System Calls

What are they?

- Standard interface to allow the kernel to safely handle user requests
  - Read from hardware
  - Spawn a new process
  - Get current time
  - Create shared memory
- Message passing technique between
  - OS kernel (server)
  - User (client)

Executing System Calls

- User program issues call
- Core kernel looks up call in syscall table
- Kernel module handles syscall action
- Module returns result of system call
- Core kernel forwards result to user

Module is not Loaded...

- User program issues call
- Core kernel looks up call in syscall table
- Kernel module isn't loaded to handle action
- ...
- Where does call go?

System Call Wrappers

- Wrapper calls system call if it is loaded
  - Otherwise it returns an error
- Needs to be in a separate location so that the function can actually be called
  - Uses a function pointer to point to the kernel module implementation
- You'll need to create a system call wrapper for each system call you add

Adding System Calls

- For project 2, you'll need to add and implement:
  - int start_elevator(void);
  - int issue_request(int, int, int);
  - int stop_elevator(void);
- As an example, let's add a call to printk an argument passed in:
  - int test_call(int);

Adding System Calls

- Files to add (module files):
  - /usr/src/test_kernel/example3_syscall/
  - /usr/src/test_kernel/example3_syscall/test_call.c
  - /usr/src/test_kernel/example3_syscall/hello.c
  - /usr/src/test_kernel/example3_syscall/Makefile
- Files to modify (core kernel):
  - /usr/src/test_kernel/arch/x86/entry/syscalls/syscall_64.tbl
  - /usr/src/test_kernel/include/linux/syscalls.h
  - /usr/src/test_kernel/Makefile

example3_syscall/test_call.c

```
#include <linux/linkage.h>
#include <linux/kernel.h>
#include <linux/module.h>

/* System call stub */
long (*STUB_test_call)(int) = NULL;
EXPORT_SYMBOL(STUB_test_call);

/* System call wrapper */
asmlinkage long sys_test_call(int test_int) {
  if (STUB_test_call != NULL)
    return STUB_test_call(test_int)
  else
    return -ENOSYS;
}
```

Holds syscall pointer
Exports pointer for public use
Defines syscall wrapper

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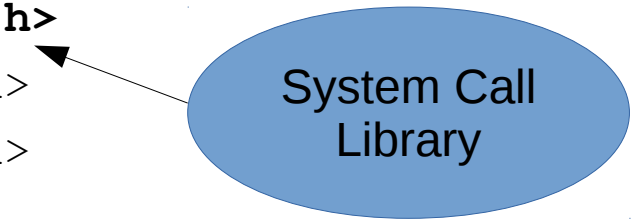

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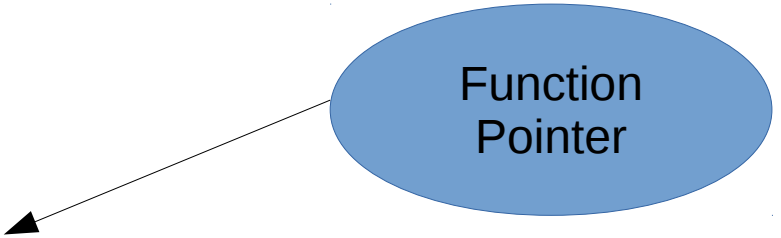

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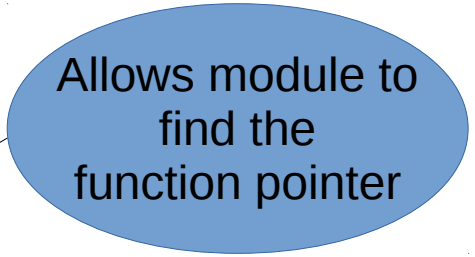

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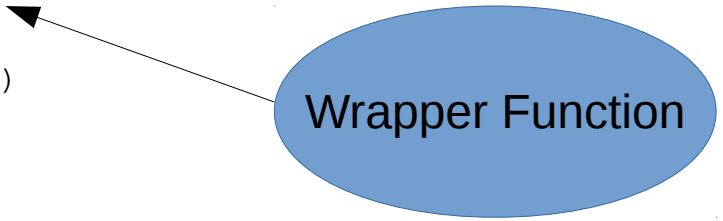

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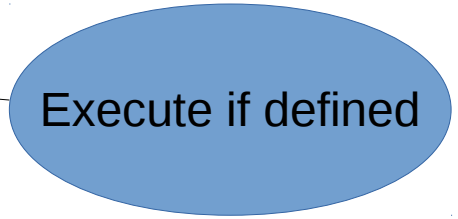

