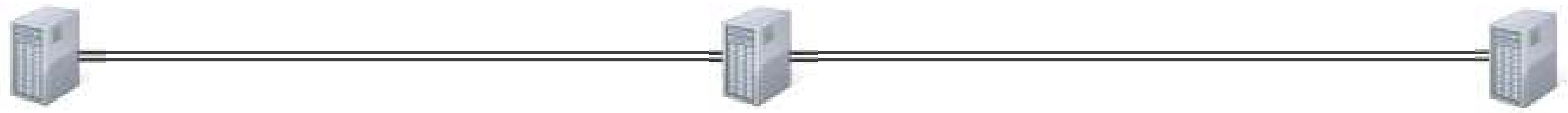
Operating Systems

(Signals)



Deepika H V

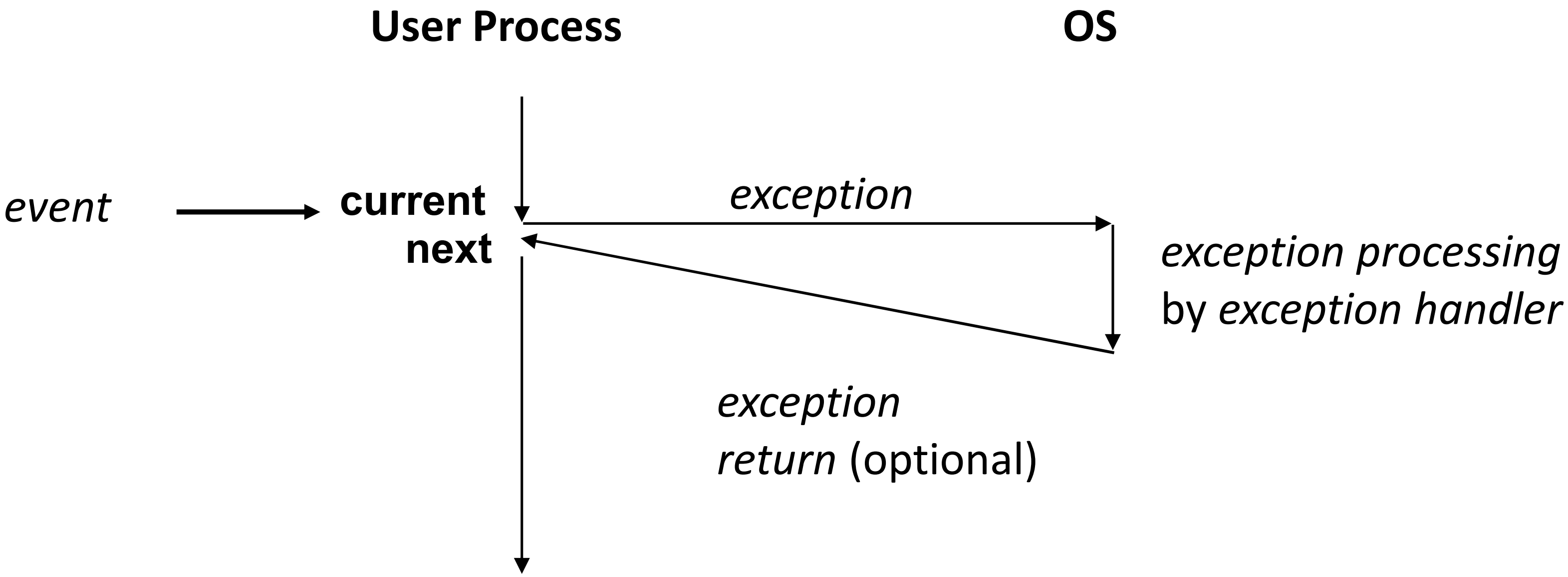
System Software for HPC

C-DAC Bangalore

(deepikahv@cdac.in)

Interrupts

- A exception that causes a processor to (temporarily) transfer control to another program, or function.
- When that function completes, control is (typically) returned to the interrupted process, which resumes from the point it was interrupted



User Process
OS
event
current
next
exception
exception processing by *exception handler*
exception *return* (optional)

