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學習

Intel x86 Assembly Language & Microarchitecture

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1: x86

x86。

x86。 x86Documentation。

Examples

x86

x86Intel 8086。 208016。

x86。 C。 “”。 。

NASMNetwide Assemblerhttp://nasm.us/。 NASM。

3264NASMWindows。 NASMWindows。

Linux

NASMLinux。

```
nasm -v
```

。 NASMNASM。 DebianUbuntu

```
sudo apt-get install nasm
```

RPM

```
sudo yum install nasm
```

Mac OS X.

OS XYosemiteEl CapitanNASM。 El Capitan0.98.40。 。 NASM2.112.12。

NASMOS X。

NASM。 / usr / local

```
$ sudo su
<user's password entered to become root>
# cd /usr/local/bin
# cp <path/to/unzipped/nasm/files/nasm> ./
# exit
```

NASM`/usr/local/bin` 。

```
$ echo 'export PATH=/usr/local/bin:$PATH' >> ~/.bash_profile
```

/usr/local/bin。 nasm -v。

x86 Linux Hello World

32x86 LinuxNASMHello Worldlibc。 。 ; 。

UnixasmCC ++。 POSIXAPIABI。

---

write(2)_exit(2) exit(3) libcstdio。 _exit()sys_exit_groupsys_exit 。 syscalls(2)libclibc。

argseax int 0x80。 AssemblyCasm。

32ABI/usr/include/i386-linux-gnu/asm/unistd_32.h /usr/include/x86_64-linux-gnu/asm/unistd_32.h 。

#include <sys/syscall.h>echo '#include <sys/syscall.h>' | gcc -E - -dM | lessdefs Casm

---

```
section .text             ; Executable code goes in the .text section
global _start             ; The linker looks for this symbol to set the process entry point,
so execution start here
;;;a name followed by a colon defines a symbol.  The global _start directive modifies it so
it's a global symbol, not just one that we can CALL or JMP to from inside the asm.
;;; note that _start isn't really a "function".  You can't return from it, and the kernel
passes argc, argv, and env differently than main() would expect.
 _start:
    ;;; write(1, msg, len);
    ; Start by moving the arguments into registers, where the kernel will look for them
    mov     edx,len       ; 3rd arg goes in edx: buffer length
    mov     ecx,msg       ; 2nd arg goes in ecx: pointer to the buffer
    ;Set output to stdout (goes to your terminal, or wherever you redirect or pipe)
    mov     ebx,1         ; 1st arg goes in ebx: Unix file descriptor. 1 = stdout, which is
normally connected to the terminal.

    mov     eax,4         ; system call number (from SYS_write / __NR_write from unistd_32.h).
    int     0x80          ; generate an interrupt, activating the kernel's system-call
handling code.  64-bit code uses a different instruction, different registers, and different
call numbers.
    ;; eax = return value, all other registers unchanged.

    ;;;Second, exit the process.  There's nothing to return to, so we can't use a ret
instruction (like we could if this was main() or any function with a caller)
    ;;; If we don't exit, execution continues into whatever bytes are next in the memory page,
    ;;; typically leading to a segmentation fault because the padding 00 00 decodes to  add
[eax],al.

    ;;; _exit(0);
    xor     ebx,ebx       ; first arg = exit status = 0.  (will be truncated to 8 bits).
Zeroing registers is a special case on x86, and mov ebx,0 would be less efficient.
                      ;; leaving out the zeroing of ebx would mean we exit(1), i.e. with an
error status, since ebx still holds 1 from earlier.
    mov     eax,1         ; put __NR_exit into eax
    int     0x80          ;Execute the Linux function
```

```
section     .rodata       ; Section for read-only constants

            ;; msg is a label, and in this context doesn't need to be msg:.  It could be on a
separate line.
            ;; db = Data Bytes: assemble some literal bytes into the output file.
msg     db  'Hello, world!',0xa     ; ASCII string constant plus a newline (0x10)

            ;;  No terminating zero byte is needed, because we're using write(), which takes
a buffer + length instead of an implicit-length string.
            ;; To make this a C string that we could pass to puts or strlen, we'd need a
terminating 0 byte. (e.g. "...", 0x10, 0)

len     equ $ - msg       ; Define an assemble-time constant (not stored by itself in the
output file, but will appear as an immediate operand in insns that use it)
                          ; Calculate len = string length.  subtract the address of the start
                          ; of the string from the current position ($)
  ;; equivalently, we could have put a str_end: label after the string and done   len equ
str_end - str
```

Linux`Hello.asm`32

```
nasm -felf32 Hello.asm                  # assemble as 32-bit code.  Add -Worphan-labels -g -
Fdwarf  for debug symbols and warnings
gcc -nostdlib -m32 Hello.o -o Hello     # link without CRT startup code or libc, making a
static binary
```

3264LinuxNASM / YASMGNU ATTGNU `as` ◦ 6432`-m32`◦

`strace`

```
$ strace ./Hello
execve("./Hello", ["./Hello"], [/* 72 vars */]) = 0
[ Process PID=4019 runs in 32 bit mode. ]
write(1, "Hello, world!\n", 14Hello, world!
)         = 14
_exit(0)                                = ?
+++ exited with 0 +++
```

stderrstdout`write`◦ ◦ syscallgdb◦

x86-64args◦ `syscallint 0x80` ◦

x86 https://riptutorial.com/zh-TW/x86/topic/1164/x86

2:

x86 - ◦ - ◦ ◦ ◦

64IA-32 x86◦

Examples

MOV0

```
B8 00 00 00 00    MOV eax, 0
```

5◦

MOVXOR

```
33 C0             XOR eax, eax
```

2 ◦

Carry

Carry C

```
    mov  al, 1
    jc   NotZero
    mov  al, 0
NotZero:
```

'sbb'

“”

```
    sbb  al,al    ; Move Carry to al
```

Cal◦ 0xFF -1 ◦ 0x01

```
    and  al, 0x01 ; Mask down to 1 or 0
```

-
-
-

-
-

0

```
    cmp   eax, 0
```

```
83 F8 00      cmp   eax, 0
```

test

```
    test   eax, eax      ; Equal to zero?
```

```
85 c0         test   eax, eax
```

-
-

。

Linux

32Linuxsysenter`int 0x80`。
32Linux

```
mov eax, <System call number>
mov ebx, <Argument 1> ;If applicable
mov ecx, <Argument 2> ;If applicable
mov edx, <Argument 3> ;If applicable
push <label to jump to after the syscall>
push ecx
push edx
push ebp
mov ebp, esp
sysenter
```

。
ebpesp33212。ebpedxecxLEAESP。

```
mov eax, <System call number>
mov ebx, <Argument 1>
mov ecx, <Argument 2>
mov edx, <Argument 3>
push <label to jump to after the syscall>
lea ebp, [esp-12]
sysenter
```

sys_exit

```
mov eax, 1
```

```
xor ebx, ebx ;Set the exit status to 0
mov ebp, esp
sysenter
```

35

```
    imul ecx, 3      ; Set ecx to 5 times its previous value
    imul edx, eax, 5 ; Store 5 times the contend of eax in edx
```

lea

◦ ◦ 3264esprsp 35lea◦ ◦

```
    lea ecx, [2*ecx+ecx] ; Load 2*ecx+ecx = 3*ecx into ecx
    lea edx, [4*edx+edx] ; Load 4*edx+edx = 5*edx into edx
```

```
    lea ecx, [3*ecx]
    lea edx, [5*edx]
```

ebprbp imul◦

-
- ebprbpimul
-
-

https://riptutorial.com/zh-TW/x86/topic/3215/

3: -

Examples

CPU。 。

/ - “”。 - - 。

1000。 “” - 。 。

。 -

。 - 。

Segmentation。 Segment。

- 。 Segments - 。

“”。

。 “”IntelARMMIPSPower。

。 。 。

- “”。 “”“”。

“” - 。 “”。

- 。 - 。

4 GB32。 。 1000“”。 。

“”。 “” - 。

- 。 - 。
- 。 “”。
- 。 。
- 。

- MessageBox。 Mac -

PagingCPUPaging。

PagingAddress。

```
+-----------------+------------+
| Page index      | Byte index |
+-----------------+------------+
```

。

。“”

```
+-----------+------------+------------+
| Dir index | Page index | Byte index |
+-----------+------------+------------+
```

Directory“”。

CPU - 。;;。CPU。

“” - 。Pages。

Pages。 - 。 - 。 。

TLBOS。TLB - 。

80386

803863232。 Paging4K32--101012

```
+-----------+------------+------------+
| Dir index | Page index | Byte index |
+-----------+------------+------------+
 3         2 2          1 1          0  Bit
 1         2 1          2 1          0  number
```

124K。101,024 - 44K

- 1,024 - 。
- 1,024 - 。
- 。

1,024。 。 32 - Page20。12;;

```
+--------------+----+------+-----+---+---+
| Page Address | OS | Used | Sup | W | P |
```

```
+--------------+----+------+-----+---+---+
Page Address = Top 20 bits of Page Table or Page address
OS           = Available for OS use
Used         = Whether this page has been accessed or written to
Sup          = Whether this page is Supervisory - only accessible by the OS
W            = Whether this page is allowed to be Written
P            = Whether this page is even Present
```

P0 -

PDBR PDBR

CPU。 CR3 。 PDBR 。

CPU。

1. 10PDBR;
2. 10;
3. 12。

1.2.

