CS680 Linux Kernel Programming, Spring 2017

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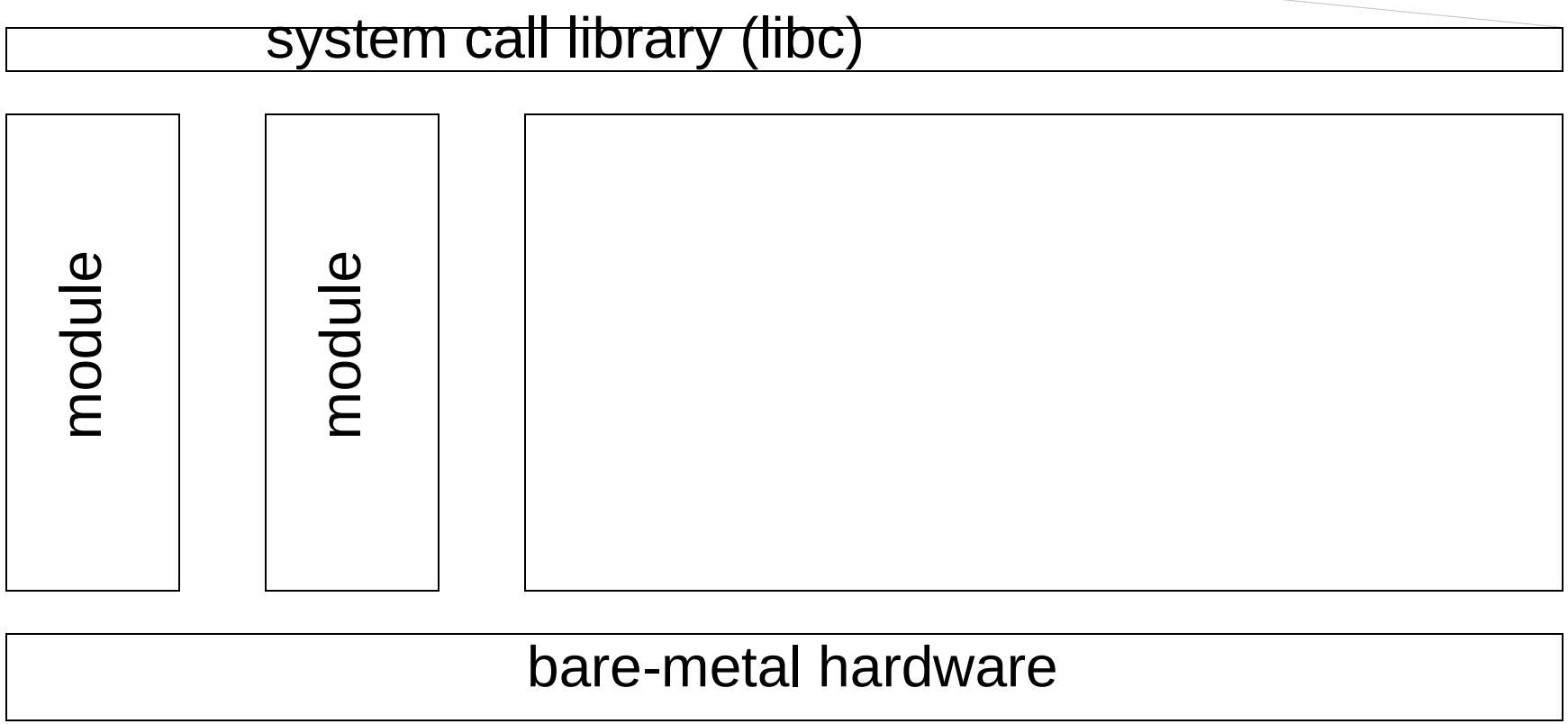
kernel version 4.10 as of 1/16/2017

