67,141,142,155,158,168,343,380,383,397,506,716 and protected mode, 142,169,170,700 avoid loading whenever possible, 177,182 avoiding loading by sharing segments across modules, 192,623,624 bug in disabling of interrupts while loading, 144 can be loaded directly from any addressable memory location, 175,176,736,742 can each only point to a 64-Kb chunk, 160-162,167,380,381 common, 192 copying, 173,174 copying and storing, 142,169 directives. 168 disabling of interrupts while loading, 143,149 grouping, 192,199 loading with a segment that can vary during program execution, 175 manipulating, 169,170 must be loaded when a high level language passes a far pointer, 177 organize so that override prefixes aren't needed inside loops, 194-196,397 setting, 173-175,198,358 speed of manipulation, 169,170 use for temporary storage, 142,170-173,700 segment selectors, 169,170,700 segmented memory architecture, 6,133,155,167,269,505 segments, 155-159,167,168,198,380-383,396,400,401,420,700,723 default memory-addressing segments, 142,143,159,192,208,239,391,393,397,401 joining or separating via the $\langle B \rangle$ segment $\langle b \rangle$ directive, 191,192 sharing among multiple modules, 191,192,623,624 sharing between high level language and assembler, 199 shifted when used to address memory, 156-158 working with multiple segments, 193,194 working with multiple segments in multi-module programs, 191,623,624 self-modifying code, 65,615-617 self-reliance, 7 serial communications support by DOS and BIOS, 61 serial ports/adapters, 8,28,29,129,401,672,712,728 SF (sign flag>, 144,148,291,292,329,330,354,561,655,657 sharing code, 646-650 Sheppard, Byron, 52 shifting and rotating memory, 326 shifts and rotates by 1 bit, relative undesirability of, 324-327 shifts and rotates by CL bits, 324-327,538 relative desirability of, 324-327

shifts and rotates by CL bits don't affect CL, 326,373 shifts, multi-bit, <see multi-bit shifts and rotates> shl instruction, 139,329 short jumps, <see jmp short> shorter is better (smaller/faster), 83,92,93,110,281,299,305,333,589,698,699, 705,717,720 shr instruction, 68,116,325,329-331,538 effect on prefetch queue, 86-89 suffers from DRAM refresh, 97,98 SI register, 137,140,149,159,347,349,350,353,358-361,380,643 index addressing component, 207 specializes as memory-addressing register for string instructions, 140,193, 316,350,351,359 used as memory-addressing register, 140,200,208,223,246,309,347,391 sign flag, <see SF> size versus speed, <see bytes versus cycle> smaller is better, <see shorter is better> smaller is slower. 589 source code control, 9 SP register (stack pointer), 135,137,144,159,170,232,233,237-239,291,306,630, 711,740 always addresses the stack segment. 141 is a general-purpose register when not being used to maintain a stack, 136, 141 never push directly, 141 not usually available as a general-purpose register, 136,141,172 points to top of stack, 136,141,232,233,237 should always be even, 306,711,712 used as memory-addressing register, 232,233,239 speaker, 24,25,60,64,650 special forms of common instructions. 224.226.230.232 assembler automatically selects whenever possible, 226,232,274,287,306,342 look the same as more general forms, 273 two legitimate machine language forms of, 274,306,342,344 special compressed forms of instructions, 643 assembler automatically uses only when it knows enough to do so, 643 forward references to, 643-645 speed of development, 9 speed versus size, <see bytes versus cycles> SS register. 137.142-144.158.159.190.192.193.396 default access to, 143,159,208,239 don't use for temporary storage, 170