- “”;
- “” - ;
- “” - 。

14。 ;;。

。 。 。

80486

80486 Paging Subsystem80386。 - 。

“80386”。

Pentium。 。

Pentium - 4 MB4 MB1,0244K。

```
+-----------+----------------------+
| Dir Index | 4MB Byte Index       |
+-----------+----------------------+
 3         2 2                    0   Bit
 1         2 1                    0   number
```

```
+-----------+----+---+------+-----+---+---+
```

```
| Page Addr | OS | S | Used | Sup | W | P |
+-----------+----+---+------+-----+---+---+
Page Addr = Top 20 bits of Page Table or Page address
OS        = Available for OS use
S         = Size of Next Level: 0 = Page Table, 1 = 4 MB Page
Used      = Whether this page has been accessed or written to
Sup       = Whether this page is Supervisory - onlly accessible by the OS
W         = Whether this page is allowed to be Written
P         = Whether this page is even Present
```

- 4 MB4 MB4K4K。
- 4 MB - 。

。

PAE

PC。“” - “”“” - “”。

RAM - 32。Pentium ProPentium M64。 - 。

32。3264。4K6452122012。

644K5121,024。32

```
+-----+-----------+------------+------------+
| DPI | Dir Index | Page Index | Byte Index |
+-----+-----------+------------+------------+
 3   3 2         2 2          1 1          0   Bit
 1   0 9         1 0          2 1          0   number

 DPI        = 2-bit index into Directory Pointer Table
 Dir Index  = 9-bit index into Directory
 Page Index = 9-bit index into Page Table
 Byte Index = 12-bit index into Page (as before)
```

PDPT64。 PDBR CR3 PDPT - CR3324 GBRAM。 CR3PDPT32。

PSE

4MB。10 + 124MB9 + 122MB。

PSE-32PSE-40

Pentium ProPentum MPAEIntelPentium II“”32。

4MB

```
+-----------+------------+---------+
| Dir Index |  Unused    | Control |
+-----------+------------+---------+
```

DirPage Index。*31*

```
+-----------+------+-----+---------+
| Dir Index |Unused|Upper| Control |
+-----------+------+-----+---------+
```

PAE4 GBRAM - RAM4GB。43636PSE-36。。

4GB4GB - 4K。 - PAELinux。

AMDPSE8“PSE-40”

- https://riptutorial.com/zh-TW/x86/topic/3218/---

4:

/ Agner Fog 。 x86 ABIs x86-64 WindowsSystem VLinux。

- SystemV x86-64 ABI 。 Windows。 github wikiHJ Lu3264x32。 ABI/。 clang / gcc sign / zero narrow args32 ABI。 Clang。
- SystemV 32biti386ABI LinuxUnix。 。
- OS X 32x86 。 64System V. AppleFreeBSD pdf。
- Windows x86-64 `__fastcall`
- Windows `__vectorcall` 3264
- Windows 32bit `__stdcall` Win32 API。 `__cdecl` 。
- Windows64x86-64 SysV ABIAMD。

Examples

32cdecl

cdeclWindows 32POSIXi386 System V ABI 。 。

。 。

EAXEDXEAX64。st0x87。 。 EAX。

Clobbered

EBXEDIESIEBPESPFP / SSE。

EAXECXEDXFLAGSDFx87;。

64V.

POSIX64。

8RDIRSIRDXRCXR8R9R10R11。。。

RAX。。

Clobbered

RBPRBXR12-R15。。

32stdcall

stdcall32Windows API。

。。

EAX。

Clobbered

EMAECXEDX。EBXESIEDIEBP。

32cdecl -

8,16,32

8,16,3232[1] 。

。

。

```
//C prototype of the callee
void  __attribute__((cdecl)) foo(char a, short b, int c, long d);

foo(-1, 2, -3, 4);


;Call to foo in assembly

push DWORD 4              ;d, long is 32 bits, nothing special here
push DWORD 0ffffffdh      ;c, int is 32 bits, nothing special here
push DWORD 0badb0002h     ;b, short is 16 bits, higher WORD can be any value
push DWORD 0badbadffh     ;a, char is 8 bits, higher three bytes can be any value
call foo
add esp, 10h              ;Clean up the stack
```

64

64littel endian[2] 32。

```
//C prototype of the callee
void  __attribute__((cdecl)) foo(char a, short b, int c, long d);

foo(0x0123456789abcdefLL);

;Call to foo in assembly

push DWORD 89abcdefh        ;Higher DWORD of 0123456789abcdef
push DWORD 01234567h        ;Lower DWORD of 0123456789abcdef
call foo
add esp, 08h
```

AL8eax。

AX16eax。

EAX32。

EDX:EAX64EAX32EDX。

```
//C
char foo() { return -1; }

;Assembly
mov al, 0ffh
ret

//C
unsigned short foo() { return 2; }

;Assembly
mov ax, 2
ret

//C
int foo() { return -3; }

;Assembly
mov eax, 0fffffffdh
ret

//C
int foo() { return 4; }

;Assembly
xor edx, edx            ;EDX = 0
mov eax, 4            ;EAX = 4
ret
```

---

[1]4。x86 CPU24。

[2]DWORD

32cdecl -

floatdouble

32。
64Little Endian[1] 32。

```
//C prototype of callee
double foo(double a, float b);

foo(3.1457, 0.241);

;Assembly call

;3.1457 is 0x40092A64C2F837B5ULL
;0.241 is 0x3e76c8b4

push DWORD  3e76c8b4h        ;b, is 32 bits, nothing special here
push DWORD 0c2f837b5h        ;a, is 64 bits, Higher part of 3.1457
push DWORD  40092a64h        ;a, is 64 bits, Lower part of 3.1457
call foo
add esp, 0ch

;Call, using the FPU
;ST(0) = a, ST(1) = b
sub esp, 0ch
fstp QWORD PTR [esp]        ;Storing a as a QWORD on the stack
fstp DWORD PTR [esp+08h]    ;Storing b as a DWORD on the stack
call foo
add esp, 0ch
```

80[2]TBYTE32164 + 4 + 2 = 1041232。
Little Endian79-64[3] 63-3231-0。

```
//C prototype of the callee
void  __attribute__((cdecl)) foo(long double a);

foo(3.1457);

;Call to foo in assembly
;3.1457 is 0x4000c9532617c1bda800

push DWORD 4000h        ;Bits 79-64, as 32 bits push
push DWORD 0c9532617h        ;Bits 63-32
push DWORD 0c1bda800h        ;Bits 31-0
call foo
add esp, 0ch

;Call to foo, using the FPU
;ST(0) = a
```

```
sub esp, 0ch
fstp TBYTE PTR [esp]        ;Store a as ten byte on the stack
call foo
add esp, 0ch
```

`ST(0)` [4]。

```
//C
float one() { return 1; }

;Assembly
fld1            ;ST(0) = 1
ret

//C
double zero() { return 0; }

;Assembly
fldz            ;ST(0) = 0
ret

//C
long double pi() { return PI; }

;Assembly
fldpi            ;ST(0) = PI
ret
```

---

[1]DWORD。

[2]TBYTETen Bytes。

[3]WORD。

[4] TBYEFP。

64Windows

4RCXRDXR8R9。 XMM0XMM3。

。

64。

44QWORD。 。

RAX。64RAX。

Clobbered

RCXRDXR8R9XMM0XMM3RAXR10R11XMM4XMM5。。

16。“”816n + 816。

。

5amd64 Raymond Chen

32cdecl -

```
struct t
{
    int a, b, c, d;     // a is at offset 0, b at 4, c at 8, d at 0ch
    char e;             // e is at 10h
    short f;            // f is at 12h (naturally aligned)
    long g;             // g is at 14h
    char h;             // h is at 18h
    long i;             // i is at 1ch (naturally aligned)
};
```

。32;32cdecl。

。

```
int __attribute__((cdecl)) foo(struct t a);

struct t s = {0, -1, 2, -3, -4, 5, -6, 7, -8};
foo(s);
```

```
; Assembly call

push DWORD 0ffffffh8h    ; i (-8)
push DWORD 0badbad07h    ; h (7), pushed as DWORD to naturally align i, upper bytes can be
garbage
push DWORD 0ffffffah    ; g (-6)
push WORD 5              ; f (5)
push WORD 033fch         ; e (-4), pushed as WORD to naturally align f, upper byte can be
garbage
push DWORD 0ffffffdh    ; d (-3)
push DWORD 2             ; c (2)
push DWORD 0ffffffffh    ; b (-1)
push DWORD 0             ; a (0)
call foo
add esp, 20h
```

1 。 `struct S *retval` `struct S` `struct S`。

`eax`;`eax` `call`。

```
struct S
{
    unsigned char a, b, c;
};

struct S foo();         // compiled as struct S* foo(struct S* _out)
```

。

```
sub esp, 04h        ; allocate space for the struct

; call to foo
push esp            ; pointer to the output buffer
call foo
add esp, 00h        ; still as no parameters have been passed
```