1. LAMP, virtualization, datacenter computing infrastructure, Review of Intel architecture based on Intel 64 and IA-32 Architectures Software Developer's Manual (4684 pages!), Intel and AT&T Linux assembly, assembly in-line programming
2. Setting up LXR (Linux cross referencer) on your laptop and in-class demonstration, compiling the kernel, Module programming, Booting - machine BIOS, disk MBR, Grub Linux loader, preliminary setup (setup(), startup_32() 1-compressed and 2-decompressed)
3. Booting continues, Overview of kernel startup and initialization (start_kernel())
4. Memory - overview, BIOS e820 mem map, memblock, segmentation
5. Memory - mapping, paging (get_free_pages),
6. **Test 1: 10-11:30am, Tue, 2/14/2017 (week5)**
   Memory - caching (kmalloc) and process address space (vmalloc)
7. Process - thread union, kernel stack, task and thread struct, PID0 (swapper)
8. Process - PID1 (init), PID2 (kthreadd), PID3 (softirqd), PID4 (migrationd)
9. Process - process scheduling schedule() and process switching context_switch()
   Interrupts - exceptions do_trap() and hard interrupts do_IRQ()
10. **Test 2: 10-11:30am, Tue, 3/28/2017 (week10)**
    Interrupts - soft interrupts do_softirq(), ksoftirqd, timer interrupts run_timer_softirq()
11. File system - virtual file system, registering, mounting, Block IO,
12. File system - IO scheduler, device driver, vfs_read(), Ext4 example
13. Networking - receiving packets: NIC, ISR, Softirq, IP, TCP, Inet, BSD, User, sys_send()
14. Networking - sending packets: User, BSD, Inet, TCP, IP, Softirq, Qdisc, ISR, NIC, sys_recv()
15. **Final exam (week15): See the registrar's page: http://www.njit.edu/registrar**

Chapter 1 Introduction to the Linux Kernel

1. LAMP, cloud computing, data center technologies, data analytics, big data, cognitive computing, etc.
2. Virtualization and virtual machines (kvm, xen, virtualbox, ...)
3. Intel Architecture
4. Assembly - AT&T (Motolora) and intel



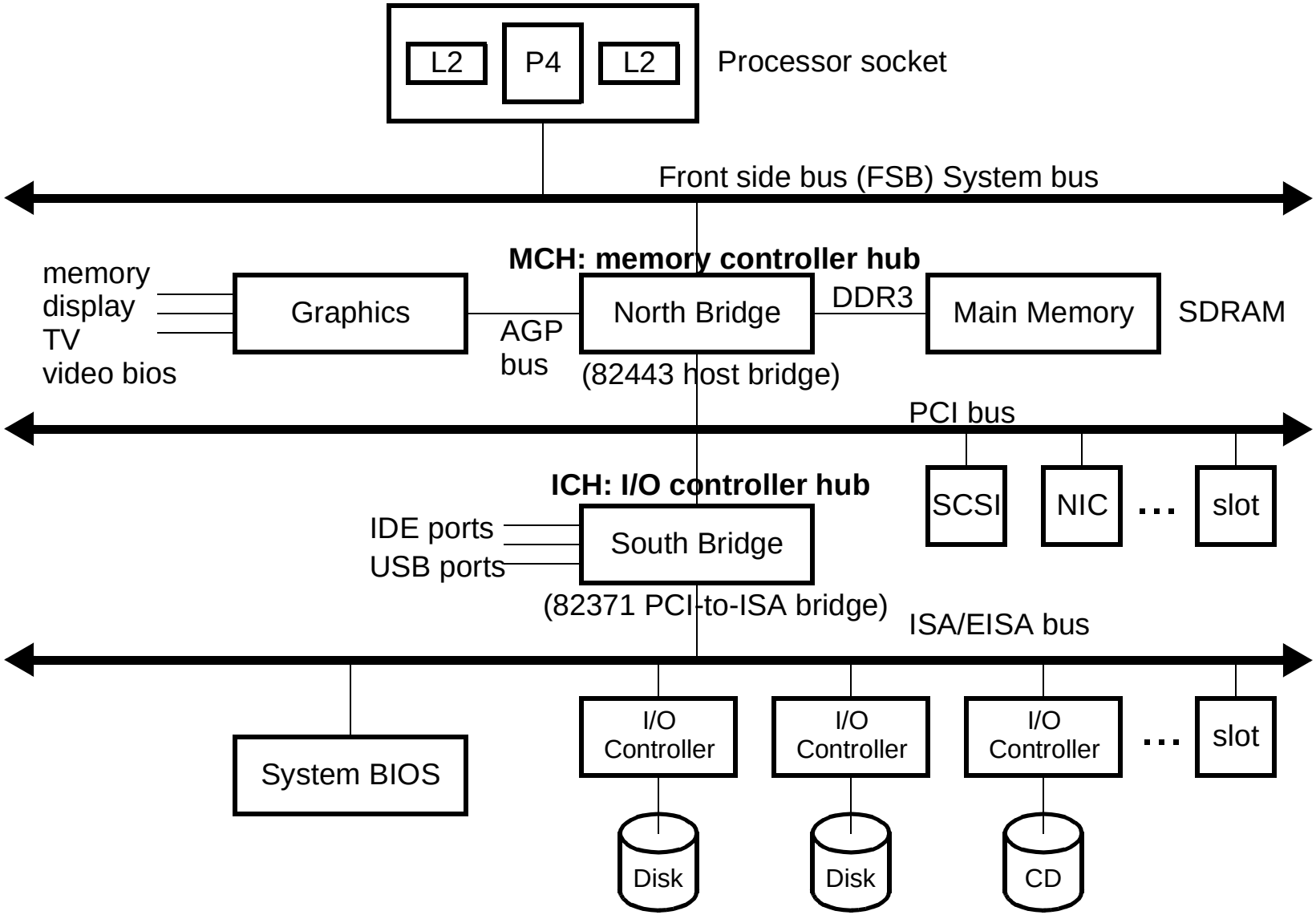
LAMP: Linux Apache my(maria)Sql PHP/Python

