# System Calls and Signals: Communication with the OS

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## System Call

An operation (function) that an OS provides for running applications to use



## Kernel

The core process of the operating system



## strace ./hello

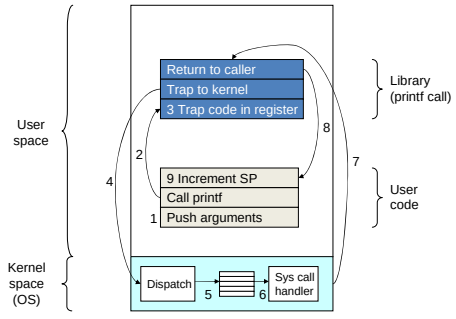
```
fstat(1, {st_mode=S_IFCHR|0600,
  st_rdev=makedev(136, 7), ...}) = 0

mmap(NULL, 4096, PROT_READ|PROT_WRITE,
  MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
  0x2a95557000

write(1, "Hello world!\n", 13Hello world!
)          = 13

exit_group(0)
```

## System Call





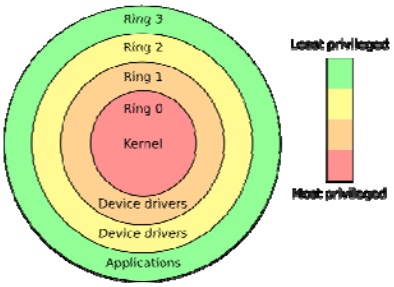

## Context Switch

The act of switching from one process to another

## Context

- General Purpose Registers
- Program counter
- CPU status word
- Stack pointer
- Memory management details

## x86 Privilege Levels




## Linux Syscalls

- 325 syscall slots reserved (2.6.23.1 kernel)
  - Not all are used

| Syscall | Purpose |
|---|---|
| exit | Causes a process to terminate |
| fork | Creates a new process, identical to the current one |
| read | Reads data from a file or device |
| write | Writes data to a file or device |
| open | Opens a file |
| close | Closes a file |
| creat | Creates a file |

## Using Syscalls

```
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>

int main()
{
        int fd;
        char buffer[100];
        strcpy(buffer, "Hello, World!\n");

        fd = open("hello.txt", O_WRONLY | O_CREAT);
        write(fd, buffer, strlen(buffer));
        close(fd);
        exit(0);

        return 0;
}
```

## OR-ing Flags

- Define constants as powers of 2
- Bitwise OR to combine
- Bitwise AND to test

```
#define O_RDONLY      0
#define O_WRONLY      1
#define O_RDWR        2
#define O_CREAT      16
```

## File Descriptors

- Integer identifying a unique open file
  - Similar to FILE *
- OS maintains additional information about the file to do things such as clean up on process termination
- Three standard file descriptors opened automatically:

0 – stdin
1 – stdout
2 – stderr

# fork()

- Creates a new process identical to the calling one
- Return value differs
  - "Child" process return value is 0
  - "Parent" process gets child's process id number
- Often used with execv family of functions to launch a new program

# Fork Example

```
#include <stdio.h>
#include <unistd.h>

int main()
{
        if(fork()==0)
        {
                printf("Hi from the child!\n");
        }
        else
        {
                printf("Hi from the parent\n");
        }

        printf("Hi from both\n");
        return 0;
}
```

# Output

Hi from the child!
Hi from both
Hi from the parent
Hi from both

# Spawning A Program

```
#include <stdio.h>
#include <unistd.h>

int main()
{
        if(fork()==0)
        {
                char *args[3] = {"ls", "-al", NULL};
                execvp(args[0], args);
        }
        else
        {
                int status;
                wait(&status);
                printf("Hi from the parent\n");
        }
        return 0;
}
```

# Signals

- Notifications sent to a program by OS
  - Indicate special events
- Allows for asynchronous notification rather than polling
- Polling – to explicitly ask if something occurred, usually repeatedly