。

```
struct S foo()
{
    struct S s;
    s.a = 1; s.b = -2; s.c = 3;
    return s;
}
```

```
; Assembly code
push ebx
mov eax, DWORD PTR [esp+08h]   ; access hidden parameter, it is a pointer to a buffer
mov ebx, 03fe01h               ; struct value, can be held in a register
mov DWORD [eax], ebx           ; copy the structure into the output buffer
pop ebx
ret 04h                        ; remove the hidden parameter from the stack
                               ; EAX = pointer to the output buffer
```

---

1 “”32。 `eax`。 LinuxGCC

WindowscdeclSystem V ABI“”32。 `eax`、`edx`64。 MSVCClangWin32。

https://riptutorial.com/zh-TW/x86/topic/3261/

5:

LAPIC	*APIC BASE*
APIC ID	+ 20H
	+ 0F0H
ICR;0-31	+ 300H
ICR;32-63	+ 310H

LAPIC*APIC BaseIA32_APIC_BASE* 。

。

LAPIC/“”。

。

- 1
- 。
-
- 。
- NASM ORG。 *ORG* 。

CPU *LAPIC* 。
APICLAPICeIOAPICxAPIC。

- 810。

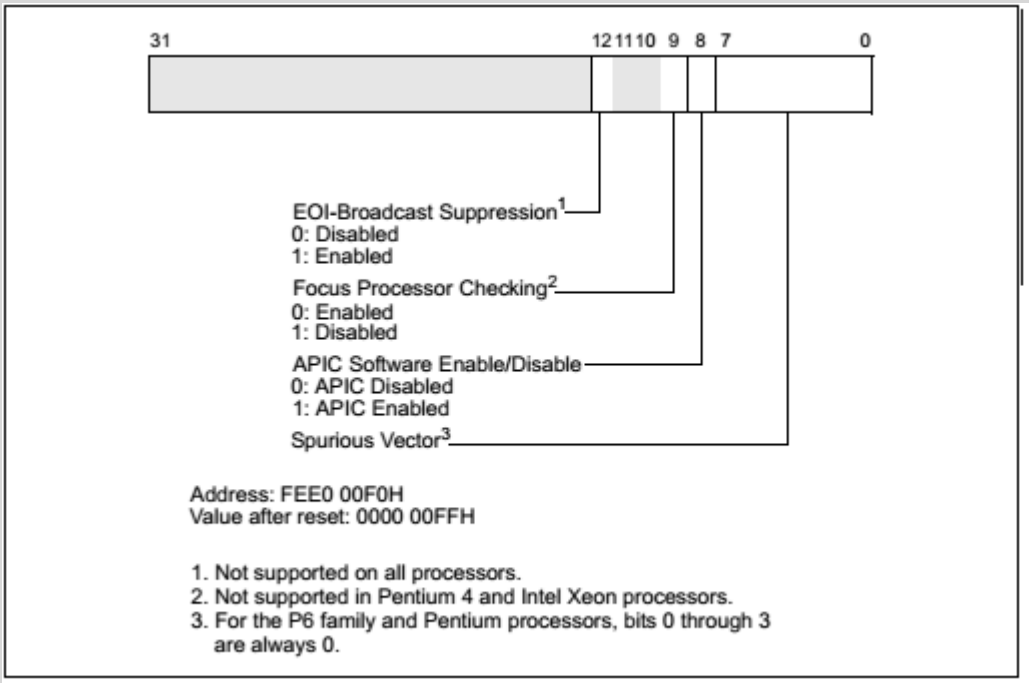


Figure 10-23. Spurious-Interrupt Vector Register (SVR)

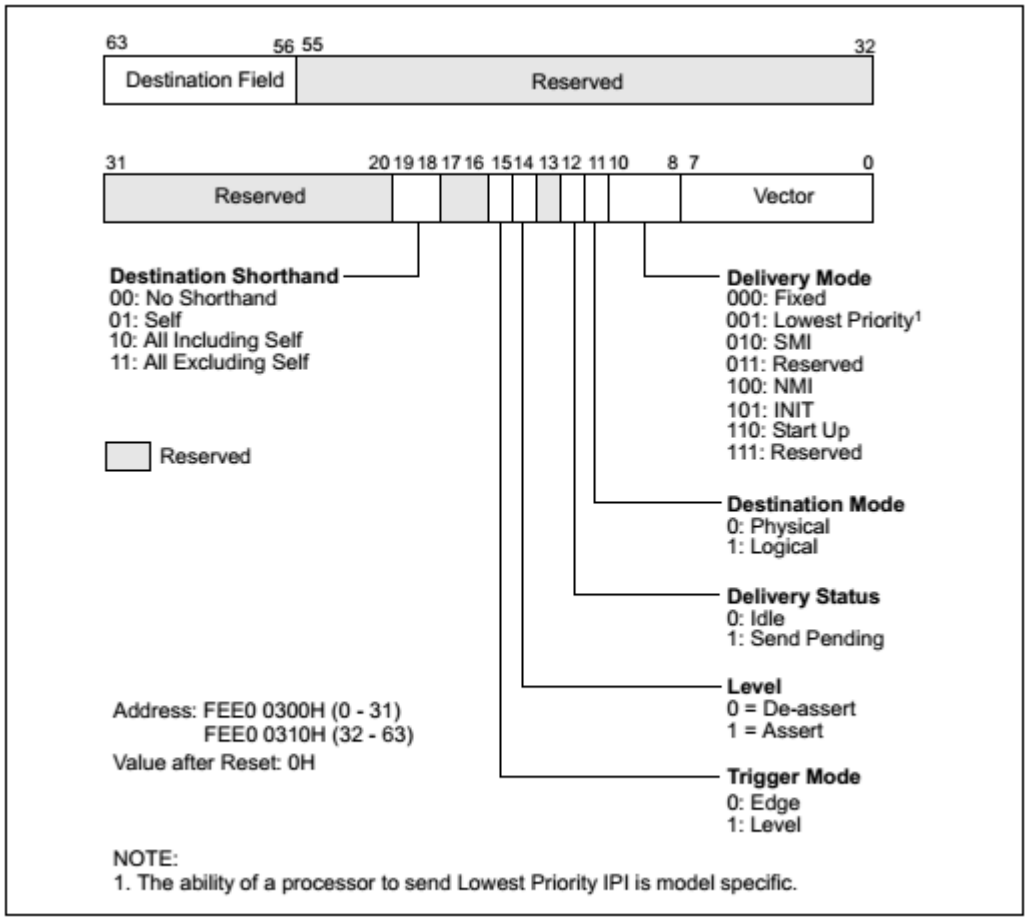


Figure 10-12. Interrupt Command Register (ICR)