Haves	Have Nots
Closed	Open
$$$	$000
Microsoft	LAMP
Windows	Linux
IIS	Apache
SQL	My(Maria)SQL
.net	PHP/Python
GUI	CLI
IDE	emacs/vi
C#	C
powershell (win10 suports bash)	bash

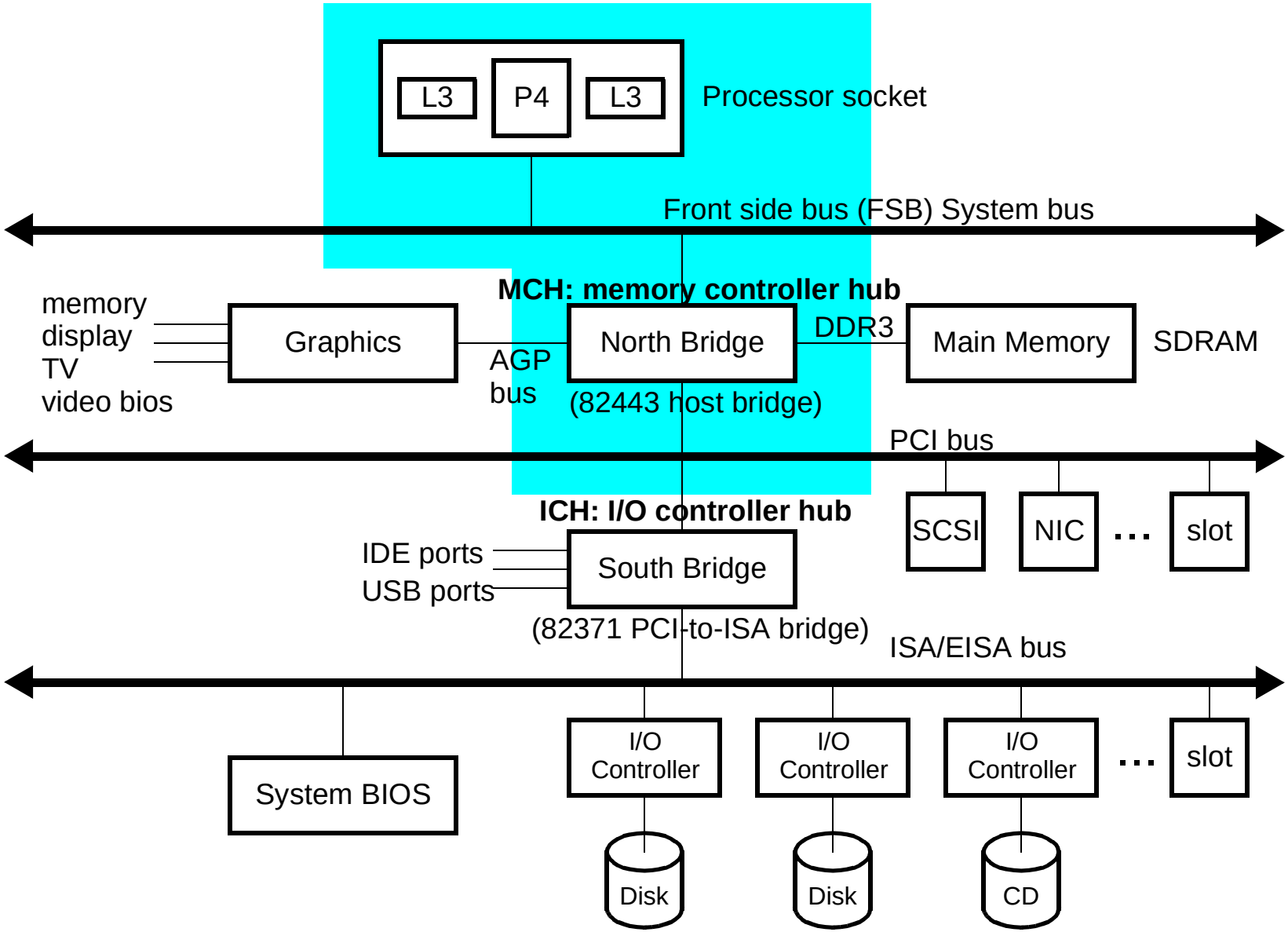
Virtualization: Hypervisor and Virtual Machines

- KVM - Kernel based VM, starting 2.6.20
- VMware (EMC) - vSpher Hypervisor, free version
- Xen (Citrix) - Express version free
- Microsoft - Hyper-V hypervisor
- Oracle (Sun) - Virtual Box
- UML - user mode linux
- BSD - bhybe “Bee Hyve”

