



NOVA system call internals

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Execution context

- ▶ In NOVA, execution context (Ec) represents a thread of execution (similar to tasks in other Oses).
- ▶ Data stored in the execution context:

```
class Ec {  
    void      (*cont)(); // Continuation address  
    Exc_regs  regs;      // Registers  
    static Ec * current; // Currently running Ec  
};
```

- ▶ Ec::regs stores user space registers (i.e. syscall parameters)
- ▶ Ec::current is a (global) pointer to the currently executing Ec.
- ▶ First Ec is created in bootstrap(), init.cc:

```
// Create a new Ec with Ec::root_invoke as entry point  
Ec::current = new Ec (Ec::root_invoke, addr);  
// Start executing the new "task" (in kernel space)  
Ec::current->make_current();  
UNREACHED; // This is never executed.
```



Context switch in the kernel

```
void Ec::make_current()
{
    current = this;

    Tss::run.sp0 = reinterpret_cast<mword>(&regs + 1);

    asm volatile ("mov %0, %%esp;"
                 "jmp *%1"
                 :
                 : "g" (KSTCK_ADDR + PAGE_SIZE), "rm" (Ec::cont)
                 : "memory");
    UNREACHED;
}
```

1. Remember which Ec is current
2. Set kernel stack pointer (See “CPU initialization” and “Syscall entry” slides)
3. Reset stack (mov) and jump to address stored in Ec::cont (jmp).



Kernel side of system calls

- ▶ CPU initialization
- ▶ Kernel entry code
- ▶ Syscall handler
- ▶ Kernel exit code



CPU initialization

- ▶ Set Model-Specific Registers (MSR) to tell the CPU what to do when user space invokes the `sysenter` instruction (see `init.cc`, `init()`)

```
Msr::write<mword>(Msr::IA32_SYSENTER_CS,  
                 SEL_KERN_CODE);  
Msr::write<mword>(Msr::IA32_SYSENTER_ESP,  
                 reinterpret_cast<mword>(&Tss::run.sp0));  
Msr::write<mword>(Msr::IA32_SYSENTER_EIP,  
                 reinterpret_cast<mword>(&entry_sysenter));
```

- ▶ CS (code segment) register will be set to kernel code segment
 - ▶ Note that code segment descriptor determines the privilege level of executing code.
- ▶ ESP (stack pointer) will point to `sp0` member of `Tss::run` global variable (see `tss.h`)
- ▶ EIP (instruction pointer) will be set to `entry_sysenter` (see `entry.S`)



Syscall entry

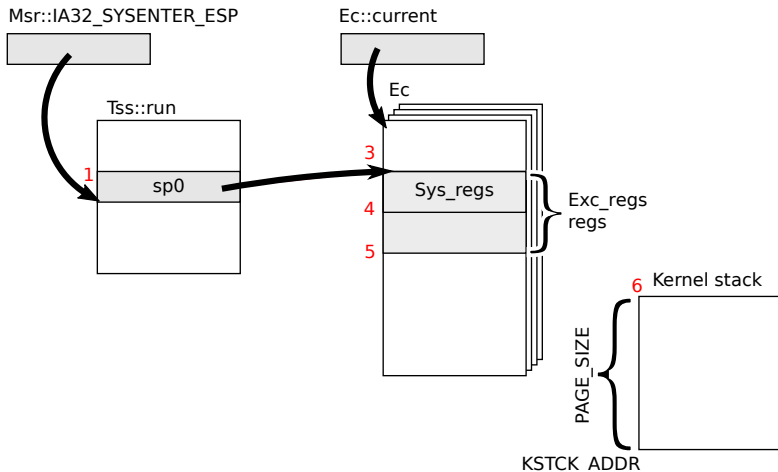
```
1  entry_sysenter:
2      cld
3      pop     %esp
4      lea    -44(%esp), %esp
5      pusha
6      mov    $(KSTCK_ADDR + PAGE_SIZE), %esp
7      jmp    syscall_handler
```

3. Set ESP to the point behind address of `Ec::current->regs` (see `Ec::make_current()` in `ec.h`).
4. Decrease ESP to skip 11 registers that are used only during exception handling (`Exc_regs`)
5. **Store 8 general purpose registers (syscall arguments) to `Ec::current->regs`**
6. Set ESP to the top of kernel stack
7. Jump to `Ec::syscall_handler`



Syscall entry – data structures and stack

Red numbers show the value of the *esp* register after execution of the same-numbered line on the previous slide.





Syscall implementation

- ▶ `Ec::syscall_handler` – A C++ function implementing the syscalls
- ▶ Where do we get the number argument?

```
void Ec::syscall_handler (uint8 number)
{
    switch(number) {
        case 0: ...
        case 1: ...
    }
    ret_user_sysexit();
    UNREACHED; // Tell the compiler to not generate
               // function epilog
}
```




Returning to user space

```
1 void Ec::ret_user_sysexit()
2 {
3     asm volatile ("lea %0, %%esp;"
4                  "popa;"
5                  "sti;"
6                  "sysexit"
7                  : : "m" (current->regs) : "memory");
8     UNREACHED;
9 }
```

3. Set ESP to point `Ec::current->regs`.
4. **Restore 8 general purpose registers from there.**
5. Enable interrupts.
6. Return to user space.



sysenter/sysexit

- ▶ Faster alternative to `int 0x80` and `iret`.
- ▶ Does not use stack to store return address.
- ▶ `sysexit` sets $EIP \leftarrow EDX$, $ESP \leftarrow ECX$ and decreases the privilege level.
- ▶ Therefore the user space `syscall` wrapper must be different from the “`int 0x80`” variant:

```
unsigned syscall1 (unsigned w0) {
    asm volatile (
        "    mov %%esp,%%ecx;"
        "    mov $1f,%%edx;" // set edx to the addr. of label 1:
        "    sysenter;"
        "1:"                // continue here after sysexit
        : "+a" (w0) : : "ecx", "edx", "memory");
    return w0;
}
```