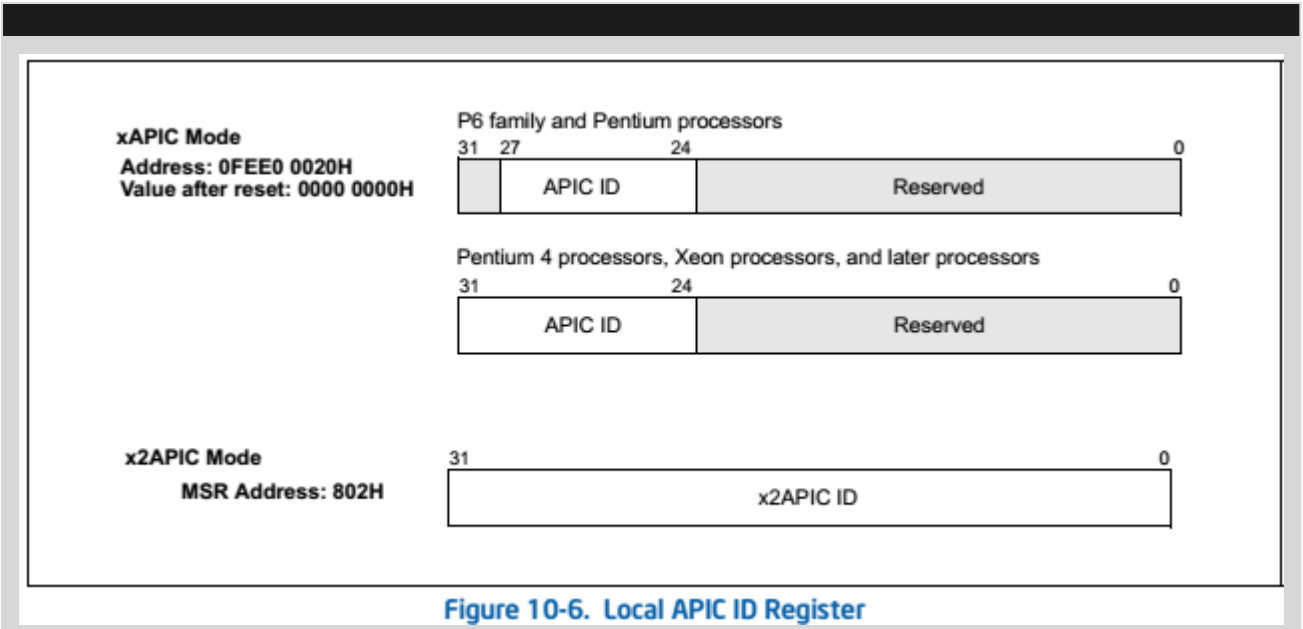


Figure 10-6. Local APIC ID Register

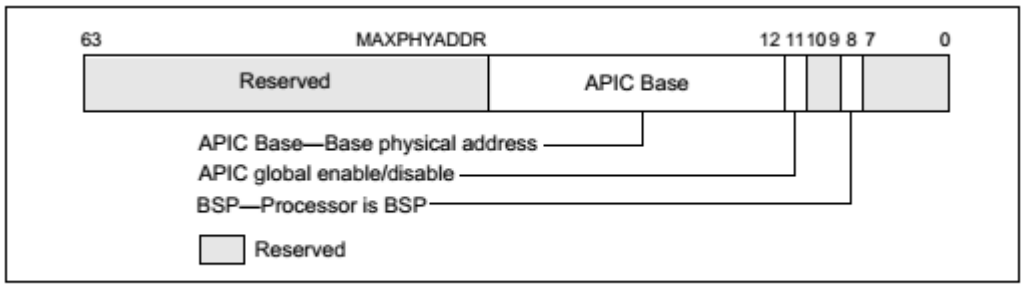


Figure 10-5. IA32_APIC_BASE MSR (APIC_BASE_MSR in P6 Family)

MSR	
IA32_APIC_BASE	1BH

1 。

Examples

AP BSPLAPIC ID。

```
; Assemble boot sector and insert it into a 1.44MiB floppy image
;
; nasm -f bin boot.asm -o boot.bin
; dd if=/dev/zero of=disk.img bs=512 count=2880
; dd if=boot.bin of=disk.img bs=512 conv=notrunc

BITS 16
; Bootloader starts at segment:offset 07c0h:0000h
section bootloader, vstart=0000h
jmp 7c0h:__START__

__START__:
 mov ax, cs
 mov ds, ax
 mov es, ax
 mov ss, ax
```

```
xor sp, sp
cld

;Clear screen
mov ax, 03h
int 10h

;Set limit of 4GiB and base 0 for FS and GS
call 7c0h:unrealmode

;Enable the APIC
call enable_lapic

;Move the payload to the expected address
mov si, payload_start_abs
mov cx, payload_end-payload + 1
mov di, 400h                ;7c0h:400h = 8000h
rep movsb


;Wakeup the other APs

;INIT
call lapic_send_init
mov cx, WAIT_10_ms
call us_wait

;SIPI
call lapic_send_sipi
mov cx, WAIT_200_us
call us_wait

;SIPI
call lapic_send_sipi

;Jump to the payload
jmp 0000h:8000h

;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

;CX = Wait (in ms) Max 65536 us (=0 on input)
us_wait:
 mov dx, 80h              ;POST Diagnose port, 1us per IO
 xor si, si
 rep outsb

 ret

 WAIT_10_ms     EQU 10000
 WAIT_200_us    EQU 200

;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll


enable_lapic:

 ;Enable the APIC globally
```

```
 ;On P6 CPU once this flag is set to 0, it cannot be set back to 16
 ;Without an HARD RESET
 mov ecx, IA32_APIC_BASE_MSR
 rdmsr
 or ah, 08h        ;bit11: APIC GLOBAL Enable/Disable
 wrmsr

 ;Mask off lower 12 bits to get the APIC base address
 and ah, 0f0h
 mov DWORD [APIC_BASE], eax

 ;Newer processors enables the APIC through the Spurious Interrupt Vector register
 mov ecx, DWORD [fs: eax + APIC_REG_SIV]
 or ch, 01h                                ;bit8: APIC SOFTWARE enable/disable
 mov DWORD [fs: eax+APIC_REG_SIV], ecx

 ret

;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

lapic_send_sipi:
 mov eax, DWORD [APIC_BASE]

 ;Destination field is set to 0 has we will use a shorthand
 xor ebx, ebx
 mov DWORD [fs: eax+APIC_REG_ICR_HIGH], ebx

 ;Vector: 08h (Will make the CPU execute instruction ad address 08000h)
 ;Delivery mode: Startup
 ;Destination mode: ignored (0)
 ;Level: ignored (1)
 ;Trigger mode: ignored (0)
 ;Shorthand: All excluding self (3)
 mov ebx, 0c4608h
 mov DWORD [fs: eax+APIC_REG_ICR_LOW], ebx  ;Writing the low DWORD sent the IPI

 ret

 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

lapic_send_init:
 mov eax, DWORD [APIC_BASE]

 ;Destination field is set to 0 has we will use a shorthand
 xor ebx, ebx
 mov DWORD [fs: eax+APIC_REG_ICR_HIGH], ebx

 ;Vector: 00h
 ;Delivery mode: Startup
 ;Destination mode: ignored (0)
 ;Level: ignored (1)
 ;Trigger mode: ignored (0)
 ;Shorthand: All excluding self (3)
 mov ebx, 0c4500h
 mov DWORD [fs: eax+APIC_REG_ICR_LOW], ebx  ;Writing the low DWORD sent the IPI

 ret
```

```
 IA32_APIC_BASE_MSR    EQU    1bh

 APIC_REG_SIV        EQU    0f0h

 APIC_REG_ICR_LOW    EQU 300h
 APIC_REG_ICR_HIGH    EQU 310h

 APIC_REG_ID        EQU 20h

 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

 APIC_BASE            dd     00h

 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

unrealmode:
 lgdt [cs:GDT]

 cli

 mov eax, cr0
 or ax, 01h
 mov cr0, eax

 mov bx, 08h
 mov fs, bx
 mov gs, bx

 and ax, 0fffeh
 mov cr0, eax

 sti

 ;IMPORTAT: This call is FAR!
 ;So it can be called from everywhere
 retf

 GDT:
    dw 0fh
    dd GDT + 7c00h
    dw 00h

    dd 0000ffffh
    dd 00cf9200h

 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll
 ;Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll  Ll

payload_start_abs:
; payload starts at segment:offset 0800h:0000h
section payload, vstart=0000h, align=1
 payload:

  ;IMPORTANT NOTE: Here we are in a "new" CPU every state we set before is no
  ;more present here (except for the BSP, but we handler every processor with
```

```
 ;the same code).
jmp 800h: __RESTART__

__RESTART__:
 mov ax, cs
 mov ds, ax
 xor sp, sp
 cld

 ;IMPORTANT: We can't use the stack yet. Every CPU is pointing to the same stack!

 ;Get an unique id
 mov ax, WORD [counter]
 .try:
   mov bx, ax
   inc bx
   lock cmpxchg WORD [counter], bx
  jnz .try

 mov cx, ax            ;Save this unique id

 ;Stack segment = CS + unique id * 1000
 shl ax, 12
 mov bx, cs
 add ax, bx
 mov ss, ax

 ;Text buffer
 push 0b800h
 pop es

 ;Set unreal mode again
 call 7c0h:unrealmode

 ;Use GS for old variables
 mov ax, 7c0h
 mov gs, ax

 ;Calculate text row
 mov ax, cx
 mov bx, 160d          ;80 * 2
 mul bx
 mov di, ax

 ;Get LAPIC id
 mov ebx, DWORD [gs:APIC_BASE]
 mov edx, DWORD [fs:ebx + APIC_REG_ID]
 shr edx, 24d
 call itoa8

 cli
 hlt

 ;DL = Number
 ;DI = ptr to text buffer
 itoa8:
   mov bx, dx
   shr bx, 0fh
   mov al, BYTE [bx +  digits]
   mov ah, 09h
   stosw
```

```
    mov bx, dx
    and bx, 0fh
    mov al, BYTE [bx +  digits]
    mov ah, 09h
    stosw

    ret

  digits db "0123456789abcdef"
  counter dw 0

 payload_end:



; Boot signature is at physical offset 01feh of
; the boot sector
section bootsig, start=01feh
 dw 0aa55h
```