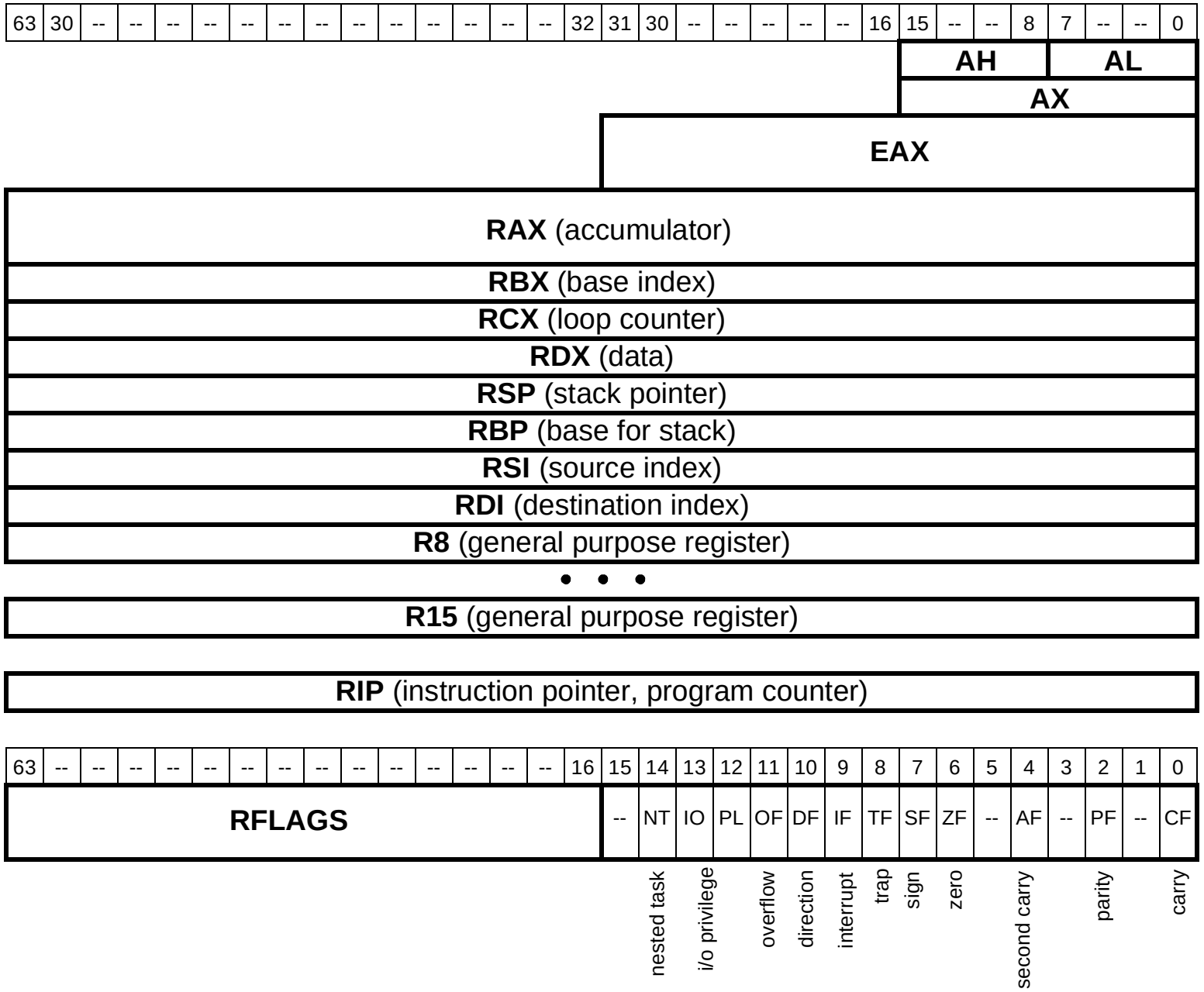
Old i386-based motherboard architecture