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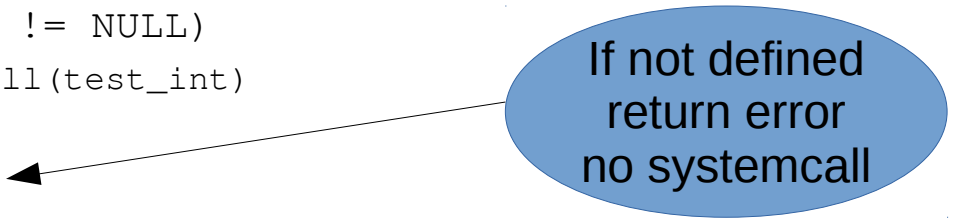

example3_syscall/hello.c

```
extern long (*STUB_test_call)(int test_int);
long my_test_call(int test) {
  printk("%s: Your int is %i\n", __FUNCTION__, test);
  return test;
}
my_module_init() {
  STUB_test_call = my_test_call;
  return 0;
}
my_module_exit() {
  STUB_test_call = NULL;
}
```

Holds module code
Registers syscall pointer
Implements syscall behavior

example3_syscall/hello.c

```
extern long (*STUB_test_call)(int);
long my_test_call(int test) {
  printk("%s: Your int is %i\n", __FUNCTION__
  return test;
}
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  return 0;
}
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  STUB_test_call = NULL;
}
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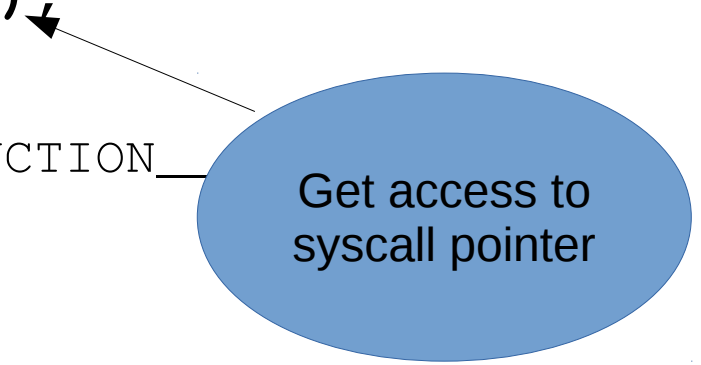
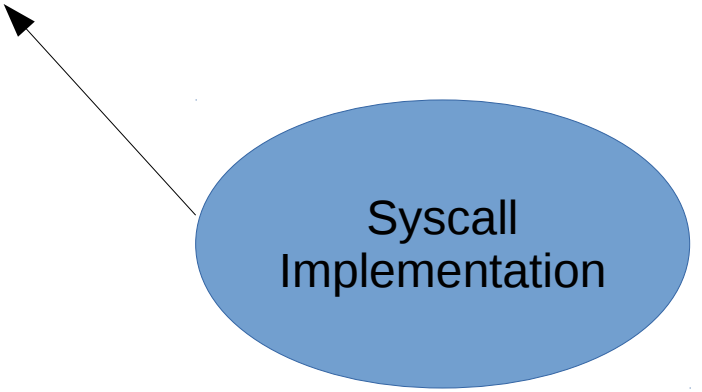


example3_syscall/hello.c

```
extern long (*STUB_test_call)(int);
long my_test_call(int test) {
  printk(KERN_NOTICE "%s: Your int is %d\n", __FUNCTION__, test);
  return test;
}
my_module_init() {
  STUB_test_call = my_test_call;
  return 0;
}
my_module_exit() {
  STUB_test_call = NULL;
}
```



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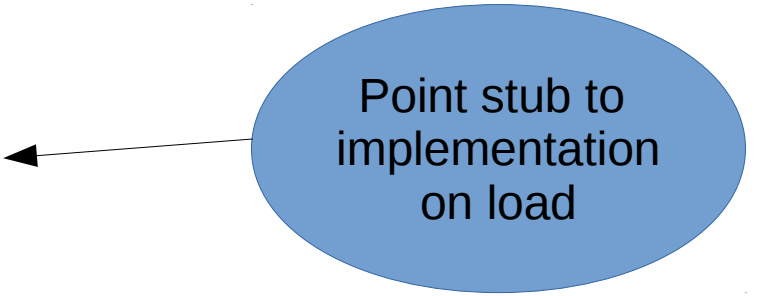

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}
my_module_init() {
  STUB_test_call =& (my_test_call);
  return 0;
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my_module_exit() {
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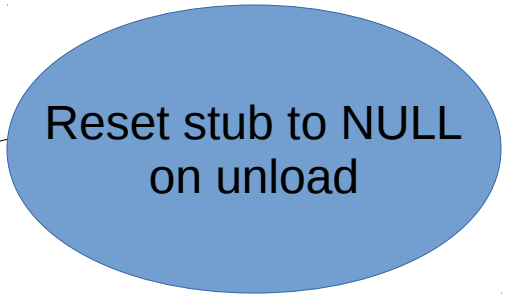

example3_syscall/Makefile