1.AP
AP*INIT-SIPI-SIPI* ISS。

ISSBSP AP。

SIPICPUSIPISIPI。。

SIPI 。
8*V* 16*vv* CPU*0vv000h*。
0vv000h WA。
WA4KiB。

08h*V* WA*08000h* 400h。

AP。

2.AP
WA。*7c00h* 。

。
AP

。
CPU。 CPUAPIC ID。

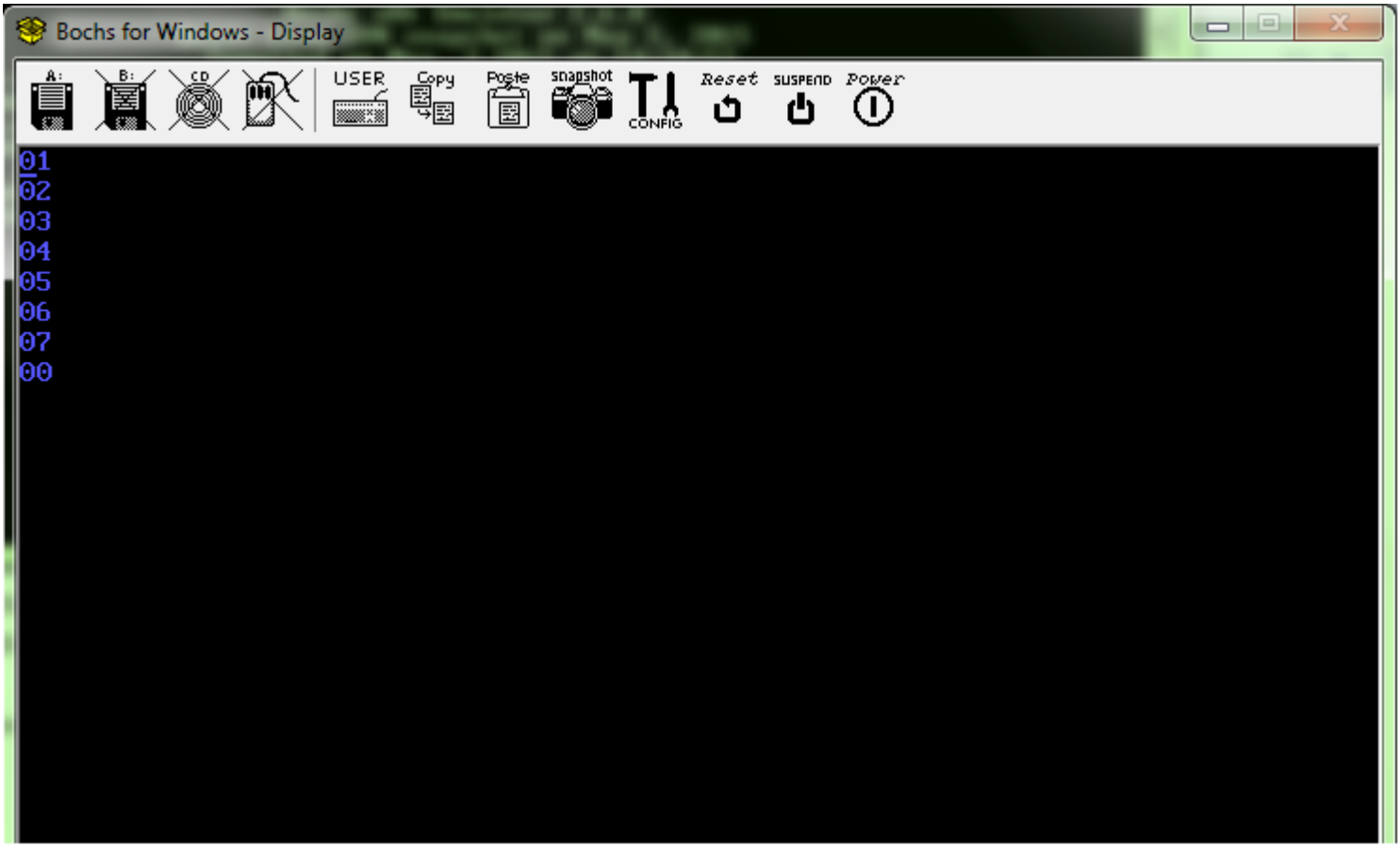
CPU*800h :(* 1000h*AP64KiB。
CPU 80 * 2 * 。

`lock cmpxchg`WORD。

- 80h1μs。

- `unrealmode`。
- BSP。

Bochs8



https://riptutorial.com/zh-TW/x86/topic/5809/

6:

。

。

Psuedo

```
function string_to_integer(str):
    result = 0
    for (each characters in str, left to right):
        result = result * 10
        add ((code of the character) - (code of character 0)) to result
    return result
```

0-9afAF。。

Examples

IA-32GAScdecl

```
# make this routine available outside this translation unit
.globl string_to_integer

string_to_integer:
    # function prologue
    push %ebp
    mov %esp, %ebp
    push %esi

    # initialize result (%eax) to zero
    xor %eax, %eax
    # fetch pointer to the string
    mov 8(%ebp), %esi

    # clear high bits of %ecx to be used in addition
    xor %ecx, %ecx
    # do the conversion
string_to_integer_loop:
    # fetch a character
    mov (%esi), %cl
    # exit loop when hit to NUL character
    test %cl, %cl
    jz string_to_integer_loop_end
    # multiply the result by 10
    mov $10, %edx
    mul %edx
    # convert the character to number and add it
    sub $'0', %cl
    add %ecx, %eax
    # proceed to next character
    inc %esi
    jmp string_to_integer_loop
string_to_integer_loop_end:
```

```
    # function epilogue
    pop %esi
    leave
    ret
```

GAS`%eax` `%esi`callee-save。

/。

C`unsigned int`4

```
#include <stdio.h>

unsigned int string_to_integer(const char* str);

int main(void) {
    const char* testcases[] = {
        "0",
        "1",
        "10",
        "12345",
        "1234567890",
        NULL
    };
    const char** data;
    for (data = testcases; *data != NULL; data++) {
        printf("string_to_integer(%s) = %u\n", *data, string_to_integer(*data));
    }
    return 0;
}
```

`string_to_integer_string_to_integer` C。

MS-DOSTASM / MASM16

16。

Int 21 / AH = 0Ah。

。

65535 = 2 16 - 1。

16。

AX。 ZF CF OF。

		ZF	CF	
16				
7FFFH				

ZF。

```
call read_uint16
jo _handle_overflow            ;Number too big (Optional, the test below will do)
jnz _handle_invalid            ;Number format is invalid

;Here AX is the number read
```

```
;Returns:
  ;
  ;If the number is correctly converted:
  ;   ZF = 1, CF = 0, OF = 0
  ;   AX = number
  ;
  ;If the user input an invalid digit:
  ;   ZF = 0, CF = 1, OF = 0
  ;   AX = Partially converted number
  ;
  ;If the user input a number too big
  ;   ZF = 0, CF = 1, OF = 1
  ;   AX = 07fffh
  ;
  ;ZF/CF can be used to discriminate valid vs invalid inputs
  ;OF can be used to discrimate the invalid inputs (overflow vs invalid digit)
  ;
  read_uint16:
    push bp
    mov bp, sp

    ;This code is an example in Stack Overflow Documentation project.
    ;x86/Converting Decimal strings to integers


    ;Create the buffer structure on the stack

    sub sp, 06h                ;Reserve 6 byte on the stack (5 + CR)
    push 0006h                 ;Header

    push ds
    push bx
    push cx
    push dx

    ;Set DS = SS

    mov ax, ss
    mov ds, ax


    ;Call Int 21/AH=0A

    lea dx, [bp-08h]            ;Address of the buffer structure
    mov ah, 0ah
    int 21h

    ;Start converting

    lea si, [bp-06h]
    xor ax, ax
```

```
 mov bx, 10
 xor cx, cx

_r_ui16_convert:

 ;Get current char

 mov cl, BYTE PTR [si]
 inc si

 ;Check if end of string

 cmp cl, CR_CHAR
 je _r_ui16_end                      ;ZF = 1, CF = 0, OF = 0

 ;Convert char into digit and check

 sub cl, '0'
 jb _r_ui16_carry_end                ;ZF = 0, CF = 1, OF = X -> 0
 cmp cl, 9
 ja _r_ui16_carry_end                ;ZF = 0, CF = 0 -> 1, OF = X -> 0


 ;Update the partial result (taking care of overflow)

 ;AX = AX * 10
 mul bx

 ;DX:AX = DX:AX + CX
 add ax, cx
 adc dx, 0

 test dx, dx
jz _r_ui16_convert            ;No overflow

 ;set OF and CF
 mov ax, 8000h
 dec ax
 stc

jmp _r_ui16_end                      ;ZF = 0, CF = 1, OF = 1

_r_ui16_carry_end:

 or bl, 1                ;Clear OF and ZF
 stc                     ;Set carry

 ;ZF = 0, CF = 1, OF = 0

_r_ui16_end:
 ;Don't mess with flags hereafter!

 pop dx
 pop cx
 pop bx
 pop ds

 mov sp, bp

 pop bp
 ret
```

```
    CR_CHAR EQU 0dh
```

NASM

NASM`PTR mov cl, BYTE PTR [si]mov cl, BYTE [si]`

MS-DOSTASM / MASM16

22 1 2 2 2 3 2 4 1。
2 LSb*n*。
16。 8。
16;53163.5 = 151[3]。

AND。
2。

a*D*b*S*。
。

。
16。
。

ñ	
	BASE2 BASE4 BASE8BASE16
。0“0”	

```
push 241
push BASE16
push 0
call print_pow2             ;Prints f1

push 241
push BASE16
push 1
call print_pow2             ;Prints 00f1

push 241
push BASE2
push 0
call print_pow2             ;Prints 11110001
```