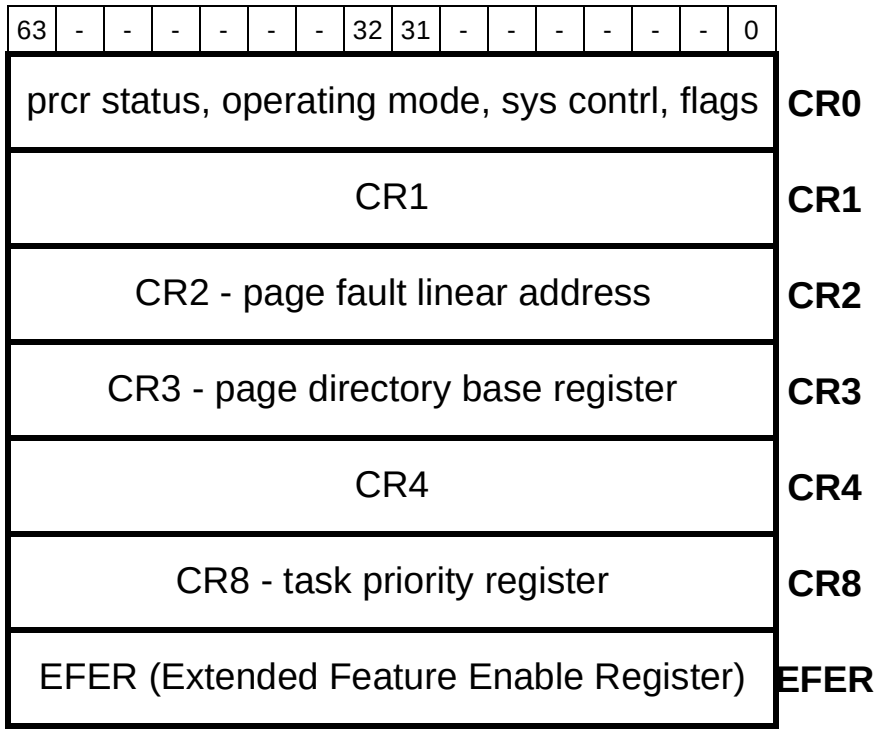
Modern motherboard - Platform Controller Hub (PCH)