```
obj-y := test_call.o
obj-m := hello.o

PWD := $(shell pwd)
KDIR := /lib/modules/`uname -r`/build

default:
  $(MAKE) -C $(KDIR) SUBDIRS=$(PWD) modules

clean:
  Rm -f *.o *.ko *.mod.* Module.* modules.*
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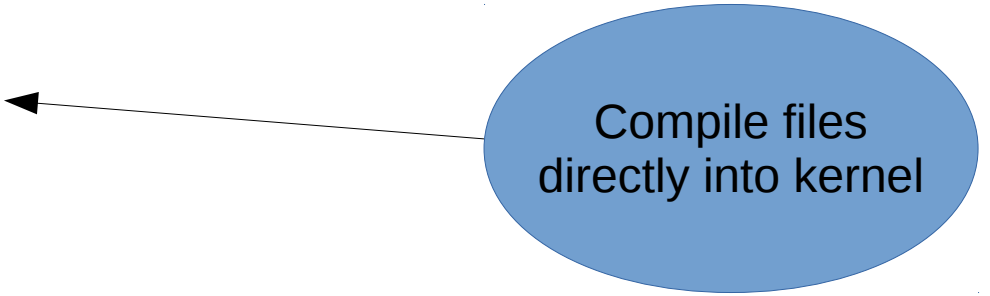

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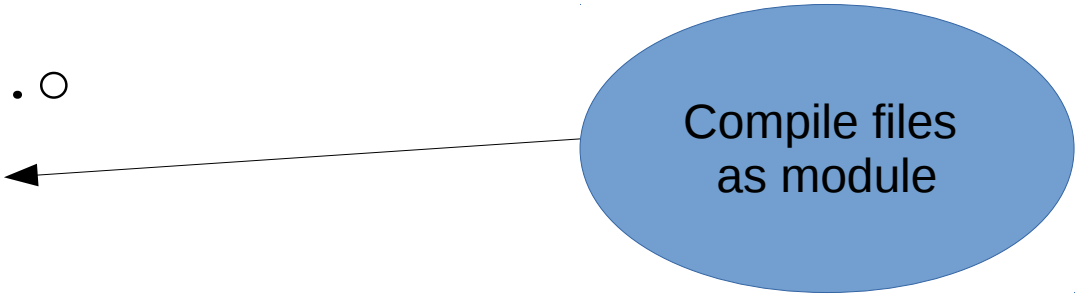

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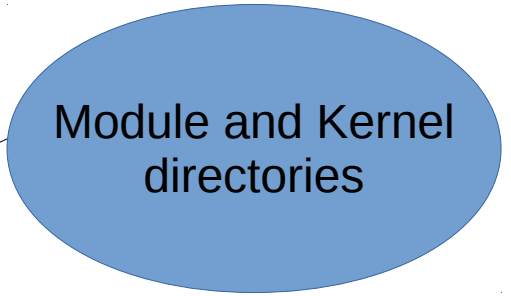

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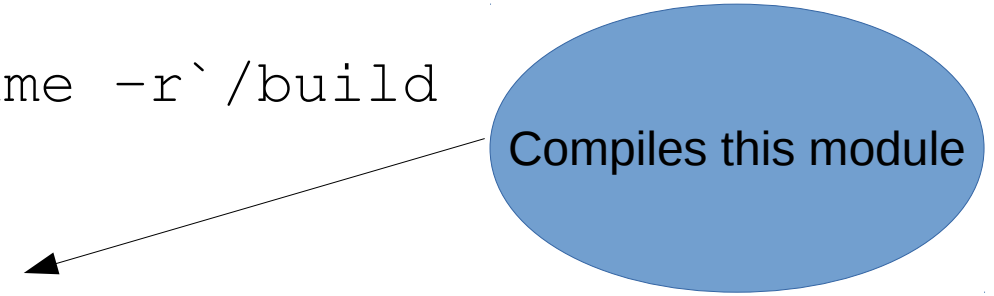