TASM `EQU`*TASM*`/m` 。

```
;Parameters (in order of push):
;
;number
;base (Use constants below)
;print leading zeros
print_pow2:
 push bp
 mov bp, sp

 push ax
 push bx
 push cx
 push dx
 push si
 push di

 ;Get parameters into the registers

 ;SI = Number (left) to convert
 ;CH = Amount of bits to shift for each digit (D)
 ;CL = Amount od bits to shift the number (S)
 ;BX = Bit mask for a digit

 mov si, WORD PTR [bp+08h]
 mov cx, WORD PTR [bp+06h]            ;CL = D, CH = S

 ;Computes BX = (1 << D)-1

 mov bx, 1
 shl bx, cl
 dec bx

 xchg cl, ch              ;CL = S, CH = D

_pp2_convert:
 mov di, si
 shr di, cl
 and di, bx         ;DI = Current digit

 or WORD PTR [bp+04h], di             ;If digit is non zero, [bp+04h] will become non zero
                      ;If [bp+04h] was non zero, result is non zero
 jnz _pp2_print                       ;Simply put, if the result is non zero, we must print
the digit


 ;Here we have a non significant zero
 ;We should skip it BUT only if it is not the last digit (0 should be printed as "0" not
 ;an empty string)

 test cl, cl
 jnz _pp_continue


_pp2_print:
 ;Convert digit to digital and print it


 mov dl, BYTE PTR [DIGITS + di]
 mov ah, 02h
 int 21h
```

```
_pp_continue:
 ;Remove digit from the number

 sub cl, ch
jnc _pp2_convert

 pop di
 pop si
 pop dx
 pop cx
 pop bx
 pop ax

 pop bp
 ret 06h
```

```
This data must be put in the data segment, the one reached by `DS`.

DIGITS    db    "0123456789abcdef"

;Format for each WORD is S D where S and D are bytes (S the higher one)
;D = Bits per digit  --> log2(BASE)
;S = Initial shift count --> D*[ceil(16/D)-1]

BASE2    EQU    0f01h
BASE4    EQU    0e02h
BASE8    EQU    0f03h
BASE16    EQU    0c04h
```

NASM

NASMPTR `mov si, WORD PTR [bp+08h]mov si, WORD PTR [bp+08h]`

$2^{255}2^{16}16$。

1. `BASEx` $x2^{n}$。
   $DD = n$。
   S。$S = N \cdot \lceil 16/ \rceil - 1$。
2. `DIGITS`。

32

$D = 5S = 15$`BASE32 EQU 0f05h`。

`DIGITS db "0123456789abcdefghijklmnopqrstuv"`。

`DIGITS`。

---

[1]BB。$log_2 B$。$log_2 2^n = n$。

[2]$2\ 2^n$。

$^{3}B = 2^{n}n$ | 16 *n*16。 162*n*2。 *B*2 $^{2^{k}}log_{2}$ log_{2} *B* 。

MS-DOSTASM / MASM16

16

Int 21 / AH = 02h。
`div`101610 ^{4} 。

。
16。

16	
	0。 0“0”

```
push 241
push 0
call print_dec          ;prints 241

push 56
push 1
call print_dec          ;prints 00056

push 0
push 0
call print_dec          ;prints 0
```

```
;Parameters (in order of push):
;
;number
;Show leading zeros
print_dec:
 push bp
 mov bp, sp

 push ax
 push bx
 push cx
 push dx

 ;Set up registers:
 ;AX = Number left to print
 ;BX = Power of ten to extract the current digit
 ;DX = Scratch/Needed for DIV
 ;CX = Scratch

 mov ax, WORD PTR [bp+06h]
 mov bx, 10000d
 xor dx, dx

_pd_convert:
```

```
 div bx                          ;DX = Number without highmost digit, AX = Highmost digit
 mov cx, dx                      ;Number left to print

 ;If digit is non zero or param for leading zeros is non zero
 ;print the digit
 or WORD PTR [bp+04h], ax
 jnz _pd_print

 ;If both are zeros, make sure to show at least one digit so that 0 prints as "0"
 cmp bx, 1
 jne _pd_continue

_pd_print:

 ;Print digit in AL

 mov dl, al
 add dl, '0'
 mov ah, 02h
 int 21h

_pd_continue:
 ;BX = BX/10
 ;DX = 0

 mov ax, bx
 xor dx, dx
 mov bx, 10d
 div bx
 mov bx, ax

 ;Put what's left of the number in AX again and repeat...
 mov ax, cx

 ;...Until the divisor is zero
 test bx, bx
jnz _pd_convert

 pop dx
 pop cx
 pop bx
 pop ax

 pop bp
 ret 04h
```

NASM

NASM`PTRmov ax, WORD PTR [bp+06h]mov ax, WORD [bp+06h]`

https://riptutorial.com/zh-TW/x86/topic/3273/

7:

Examples

Microsoft Assembler - MASM

8086/8088IBM PCMASM。“”。

```
MaxSize      EQU     16          ; Define a constant
Symbol       DW      0x1234      ; Define a 16-bit WORD called Symbol to hold 0x1234

             MOV     AX, 10      ; AX now holds 10
             MOV     BX, MaxSize ; BX now holds 16
             MOV     CX, Symbol  ; ????
```

MOVSymbolCX SymbolCX CX0x12340x0102 CX0x1234 - OFFSET

```
             MOV     AX, [Symbol]      ; Contents of Symbol
             MOV     CX, OFFSET Symbol ; Address of Symbol
```

80868080,80084004。 。 。

。 dest source。 - 。 “” - 。

```
; Zero operand examples
NOP             ; No parameters
CBW             ; Convert byte in AL into word in AX
MOVSB           ; Move byte pointed to by DS:SI to byte pointed to by ES:DI
                ; SI and DI are incremented or decremented according to D bit

; Prefix examples
REP   MOVSB     ; Move number of bytes in CX from DS:SI to ES:DI
                ; SI and DI are incremented or decremented according to D bit

; One operand examples
NOT      AX     ; Replace AX with its one's complement
MUL      CX     ; Multiply AX by CX and put 32-bit result in DX:AX

; Two operand examples
MOV      AL, [0x1234] ; Copy the contents of memory location DS:0x1234 into AL register
```

。 “”LDM“”LDI 。 MOV - 。 .....

ATT -

8086IBM PCMicrosoftUnix。 ATTUnix。 - source dest。

ATTx86

- %
  %al

%bx
- $
  $4
- source dest
- movw $4, %ax ; Move word 4 into AX

BorlandTurbo Assembler - TASM

BorlandPascal“Turbo Pascal”。C / C ++PrologFortran。“Turbo Assembler”“TASM”。

TASMIDEALMASM。MASMMASM - BorlandMASM“”QUIRKS。

TASMMASMASM - IDEAL。

GNU -

GNUx86UnixATT/。

Netwide Assembler - NASM

NASMx86 - x86MacOS。

Intel“” - “”。

。

```
response:    db       'Y'     ; Character that user typed

             cmp      response, 'N' ; *** Error! Unknown size!
             cmp byte response, 'N' ; That's better!
             cmp      response, ax  ; No error!
```

NASM。 - “”“”。

NASM

```
       STRUC     Point
X      resw      1
Y      resw      1
       ENDSTRUC
```

XY。“”XY

```
       STRUC     Point
Pt_X   resw      1
Pt_Y   resw      1
       ENDSTRUC
```

NASM。“”

```
        STRUC       Point
.X      resw        1
.Y      resw        1
        ENDSTRUC

Cursor  ISTRUC      Point
        ENDISTRUC

        mov         ax,[Cursor+Point.X]
        mov         dx,[Cursor+Point.Y]
```

NASM

```
        mov         ax,[Cursor.X]
        mov         dx,[Cursor.Y]
```

- YASM

YASMNASMIntelATT。

https://riptutorial.com/zh-TW/x86/topic/2403/

8:

Examples

```
jmp a_label                     ;Jump to a_label
jmp bx                          ;Jump to address in BX
jmp WORD [aPointer]             ;Jump to address in aPointer
jmp 7c0h:0000h                  ;Jump to segment 7c0h and offset 0000h
jmp FAR WORD [aFarPointer]      ;Jump to segment:offset in aFarPointer
```

`jmp a_label`

- ◦ `CS` ◦
- *rel*[1] `IP = IP + rel` ◦

`EB <rel8>EB <rel16/32>` ◦

NASM `jmp SHORT a_label  jmp WORD a_labeljmp DWORD a_label`◦

`jmp bxjmp WORD [aPointer]`

- ◦ `CS` ◦
- *regmem* `IP = reg  IP = mem` ◦

`FF /4` ◦

`jmp 7c0h:0000h`

- ◦
- **absolute***offset* `CS = segment, IP = offset` ◦

`EA <imm32/48>`◦

NASM `jmp 7c0h: WORD 0000hjmp 7c0h: DWORD 0000h`◦

`jmp FAR WORD [aFarPointer]`

- **far**◦
- *mem* [2] `CS = mem[23:16/32], IP = [15/31:0]` ◦

`FF /5` ◦

NASM*16:16* `jmp FAR WORD [aFarPointer]`*16:32* `jmp FAR DWORD [aFarPointer]` ◦

- ◦

```
mov bx, target            ;BX = absolute address of target
jmp bx
```

- 。

1。

2*seg16off16seg16off32 16:1616:32* 。

。 。

x86EFLAGS。

subadd xorand “”。 *CF OF SF ZF AF PF*。 cmpxchg*ZF* 。

。

x86 。

。 sub eax, ebx

ZF	。 *EAX - EBX =0*⇒EAX= EBX	。 *EAX - EBX≠0*⇒EAX≠EBX
CF	MSb。 *EAX - EBX <0*⇒EAX<EBX	。 *EAX - EBX*≮0⇒EAX≮EBX
SF	MSb。	MSb。
	。	。
PF	。	。
AF	BCD。 4。	BCD。 4。

---

suband instructions。

cmptest。 。

sub	cmp
and	test

```
test eax, eax             ;and eax, eax
                          ;ZF = 1 iff EAX is zero

test eax, 03h             ;and eax, 03h
                          ;ZF = 1 if both bit[1:0] are clear
                          ;ZF = 0 if at least one of bit[1:0] is set

cmp eax, 241d             ;sub eax, 241d
                          ;ZF = 1 iff EAX is 241
                          ;CF = 1 iff EAX < 241
```

CPU[1]sign。 。 。

---

[1]。 。

CPU。 *Jcc* - [1] 。

。 jae jnbjnc*CF = 0* 。

。

cmp。 cmp。

ZF。 *ZF = 1* 。

```
je a_label           ;Jump if operands are equal
jz a_label           ;Jump if zero (Synonym)

jne a_label          ;Jump if operands are NOT equal
jnz a_label          ;Jump if not zero (Synonym)
```

je jz	ZF = 1
jne jnz	ZF = 0

...