Greneral Purpose, Pointer, Index, Instruction Registers



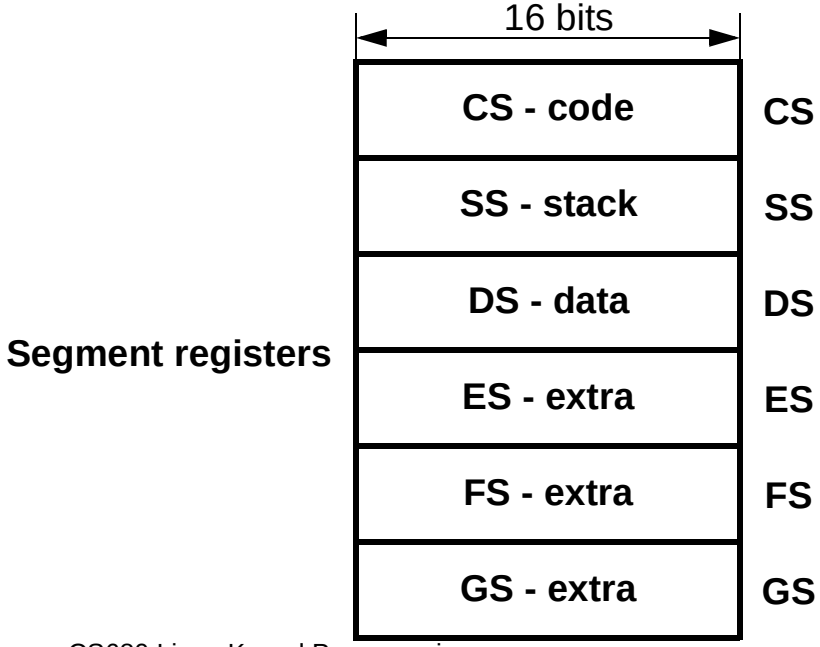
Control registers



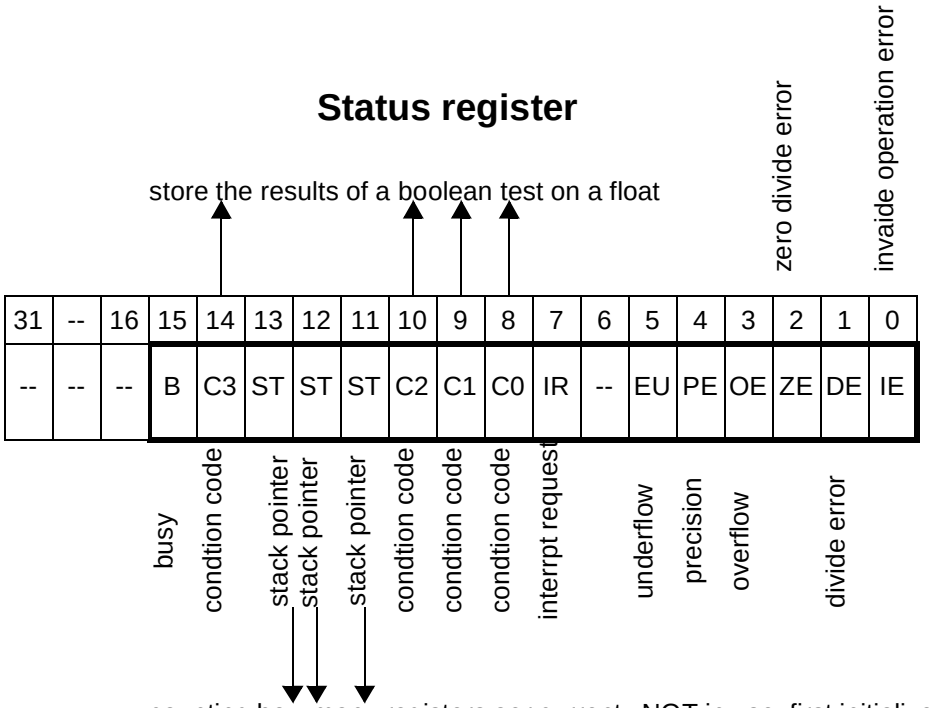
IDTR interrupt descriptor table register