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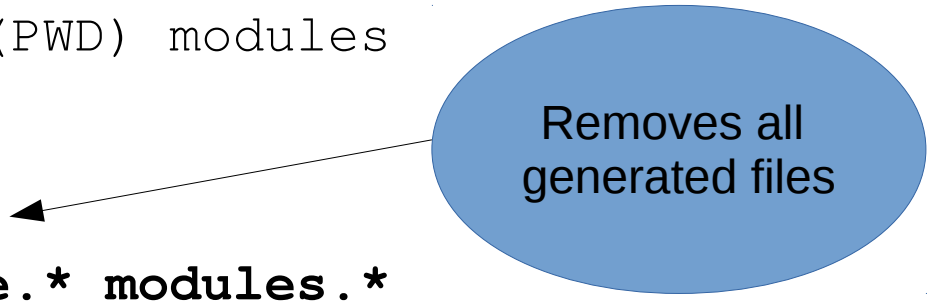

arch/x86/entry/syscalls/syscall_64.tbl

```
327     64      preadv2         sys_preadv2
328     64      pwritev2        sys_pwritev2
329     common  pkey_mprotect   sys_pkey_mprotect
330     common  pkey_alloc      sys_pkey_alloc
331     common  pkey_free       sys_pkey_free
332     common  statx           sys_statx
333     common  test_call       sys_test_call
```

Line:342

System call table

Remember syscall numbers for userspace applications

```
#
# x32-specific system call numbers start at 512 to avoid cache impact
# for native 64-bit operation.
#
512     x32     rt_sigaction            compat_sys_rt_sigaction
513     x32     rt_sigreturn            stub_x32_rt_sigreturn
514     x32     ioctl                       compat_sys_ioctl
515     x32     readv                    compat_sys_readv
```

include/linux/syscalls.h

```
Asmlinkage long sys_copy_file_range(int fd_in, loff_t __user *off_in,
                                    int fd_out, loff_t __user *off_out,
                                    size_t len, unsigned int flags);

asmlinkage long sys_mlock2(unsigned long start, size_t len, int flags);

asmlinkage long sys_pkey_mprotect(unsigned long start, size_t len, unsigned
                                  long prot, int pkey);
asmlinkage long sys_pkey_alloc(unsigned long flags, unsigned long init_val);
asmlinkage long sys_pkey_free(int pkey);
asmlinkage long sys_statx(int dfd, const char __user *path, unsigned flags,
                          unsigned mask, struct statx __user *buffer);

asmlinkage long sys_test_call(int test_int);

#endif
```

End of Document

Defines syscall prototype

./Makefile

Line:953

Directories that have files to be built directly into the kernel

```
...
ifeq ($(KBUILD_EXTMOD),)
core-y          += kernel/ certs mm/ fs/ ipc/ security/ crypto/ block/ example3_syscall/

vmlinux-dirs    := $(patsubst %/,%,$(filter %/, $(init-y) $(init-m) \
                     $(core-y) $(core-m) $(drivers-y) $(drivers-m) \
                     $(net-y) $(net-m) $(libs-y) $(libs-m) $(virt-y)))

vmlinux-alldirs := $(sort $(vmlinux-dirs) $(patsubst %/,%,$(filter %/, \
                     $(init-) $(core-) $(drivers-) $(net-) $(libs-) $(virt-))))

init-y          := $(patsubst %/, %/built-in.o, $(init-y))
core-y          := $(patsubst %/, %/built-in.o, $(core-y))
drivers-y       := $(patsubst %/, %/built-in.o, $(drivers-y))
net-y           := $(patsubst %/, %/built-in.o, $(net-y))
libs-y1         := $(patsubst %/, %/lib.a, $(libs-y))
libs-y2         := $(filter-out %.a, $(patsubst %/, %/built-in.o, $(libs-y)))
virt-y          := $(patsubst %/, %/built-in.o, $(virt-y))
...
```