Interrupt

Teacher ←is→ OS

Students ←is→ I/O device

Types

- **Hardware Interrupts**
  - asynchronous entities
  - typically employed to provide an effective means for a system to react to outside stimuli.
- **Software Interrupts (Exceptions)**
  - Has both synch and asynch
  - Exceptions generated by processes.
  - Caused by events that occur as result of executing an instruction

Hardware Interrupts

- **I/O interrupts**
  - hitting ctl-c at the keyboard
  - arrival of a packet from a network
  - arrival of a data sector from a disk
- **Hard reset interrupt**
  - hitting the reset button
- **Soft-reset interrupts**
  - hitting ctl-alt-delete on a PC

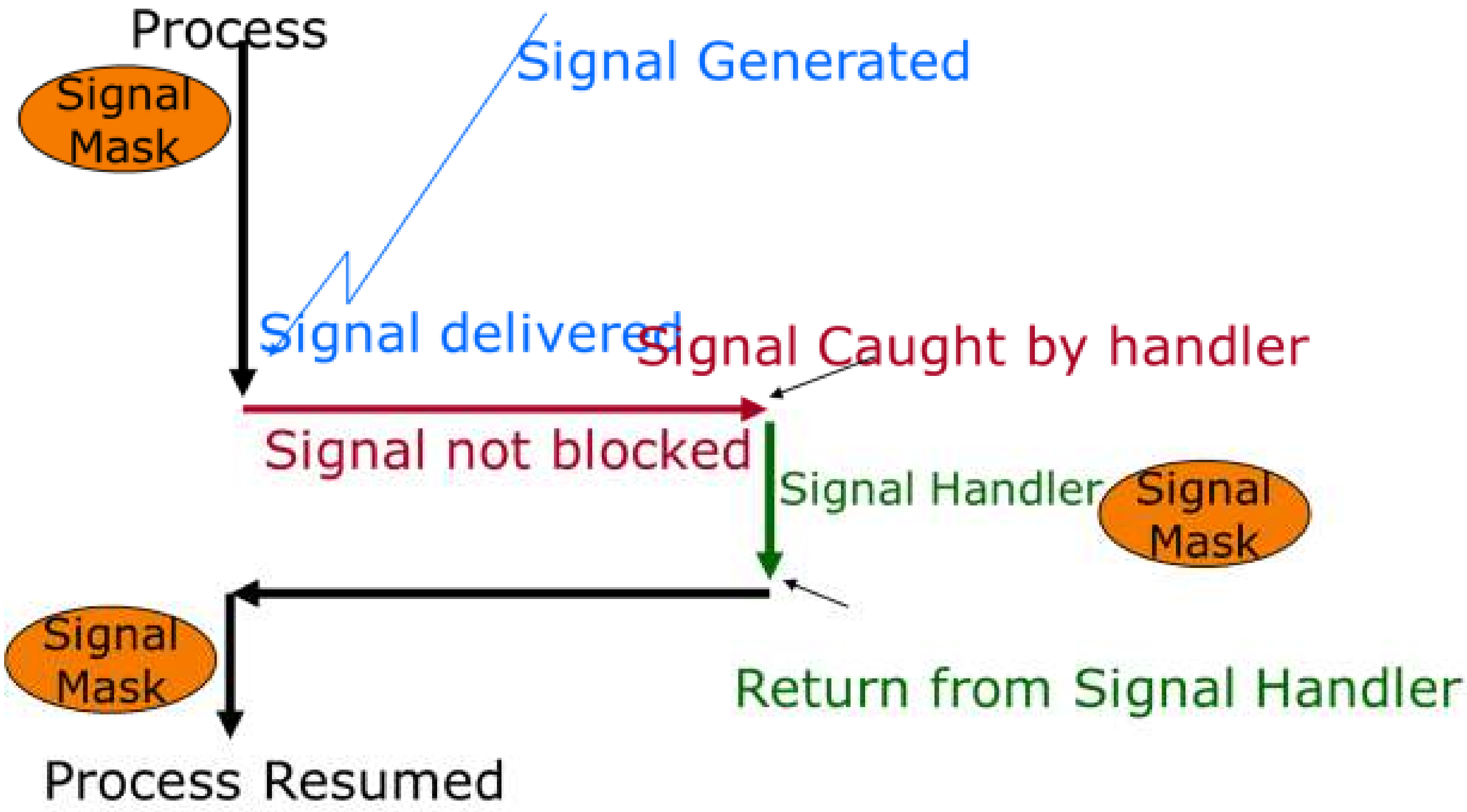
Software Interrupts

- **Traps**
  - Intentional - system calls, breakpoint traps, special instruction
  - Returns control to “next” instruction
- **Faults**
  - Unintentional but possibly recoverable - page faults.
  - Either re-executes faulting instruction.
- **Aborts**
  - unintentional and unrecoverable -parity error, machine check.
  - Aborts current program

Signals

- **A notification of an event**
  - Event gains attention of the OS
  - OS stops the current process, sending it a signal
  - Signal handler executes to completion
  - Application process resumes where it left off
- **Different signals are identified by small integer ID's**

ID	Name	Default Action	Corresponding Event
2	SIGINT	Terminate	Interrupt from keyboard (ctl-c)
9	SIGKILL	Terminate	Kill program (cannot override or ignore)
11	SIGSEGV	Terminate & Dump	Segmentation violation
14	SIGALRM	Terminate	Timer signal
17	SIGCHLD	Ignore	Child stopped or terminated


Process
Signal Mask
Signal Generated
Signal delivered
Signal Caught by handler
Signal not blocked
Signal Handler
Signal Mask
Signal Mask
Return from Signal Handler
Process Resumed

Signal Masks

- **Process can temporarily prevent signal from being delivered by *blocking* it.**
- ***Signal Mask* contains a set of signals currently blocked.**
- **Important! Blocking a signal is different from ignoring signal. Why?**