together with SP must point to a valid stack, 143,190 SS: segment override prefix, 193 stack, 136,232-234,237-240,291,294,517,568,582,626,627,630,632,633,635,650, 651,657,711,721,722,725,740,741 allocating space on in a subroutine, 635 clearing by reloading SP, 630 don't access popped stack data, 237,238 not inactive even when not accessed directly because of interrupts, 136,143 stack addressing, 224,232,237,244 stack addressing registers, 137 stack frames, 141,175,179,193,208,233,239-245,286,544,715,740 all <I>mod-reg-rm<i> addressing modes can often be used to point to, 244 negative displacements, 242,243 try to use 1-byte displacements, 243,244 stack-oriented instructions, 224 stack pointer, <see SP register> stack segment, <see SS register> standard input, 638,639 redirected, 639,640 standard output, 638,639 static-column RAM, 698,702,703 static RAM (SRAM), 94,712 static variables, 193 statuses, carrying along, <see carrying results along in a flag> statuses, saving, 291 status flags, 144-147 stc instruction, 146 std instruction, 149,362,363,420 sti instruction, 149 stos instruction, 139,140,288,351,352,359,365,377,381,391,393,404-407, 412,413,613 doesn't affect any flags, 375 repeated, <see rep stos> stosb, <see stos> stosw, <see stos> string instructions, 79,109,139,140,143,149,158,159,182,192,209,211,218,219, 221,224-226,264,288,297,319,344,346,347,351,357-359,362-364,367, 381-383,393,395-397,400,401,404,407,413,416,417,424,466,479,482,488, 497,504,506,534,538,601,613,698,720 advance their pointer registers, 350,359,377,391,407,444 byte- and word-sized operations, hazards of mixing, 420,422-425,427 data size, 361,375,377,393,394

definition of advancing pointer registers, 359,361,362 operands to, 393-396 pointing back to last element processed, 377-379,444 repeated, <see repeated string instructions> strings, comparing, 359,404,457,462,464,610,611,613 strings, copying, 351,405,576,582,610,611,613 strings, searching, 354,404,433-436,439,442-445,454,457,464,471-473,479,482, 565,610,611,613,679,685 case-insensitive, 457,466,658,661,662,693 double-search approach, 433-435,445,462,688 substrings, <see substrings, searching for> word-sized operations, advantages of, 440,449,450,610,611 struc directive. 179.242 negative displacements, 242,243 structure elements, forward references to, 644,645 sub instruction, 147,281-283,298,300,305,306,309,311,313,314,319-321, 323,341,343,448,449 subroutines, 508 returning status from, 147,487,488 substrings, searching for, 457,471-473,479 Symdeb run from a remote terminal, 29 screen flipping, 28 system clock, 25 system memory performance relative to display memory, 63,703 system memory wait state cycle eater, 702-704,720 system software, 59,60,63,64 TASM (Turbo Assembler), 32,168,244,372,614,645 test instruction, 285,321,343 TESTCODE Zen timer file containing code to be timed, 29-31,50 TF (trap flag), 144,145,149 think functionally, 533,535 Time command, 25,35 time of day count, 25,36,37,185 timer channel 0 of the 8253, 24-28, 36, 37 interrupts, 25,26 timer channel 1 of the 8253, 24,25 DRAM refresh, 25,95 timer channel 2 of the 8253, 24-26 interrupts, 25,26 system clock. 25.26 timer interrupt, 26,35,129,136,149,186 BIOS code to handle, 35,51

timer, <see 8253 timer chip> TIMER INT BIOS routine, 25 timing diagrams, 118 tlink, 32 traditional assembler programming model, 59,60 compatibility benefits, 59,60 inadequacy of hardware representation, 61 knowing well, 59,61 knowing when to break the rules, 61 performance shortcomings, 60,61 portability benefits, 59,60 replacing with own code, 61 trap flag, <see TF> "Tricks of the Trade," 344 Turbo C, 241,623 Turbo Pascal, 735 two's complement arithmetic, 322,323,546 unconditional jumps, <see jumps, unconditional> Unix, 697,700 unpacked BCD, 334,335,339,340 converting 351,405upper case, to, 407,466,468,470,471,576,577,579,614,637, 638,661,693 user interaction, 9 V20, 267 vertical retrace, 106 VGA, <see Video Graphics Array> Video Graphics Array (VGA), and display adapter cycle eater, 105,262,728 and word-sized string instructions, 390-392 video registers, indexed, setting, 262,263 VisiCalc, 269 wait instruction, 730,731 wait state cycle eater, 83,702-704 wait states, 14,62,75-77,100,106,698,703-705,713,718 affect everything, even other cycle eaters, 100 allow slower devices to complete bus accesses, 100 are of no particular duration, 100 as they relate to display memory, 100,101 can occur only during a memory or I/O read or write, 100 code can't directly control, 94 compared to DRAM refresh, 100 controlled by device being accessed, 100 do not occur on a regularly scheduled basis, 100