CF = 0 。 *CF = 0ZF*。

```
jae a_label      ;Jump if above or equal (>=)
jnc a_label      ;Jump if not carry (Synonym)
jnb a_label      ;Jump if not below (Synonym)

ja a_label       ;Jump if above  (>)
jnbe a_label     ;Jump if not below and not equal (Synonym)
```

jae jnc jnb	CF = 0
ja jnbe	CF = 0ZF = 0

SF = 0 SF。 OF = 01SF = OF 。

ZFl。

```
jge a_label      ;Jump if greater or equal (>=)
jnl a_label      ;Jump if not less (Synonym)

jg a_label       ;Jump if greater (>)
jnle a_label     ;Jump if not less and not equal (Synonym)
```

`jge jnl`	SF = OF
`jg jnle`	SF = OFZF = 0

。

```
jbe a_label      ;Jump if below or equal (<=)
jna a_label      ;Jump if not above (Synonym)

jb a_label       ;Jump if below (<)
jc a_label       ;Jump if carry (Synonym)
jnae a_label     ;Jump if not above and not equal (Synonym)

;SIGNED

jle a_label      ;Jump if less or equal (<=)
jng a_label      ;Jump if not greater (Synonym)

jl a_label       ;Jump if less (<)
jnge a_label     ;Jump if not greater and not equal (Synonym)
```

`jbe jna`	CF = 1ZF = 1
`jb jc jnae`	CF = 1
`jle jng`	SF= OFZF = 1
`jl jnge`	SF= OF

`j<flag_name>`*flag_nameF CF* → *C PF* → *P* 。

`js`	SF = 1
`jns`	SF = 0
`jo`	OF = 1
`jno`	OF = 0

`jp` `jpe` e = even	PF = 1
`jnp` `jpo` o = odd	PF = 0

x86。`cx` `ecx`CPU1632。

`cx/ecx` `reploop`。

```
jcxz  a_label   ; jump if cx (16b mode) or ecx (32b mode) is zero
jecxz a_label   ; synonym of jcxz (recommended in source code for 32b target)
```

`jcxz` `jecxz`	cx = 016b
`jcxz` `jecxz`	ecx = 032b

1。

...

```
cmp eax, ebx
ja a_label
```

```
cmp eax, ebx
jae a_label
```

```
cmp eax, ebx
jb a_label
```

```
cmp eax, ebx
jbe a_label
```

```
cmp eax, ebx
je a_label
```

```
cmp eax, ebx
jne a_label
```

...

```
cmp eax, ebx
jg a_label
```

```
cmp eax, ebx
jge a_label
```

```
cmp eax, ebx
jl a_label
```

```
cmp eax, ebx
jle a_label
```

```
cmp eax, ebx
je a_label
```

```
cmp eax, ebx
jne a_label
```

---

a_label

“” `a_label`CPU。“”CPU。

。

`ja``jnbe`。

>	ja	jg
> =	jae	jge
<	jb	jl
<=	jbe	jle
=	je	je
≠=<>	jne	jne

https://riptutorial.com/zh-TW/x86/topic/5808/

9:

- ***.386*** **MASM**x86386。
- ***.model*** .MODEL 。
- ***.code*** 。
- ***proc*** 。
- ***ret*** 。
- ***endp*** 。
- ***public*** 。
- “ **end main** ”。
- ***call*** 。
- ***ecx*** 。
- ***ecx*** 。
- ***mul*** eax

mov。

Examples

MOV

`mov`。

/ [in] CPU。

source_of / destination_for。

`mov`。

3264x86 CPU。 `MOVSB`[s]。

1**MASM** Visual Studio 2015x86
2

```
.386
.model small
.code

public main
main proc
    mov ecx, 16       ; Move immediate value 16 into ecx
    mov eax, ecx      ; Copy value of ecx into eax
    ret               ; return back to caller
        ; function return value is in eax (16)
main endp
end main
```

3。

16 。

https://riptutorial.com/zh-TW/x86/topic/8030/

10:

Examples

x86808680881616。 16164 `CS DS ES SS` 。

`PUSHPOP` - 。

CPU

```
        +-------------------+---------+
Segment | 16-bit value      | 0 0 0 0 |
        +-------------------+---------+
                   PLUS
        +---------+-------------------+
Address | 0 0 0 0 | 16-bit value      |
        +---------+-------------------+
                  EQUALS
        +-----------------------------+
Result  |  20-bit memory address      |
        +-----------------------------+
```

- `CS DSSS`;
- `CS DSSS`4K - 1664K。

80286“”“”qv。

- 16。
- “” - 。

.....

802868086“”“”。 x863264。

“”。 Segment.....。 SegmentBaseLimitSegmentOS Kernel 。

16

```
+------------+-----+------+
| Desc Index | G/L | Priv |
+------------+-----+------+
 Desc Index = 13-bit index into a Descriptor Table (described below)
 G/L        = 1-bit flag for which Descriptor Table to Index: Global or Local
 Priv       = 2-bit field defining the Privilege level for access
```

/

/GDTLDT。 LDT - 。 。

64K8,1928。 8,192

-

- 。
- - 。 0x00000
  。 ;。
- 。 ;
  。 ;
  。 “” - 。
- 。 ;
  。 Segment - ;
  。 。

。 - ..... CPU。

13 - Windows.....

- ;
- ;
- ;
- ReadExecuted;
- 。

  Segment。
- GDT0x0000。 NULL ;
- 。
- 1,2,4。

。 CPU。

- 1. NULL;
  2. ;
  3. 。

。

- GDTR；

```
 GDT_Ptr    dw      SIZE GDT
            dd      OFFSET GDT

            ...

            lgdt    [GDT_Ptr]
```

- CR0PM

```
     mov   eax, cr0      ; Get CR0 into register
     or    eax, 0x01     ; Set the Protected Mode bit
     mov   cr0, eax      ; We're now in Protected Mode!
```

- GDT

```
     jmp   0x0008:NowInPM  ; This is a FAR Jump. 0x0008 is the Code Descriptor

NowInPM:
     mov   ax, 0x0010      ; This is the Data Descriptor
     mov   ds, ax
     mov   es, ax
     mov   ss, ax
     mov   sp, 0x0000      ; Top of stack!
```

CPU。。

- - A20；
- -。

。

AMD。

1. 。

。

2. 。。

GDT / LDT。

GDT04GiB。
32。

```
BITS 16

jmp 7c0h:__START__
```

```
__START__:
 push cs
 pop ds
 push ds
 pop ss
 xor sp, sp


 lgdt [GDT]            ;Set the GDTR register


 cli                ;We don't have an IDT set, we can't handle interrupts


 ;Entering protected mode

 mov eax, cr0
 or ax, 01h            ;Set bit PE (bit 0) of CR0
 mov cr0, eax            ;Apply

 ;We are now in Protected mode

 mov bx, 08h           ;Selector to use, RPL = 0, Table = 0 (GDT), Index = 1

 mov fs, bx            ;Load FS with descriptor 1 info
 mov gs, bx            ;Load GS with descriptor 1 info

 ;Exit protected mode

 and ax, 0fffeh            ;Clear bit PE (bit0) of CR0
 mov cr0, eax                  ;Apply

 sti

 ;Back to real mode

 ;Do nothing
 cli
 hlt



 GDT:
    ;First entry, number 0
    ;Null descriptor
    ;Used to store a m16&32 object that tells the GDT start and size

    dw 0fh                 ;Size in byte -1 of the GDT (2 descriptors = 16 bytes)
    dd GDT + 7c00h         ;Linear address of GDT start (24 bits)
    dw 00h                 ;Pad

    dd 0000ffffh           ;Base[15:00] = 0, Limit[15:00] = 0ffffh
    dd 00cf9200h           ;Base[31:24] = 0, G = 1, B = 1, Limit[19:16] = 0fh,
               ;P = 1, DPL = 0, E = 0, W = 1, A = 0, Base[23:16] = 00h


 TIMES 510-($-$$) db 00h
 dw 0aa55h
```