  - When a process blocks a signal, the OS does not deliver signal until the process unblocks the signal
  - A *blocked* signal is not delivered to a process until it is unblocked.
  - When a process ignores signal, signal is delivered and the process handles it by throwing it away.

Sending a signal

- **Kernel sends (delivers) a signal to a destination process by updating some state in the context of the destination process**
- **Kernel sends a signal for one of the following reasons:**
  - Kernel has detected a system event such as divide by zero (SIGFPE) or termination of a child process (SIGCHLD)
  - Another process has invoked the kill system call to explicitly request that the kernel send a signal to the destination process

Receiving

- **A destination process receives a signal when it is forced by the kernel to react in some way to the delivery of the signal**
- **Five possible ways to react:**
  - Ignore the signal (do nothing)
  - Terminate the process
  - Temporarily stop the process from running
  - Continue a stopped process (let it run again)
  - Catch the signal by executing a user-level function called a signal handler

predefined signals:

```
$ kill -l
 1) SIGHUP       2) SIGINT       3) SIGQUIT      4) SIGILL
 5) SIGTRAP      6) SIGABRT      7) SIGBUS       8) SIGFPE
 9) SIGKILL     10) SIGUSR1     11) SIGSEGV     12) SIGUSR2
13) SIGPIPE     14) SIGALRM     15) SIGTERM     17) SIGCHLD
18) SIGCONT     19) SIGSTOP     20) SIGTSTP     21) SIGTTIN
22) SIGTTOU     23) SIGURG      24) SIGXCPU     25) SIGXFSZ
26) SIGVTALRM   27) SIGPROF     28) SIGWINCH    29) SIGIO
30) SIGPWR      31) SIGSYS      34) SIGRTMIN    35) SIGRTMIN+1
36) SIGRTMIN+2  37) SIGRTMIN+3  38) SIGRTMIN+4  39) SIGRTMIN+5
40) SIGRTMIN+6  41) SIGRTMIN+7  42) SIGRTMIN+8  43) SIGRTMIN+9
44) SIGRTMIN+10 45) SIGRTMIN+11 46) SIGRTMIN+12 47)
    SIGRTMIN+13
48) SIGRTMIN+14 49) SIGRTMIN+15 50) SIGRTMAX-14 51) SIGRTMAX-
    13
52) SIGRTMAX-12 53) SIGRTMAX-11 54) SIGRTMAX-10 55) SIGRTMAX-9
56) SIGRTMAX-8  57) SIGRTMAX-7  58) SIGRTMAX-6  59) SIGRTMAX-5
60) SIGRTMAX-4  61) SIGRTMAX-3  62) SIGRTMAX-2  63) SIGRTMAX-1
64) SIGRTMAX
```