don't stop the 8088 completely, 101 external to 8088, 94 lowest level, 94,100 only display adapter wait states seriously affect PC performance, 101 system memory, <see system memory wait state cycle eater> transparent to code, 100 usually do stop the 8088, 101 warm boot and system clock, 26,27 white space, 488 word alignment, <see data alignment> word-to-doubleword conversion, 312-314 word-sized memory access advantage over two byte-sized accesses by two instructions, 81,83 penalty for using, 79,80,84 split into two byte-sized accesses, 67,78,79 WordStar, 269 xchg instruction, 139,172,226,267,285,287,288,316-319,342 AX-specific form of, 285-288,306,318,342 used to get and set a memory variable, 318 xlat instruction, 139,158,193,209,211,224,246-249,256,257,264,312,333, 468,471 xor instruction. 146.148.281-284.298.311.320-322.343.489-492.496-499. 504,505,533-537,594 Z80, 266, 267, 509 Zen (coined verb form; also Zenned, Zenning), 735,741 Zen of assembly language, 3-11,13,14,53,73,113,114,117,164,167,182,237,289, 315,332,396,489,504,508,509,533-535,537,545,559,589,615,617,635,651, 701,722,727,728,733-735,742 inguisitive, skeptical mind, 81 learning, 10 mastering, 10 Zen timer. 14.15.22.23.26.30.53.87.93.113.115.164.251.275-279.281.291.293. 294,456,492,514,517,518,557,622,694,696,703,708,719,721,733 accuracy, 29,30,34,53,86 accurate only for the particular code sequence you've timed, 116,129 avoiding interrupts while long-period Zen timer runs, 49 alternative output methods, 28,29 assembling the long-period timer for PS/2 computers, 36,37 calling interface, 15,23,27-29,34,48 choosing the long-period timing mode, 36,37 compatibility with PC-compatible computers, 30 DS set equal to CS to allow data in TESTCODE, 30-32 effect of DRAM refresh on accuracy, 30,34

effect of preceding code on accuracy, 86 effect of prefetch queue on accuracy, 30,34,53,86 effect on calling code, 29 erratic operation when undocumented timer stop is used, 37 excluding execution time of start-up code, 32 far calls to, 29 fractional counts can result from DRAM refresh, 99,128,712 fractional counts can result from display adapter cycle eater, 99,128 ideally used to measure the performance of an entire subroutine, 86 imperfections, 53 inability to measure across midnight, 35 inaccuracy introduced into system clock, 23,26,27,35,36 interrupts, 23, 25, 26, 28, 35 least variable over longer periods, 129 long-period inaccuracy in PS/2 computers, 36 long-period timer 26,34-37,48-51,164,186,492 maximum timing intervals, 34,35 minimum timing interval, 86 overflow detection, 26-28 overhead adjustment, 27,28 precision timer, 35,37,48,50,51,492 rebooting at the end of timing sessions, 26.27.35-37 rebooting immediately in case of erratic results, 37 repeating tests multiple times, 37 rounding results, 34 sample use of long-period timer, 48,49 sample use of precision timer, 30 sequence of calls to subroutines, 28 short code sequences may vary greatly from one measurement to next, 129 use with assembly language, 29 use with high level languages, 29 using, 30-32,34,48-52 variation of results on computers other than PCs, 30 variations can result from DRAM refresh, 99 zero, handling efficiently, 229,230,277-279,297-299,301,302,303,311,657,738 zero flag, <see ZF> ZF (zero flag), 144-148,277,301,307,329,330,354,371,372,375,432,433,448,449, 482,488,586,658 Zilog, 266 ZTimerOff, 15,23,26-28,30-32,34 ZTimerOn, 15,23,26-28,30-32,34,49 interrupts are turned off and must remain off for precision timer, 23

INDEX/ABRASH/

ZTimerReport, 15,28-31,34