- ◦ `fsgs`“”16//◦

- `lgdt`GDT2432 ◦ ◦ `GDT+7c00h`◦
- MBRBPB `cs` / `ds` / `ss` TP *7C00h* 0*X7C00hX7c00h + X.*
- IDT◦
- hack6◦ `lgdt`... GDT◦

GDT“ ”3A3.4.3◦

https://riptutorial.com/zh-TW/x86/topic/3679/

11:

Examples

BIOS

BIOS

/BIOS。 BIOS 。

```
int <interrupt> ; interrupt must be a literal number, not in a register or memory
```

02550x00 - 0xFF。

BIOSAH“”AL。 AH。 BIOSAX16。 。

BIOS。

BIOS

BIOS

```
mov ah, <function>
mov al, <data>
int <interrupt>
```

```
mov ah, 0x0E            ; Select 'Write character' function
mov al, <char>          ; Character to write
int 0x10                ; Video services interrupt
```

```
mov ah, 0x00            ; Select 'Blocking read character' function
int 0x16                ; Keyboard services interrupt
mov <ascii_char>, al    ; AL contains the character read
mov <scan_code>, ah     ; AH contains the BIOS scan code
```

CHS

```
mov ah, 0x02            ; Select 'Drive read' function
mov bx, <destination>   ; Destination to write to, in ES:BX
mov al, <num_sectors>   ; Number of sectors to read at a time
mov dl, <drive_num>     ; The external drive's ID
mov cl, <start_sector>  ; The sector to start reading from
mov dh, <head>          ; The head to read from
mov ch, <cylinder>      ; The cylinder to read from
int 0x13                ; Drive services interrupt
jc <error_handler>      ; Jump to error handler on CF set
```

RTC

```
mov ah, 0x00             ; Select 'Read RTC' function
int 0x1A                 ; RTC services interrupt
shl ecx, 16              ; Clock ticks are split in the CX:DX pair, so shift ECX left by 16...
or cx, dx                ; and add in the low half of the pair
mov <new_day>, al        ; AL is non-zero if the last call to this function was before
midnight
                         ; Now ECX holds the clock ticks (approx. 18.2/sec) since midnight
                         ; and <new_day> is non-zero if we passed midnight since the last read
```

RTC

```
mov ah, 0x02             ; Select 'Read system time' function
int 0x1A                 ; RTC services interrupt
                         ; Now CH contains hour, CL minutes, DH seconds, and DL the DST flag,
                         ; all encoded in BCD (DL is zero if in standard time)
                         ; Now we can decode them into a string (we'll ignore DST for now)

mov al, ch               ; Get hour
shr al, 4                ; Discard one's place for now
add al, 48               ; Add ASCII code of digit 0
mov [CLOCK_STRING+0], al ; Set ten's place of hour
mov al, ch               ; Get hour again
and al, 0x0F             ; Discard ten's place this time
add al, 48               ; Add ASCII code of digit 0 again
mov [CLOCK_STRING+1], al ; Set one's place of hour

mov al, cl               ; Get minute
shr al, 4                ; Discard one's place for now
add al, 48               ; Add ASCII code of digit 0
mov [CLOCK_STRING+3], al ; Set ten's place of minute
mov al, cl               ; Get minute again
and al, 0x0F             ; Discard ten's place this time
add al, 48               ; Add ASCII code of digit 0 again
mov [CLOCK_STRING+4], al ; Set one's place of minute

mov al, dh               ; Get second
shr al, 4                ; Discard one's place for now
add al, 48               ; Add ASCII code of digit 0
mov [CLOCK_STRING+6], al ; Set ten's place of second
mov al, dh               ; Get second again
and al, 0x0F             ; Discard ten's place this time
add al, 48               ; Add ASCII code of digit 0 again
mov [CLOCK_STRING+7], al ; Set one's place of second
...
db CLOCK_STRING "00:00:00", 0   ; Place in some separate (non-code) area
```

RTC

```
mov ah, 0x04             ; Select 'Read system date' function
int 0x1A                 ; RTC services interrupt
                         ; Now CH contains century, CL year, DH month, and DL day, all in BCD
                         ; Decoding to a string is similar to the RTC Time example above
```

```
int 0x12                ; Conventional memory interrupt (no function select parameter)
and eax, 0xFFFF         ; AX contains kilobytes of conventional memory; clear high bits of
EAX
shl eax, 10             ; Multiply by 1 kilobyte (1024 bytes = 2^10 bytes)
                        ; EAX contains the number of bytes available from address 0000:0000
```

```
int 0x19                ; That's it! One call. Just make sure nothing has overwritten the
                        ; interrupt vector table, since this call does NOT restore them to
the
                        ; default values of normal power-up. This means this call will not
                        ; work too well in an environment with an operating system loaded.
```

BIOS。 `AH0x860x80` 。 **CF**。 `jc`。

BIOSRalf Brown 。 HTML。

。

osdev.org

https://riptutorial.com/zh-TW/x86/topic/6946/

12:

Examples

16

80862016◦ 816 -

- AX◦
  ◦
- DX◦
  3216AX - ◦
- CX◦
  - LOOPNE REP /
- BX◦
  - ◦
- SI◦
  ◦
- DI◦
  ◦
- SP◦
  PUSHPOPCALLCALLRET ◦
- BP◦
  “”◦ BP◦

1. ◦
2. BX SIDI◦

   ```
   MOV    AX, [BX+5]     ; Point into Data Segment
   MOV    AX, ES:[DI+5]  ; Override into Extra Segment
   ```

3. DIMOVSCMPS ◦ ◦
4. SPBP◦

32

803861632◦ 323232◦ ◦ 1632 -

32◦ 81632E“” EAX EBX ECX EDX ESI EDI EBPESP ◦ 1632ADDCMP ◦ 8◦

1632 CMP AX,DX 16CMP AX,DXCMP EAX,EDX 32CMP EAX,EDX

“AX ”0xB8 0xB8 0x12 0x34

“EAX ”0xB8 0xB8 0x12 0x34 0x56 0x78

assember。

8

16

- AHALAX。
- BHBLBX。
- CHCLCX。
- DHDLDX。

AHALAX 8“” - AL0xFF0x00AH 。

648

- RSI SIL
- DIL for RDI
- RBP BPL
- RSP SPL

R8R15 R8B - R15B 。

8086168 - 16。 1665,536。

“” - 1664 - 。

- CS。
  IP 。
- DS。
  。
- ES。
  。
- SS。
  。

16。 。

32--4 - 8“”2416。 112 -

803864。

- FS
- GS

Segment。

C D E.....

64

AMD80386。 。

326432x8664。 64AMD。

64

- 64R RAX RBX RCX RDX RSI RDI RBPRSP。

  E。

- 864 R8 R9 R10 R11 R12 R13 R14R15。
  - 32R8DR15D DDWORD。
  - 16W R8WR15W。
- *168*
  - AL BL CLDL;
  - SIL DIL BPLSPL;
  - 8 R8BR15B。
  - AH BH CHDHREX64R8-R15SIL DIL BPLSPL。 REXAHSPL。 23-1。

3232816。 。

x86ALUNOTADD16FLAGS“”“”“”。 3232EFLAGS 6464RFLAGS。

-。 JccSETcc cc“”

E Z		ZF == 1
NE NZ		ZF == 0
O		OF == 1
NO		OF == 0
S		SF == 1
NS		SF == 0

P		PF == 1
NP		PF == 0
----------	----	----------
C B NAE		CF == 1
NC NB AE		CF == 0
A NBE		CF == 0ZF == 0
NA BE		CF == 1ZF == 1
----------	----	----------
GE NL		SF == OF
NGE L		SF = OF
G NLE		ZF == 0SF == OF
NG LE		ZF == 1SF = OF

160165,535-1 - 0xFFFF ◦ ◦ 0x8000132,76832,767 ;-32,76832,767 -

◦ “Above”“Below”“Greater”“Less”◦ JB“”JL“”◦

FLAGS

- LAHFAH
- SAHF AHFlags

◦ FLAGS / EFLAGS / RFLAGS

- PUSHF / POPF 16FLAGS/
- PUSHFD / POPFD 32EFLAGS/
- PUSHFQ / POPFQ PUSH / POP 64RFLAGS/

[R/E]FLAGS◦

ALU FLAGS

- IF◦

  STICLI◦
- DF◦

  CMPSMOVS ◦ DFCLD;STD◦
- TF◦ ◦ “”“”◦ ◦

80286

80286FLAGS

- IOPL I / O。
  I / O。 00 2 11 2。 IOPLI / O。
- NT。
  CALL。 RET。

80386

'386。

- RF。
  `386。 Resume Flag。 Resume FlagDebug。
- VM8086。
  163280386“8086”16Virtual 8086。 VM8086。

80486

。 。

- ACx8644。 。 AC。 AC set。

PentiumCPUID

- VIF。
  IF - 。
- VIP。
  VIFTaskSTI。
- ID CPUID -allowed。
  CPUID。 “”。

https://riptutorial.com/zh-TW/x86/topic/2122/

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