User-space Program

```
#include <sys/syscall.h>
#define __NR_TEST_CALL  333

int test_call(int test) {
  return syscall(__NR_TEST_CALL, test);
}

int main(int argc, char **argv) {
  if argc != 2)
    perror(“wrong number of args”);

  int test = atoi(argv[1]);
  long ret = test_call(test);

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  long ret = test_call(test);
  if (ret < 0)
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  else
    printf(“Function successful, passed in %d, returned %d\n”, test, ret);
  return 0;
}
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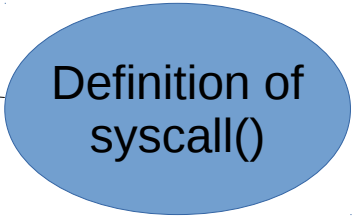
User-space Program

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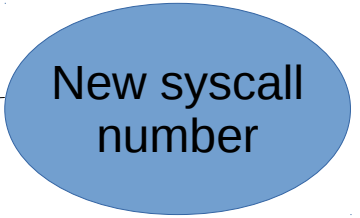


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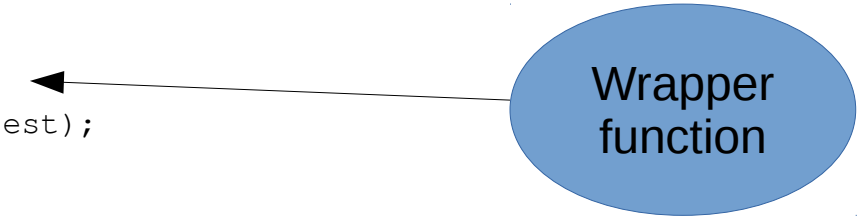

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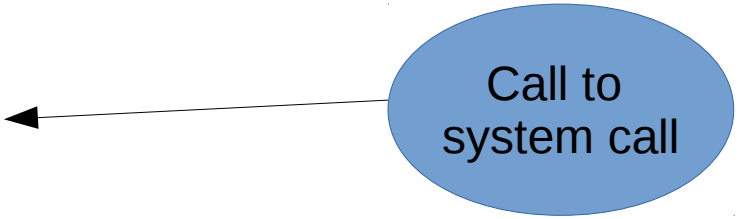

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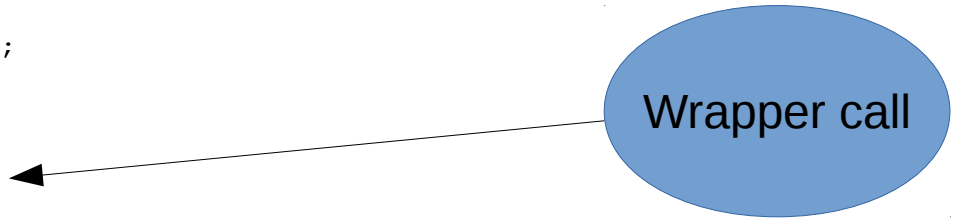

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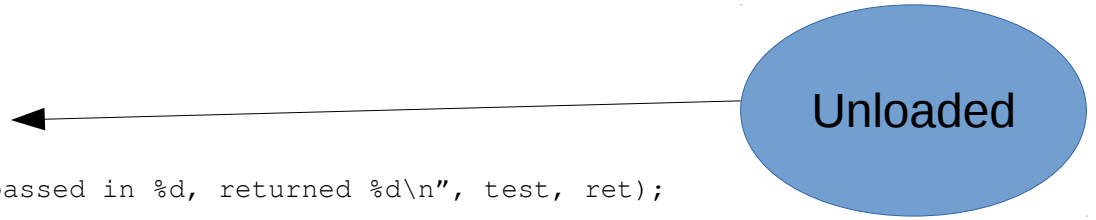

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  long ret = test_call(test);

  int test = atoi(argv[1]);
  long ret = test_call(test);
  if (ret < 0)
    perror("system call error");
  else
    printf("Function successful, passed in %d, returned %d\n", test, ret);
  return 0;
}
```

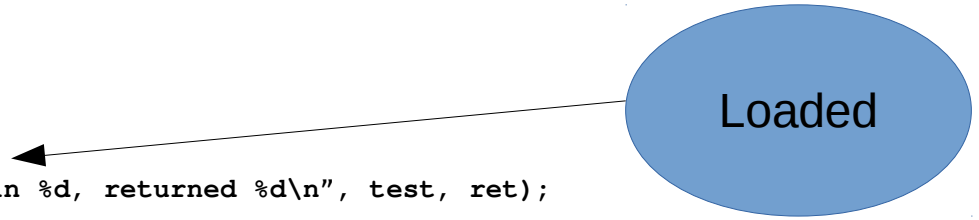

Notes

- To use this example you'll need to edit various files by hand in addition to downloading the module
  - Edit all files outside of the module
- The system call number of this example is the same as that of start_elevator (since it's the next available slot)
  - So you may either want to add this after adding these elevator calls (and change the number)
  - Or go back and replace it with them later
- Adding new system calls (and anything to the kernel proper) requires recompiling and reinstalling the entire kernel
  - If you get unknown symbol errors, that's probably why