# kill -l

| | | | | |
|---|---|---|---|---|
| **SIGHUP** | **SIGINT** | **SIGQUIT** | **SIGILL** | **SIGTRAP** |
| **SIGABRT** | **SIGBUS** | **SIGFPE** | **SIGKILL** | **SIGUSR1** |
| **SIGSEGV** | **SIGUSR2** | **SIGPIPE** | **SIGALRM** | **SIGTERM** |
| **SIGCHLD** | **SIGCONT** | **SIGSTOP** | **SIGTSTP** | **SIGTTIN** |
| **SIGTTOU** | **SIGURG** | **SIGXCPU** | **SIGXFSZ** | **SIGVTALRM** |
| **SIGPROF** | **SIGWINCH** | **SIGIO** | **SIGPWR** | **SIGSYS** |
| SIGRTMIN | SIGRTMIN+1 | SIGRTMIN+2 | SIGRTMIN+3 | SIGRTMIN+4 |
| SIGRTMIN+5 | SIGRTMIN+6 | SIGRTMIN+7 | SIGRTMIN+8 | SIGRTMIN+9 |
| SIGRTMIN+10 | SIGRTMIN+11 | SIGRTMIN+12 | SIGRTMIN+13 | SIGRTMIN+14 |
| SIGRTMIN+15 | SIGRTMAX-14 | SIGRTMAX-13 | SIGRTMAX-12 | SIGRTMAX-11 |
| SIGRTMAX-10 | SIGRTMAX-9 | SIGRTMAX-8 | SIGRTMAX-7 | SIGRTMAX-6 |
| SIGRTMAX-5 | SIGRTMAX-4 | SIGRTMAX-3 | SIGRTMAX-2 | SIGRTMAX-1 |
| SIGRTMAX | | | | |

## Common Error Signals

- **SIGILL** – Illegal Instruction
- **SIGBUS** – Bus Error, usually caused by bad data alignment or a bad address
- **SIGFPE** – Floating Point Exception
- **SIGSEGV** – Segmentation violation, i.e., a bad address

## Termination Signals

- **SIGINT** – Interrupt, or what happens when you hit CTRL + C
- **SIGTERM** – Ask nicely for a program to end (can be caught)
- **SIGKILL** – Ask meanly for a program to end (cannot be caught)
- **SIGABRT**, **SIGQUIT** – End a program with a core dump

## kill

- kill() is the system call that can send a process a signal (any signal, not just SIGKILL)

```
#include <unistd.h>
#include <sys/types.h>
#include <signal.h>

int main() {
   pid_t my_pid = getpid();
   kill(my_pid, SIGSTOP);
   return 0;
}
```

## kill

- From the shell in UNIX you can send signals to a program.
- Use ps to get a process ID

```
(1) thot $ ps -af
UID        PID  PPID  C STIME TTY          TIME CMD
jrmst106 27500 27470  0 07:13 ???      00:00:00 crashed_program
jrmst106 27507 27474  0 07:13 pts/5    00:00:00 ps -af
```

- kill it!

  `kill 27500` – Sends SIGTERM

  `kill -9 27500` – Sends SIGKILL

## Catching Signals

- Some signals can be caught like exceptions in Java
- Do some cleanup, then exit
- Generally bad to try to continue, the machine might be in a corrupt state
- Some signals can be caught safely though

## SIGALRM

```
#include <unistd.h>
#include <signal.h>

int timer = 10;

void catch_alarm(int sig_num) {
        printf("%d\n",timer--);
        alarm(1);
}

int main() {
        signal(SIGALRM, catch_alarm);

        alarm(1);
        while(timer > 0) ;
        alarm(0);
        return 0;
}
```

## SIGTRAP

- Breakpoint trap
  - Debuggers listen for this
- OS Sends it when breakpoint trap instruction is hit
  - `int 3` on x86
- `int 3` is special (Why?)
  - 1 byte encoding: 0xCC
  - All other traps are two bytes: 0xCD 0x80 (linux syscall)