Signals via keyboards

- **Ctrl-c -> 2/SIGINT signal**
  - Default handler exits process
- **Ctrl-z -> 20/SIGTSTP signal**
  - Default handler suspends process
- **Ctrl-\ -> 3/SIGQUIT signal**
  - Default handler exits process
- **Check using stty -a**

Signal via commands

- **kill -signal pid**
  - Send a signal of type signal to the process with id pid
  - Can specify either signal type name (-SIGINT) or number (-2)
- **No signal type name or number specified => sends 15/SIGTERM signal**
  - Default 15/SIGTERM handler exits process
- **Examples**
  - kill –2 1234
  - kill -SIGINT 1234

Signal via function call – raise()

- **int raise(int iSig);**
  - Commands OS to send a signal of type iSig to current process
  - Returns 0 to indicate success, non-0 to indicate failure

- **Example**

```
int ret = raise(SIGINT); /* Process commits suicide. */
assert(ret != 0);        /* Shouldn't get here. */
```

Signal via function call – kill()

- **int kill(pid_t iPid, int iSig);**
  - Sends a iSig signal to the process whose id is iPid
  - Equivalent to raise(iSig) when iPid is the id of current process

- **Example**

```
pid_t iPid = getpid(); /* Process gets its id.*/
kill(iPid, SIGINT);
```

Signal via function call - signal

- **sighandler_t signal(int iSig, sighandler_t pfHandler);**
  - Installs function pfHandler as the handler for signals of type iSig
  - pfHandler is a function pointer:

- **Returns the old handler on success, SIG_ERR on error**

- **pfHandler is invoked whenever process receives a signal of type iSig**

Predefined Signal

```
int main(void) {
   void (*pfRet)(int);
   pfRet = signal(SIGINT, SIG_IGN);
   …
}
```

```
…
static FILE *psFile; /* Must be global. */
static void cleanup(int iSig) {
   fclose(psFile);
   remove("tmp.txt");
   exit(EXIT_FAILURE);
}
int main(void) {
   void (*pfRet)(int);
   psFile = fopen("temp.txt", "w");
   pfRet = signal(SIGINT, cleanup);
   …
   raise(SIGINT);
   return 0;  /* Never get here. */
}
```

Signal sets

- Signal set is of type sigset_t
- Signal sets are manipulated by five functions:
  - #include <signal.h>
  - int sigemptyset(sigset_t *set);
  - int sigfillset(sigset_t *set);
  - int sigaddset(sigset_t *set, int signo);
  - int sigdelset(sigset_t *set, int signo);

Each process has a signal mask in the kernel

- OS uses the mask to decide which signals to deliver
- User program can modify mask with **`sigprocmask()`**

`sigprocmask()`

```
int sigprocmask(int iHow, const sigset_t *psSet,sigset_t
    *psOldSet);
```

- **`psSet`**: Pointer to a signal set
- **`psOldSet`**: (Irrelevant for our purposes)
- **`iHow`**: How to modify the signal mask
  - **`SIG_BLOCK:`** Add **`psSet`** to the current mask
  - **`SIG_UNBLOCK:`** Remove **`psSet`** from the current mask
  - **`SIG_SETMASK:`** Install **`psSet`** as the signal mask
- Returns 0 iff successful

Functions for constructing signal sets

- **`sigemptyset(), sigaddset(),`** …

Note: No parallel function in C90

Terminologies

- Signal generated
- Signal Delivered
- Lifetime
- Pending
- Signal catched
- Signal ignored
- Signal blocked

THANK YOU