GDTR global descriptor table register

Segment registers

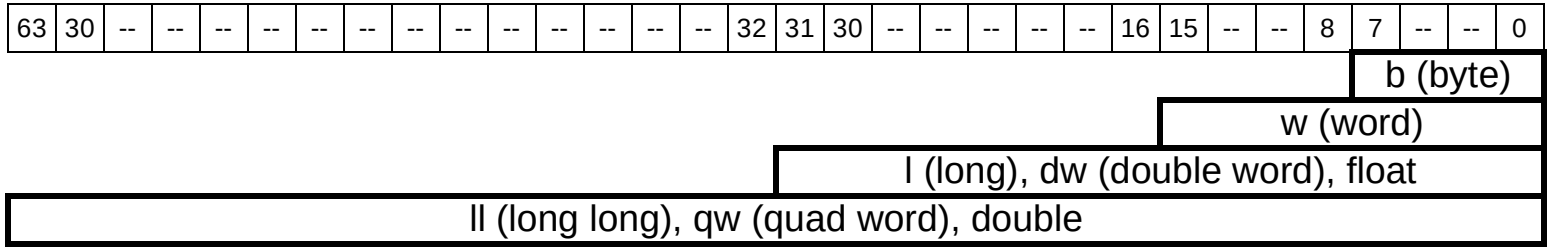


Status register



Linux Assembly Basics

Operator size:



Syntax:

	Linux/AT&T	Intel
register naming	%eax	eax
source/destnation order	movl source, destination	mov destination, source
constant/immediate value	movl $abc, %eax	mov eax, abc
hexa decimal	movl $0xd12f, %eax	mov eax, d12fh
--	--	--

Examples - see http://ibiblio.org inline assembly how-to

Linux Assembly In-lining

Format

```
_asm_ _volatile_ (
   asm insturctions
   :output
   :input
   :clobbered registers
)
```

volatile - tell the compiler not to optimize

Constraints

- m: memory operand
- o: memory operand with offset
- r: register

Modifiers

- “=” write-only
- “&” early clobber operand which is modified before the instruction is finished using the input
- & for unique reg
- $ - immediate value
- % - variable identifier
- %% - register name

Example - *test* (see IBM developerworks)

```
int test ()
{
      int x=10, y;
      printf("before: x=%x, y=%x",x,y);
      asm (
            "movl %1, %%eax;
             movl %%eax, %0;"
            :     "=r" (y)              /* output */
            :     "r" (x)               /* input */
            : "%eax"                    /* clobbered register*/
      );
      printf("after: x=%x, y=%x",x,y);}
```

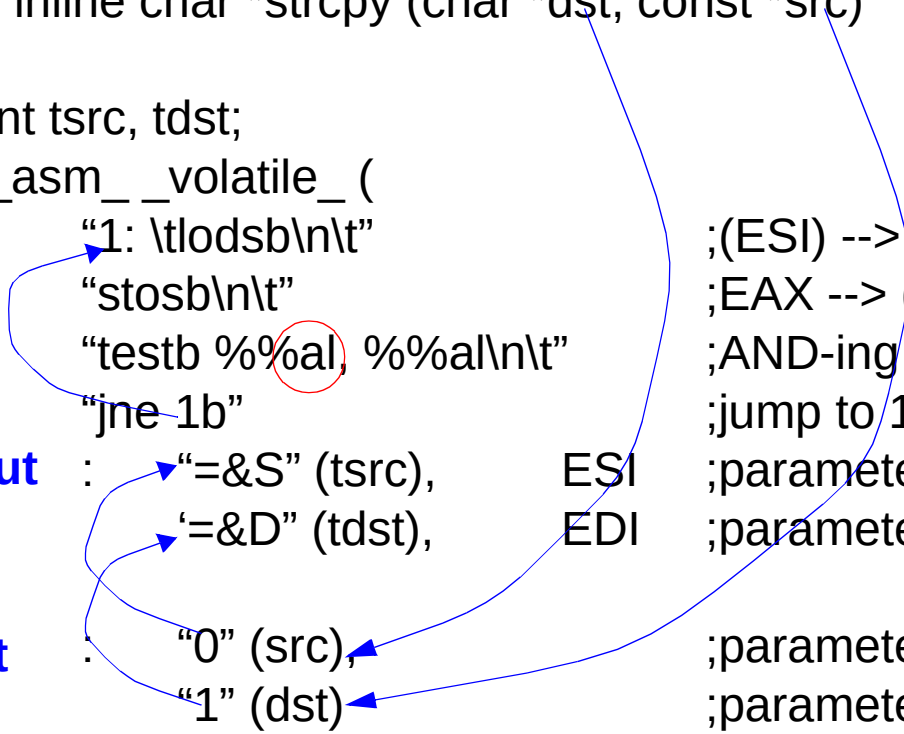
%% - to use register %eax inside "asm", %eax should be preceded by one more %, %%eax. %0 and %1 are to identify variables. Anything with single % will be treated as input/output operands and not as registers.

Example - *strcpy* (see ibiblio.org)

"Hello, World!" => "H=48 e=65 l=6C ... l=6C d=64 !=21"

```
static inline char *strcpy (char *dst, const *src)
{
        int tsrc, tdst;
        _asm_ _volatile_ (
                "1: \tlodsb\n\t"                ;(ESI) --> EAX
                "stosb\n\t"                     ;EAX --> (EDI)
                "testb %%al, %%al\n\t"          ;AND-ing al & al, set Eflags ZF bit (bit6) to 0/1
                "jne 1b"                        ;jump to 1b if not equal to 1; b=backward,1=label
output  :       "=&S" (tsrc),       ESI         ;parameter 0    &=>early clobber
                "=&D" (tdst),       EDI         ;parameter 1

input   :       "0" (src),                      ;parameter 2
                "1" (dst)                       ;parameter 3
                : "memory"
        );
        return dst;
}
```



d =	01100100
&	01100100
	01100100

not zero --> ZF bit=0

null =	00000000
&	00000000
	00000000

zero --> ZF bit=1

Linux Assembly

hello.asm

```
        .global  _start

        .text
_start:
        movl     $4, %eax          ;syscall number - sys_write
        movl     $1, %ebx          ;file descriptor - stdout; $0 stdin
        movl     $msg, %ecx        ;msg itself
        movl     $len, %edx        ;msg length
        int      $0x80             ;interrupt

        movl     $1, %eax          ;syscall number - sys_exit
        int      $0x80             ;interrupt

        .data
msg:
        .ascii   "Hello, World and Welcome to the Linux Kernel!\n"
        len =    . - msg
```

Commands to genenrate an executable file:

1. as -o hello.o hello.asm
2. ld -o hello hello.o

Essentials for Module Programming

module_init()
module_exit()

/sbin/insmod
/sbin/rmmod
/sbin/lsmod
/sbin/modprobe

messages at /var/log/messages

Hello World Module Programming (see tldp.org)

```
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/init.h>
static int hello_data __initdata=3;

static int hello_init(void)
{
   printk(KERN_INFO "Loading Hello module - Hello, World!\n");
   return 0;
}

static void hello_exit(void)
{
   printk(KERN_INFO "Exiting Hello module - Goodbye, World!\n");
}

module_init(hello_init)
module_exit(hello_exit)
```