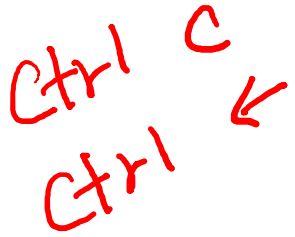
Signals and Signal Handling – Part 1

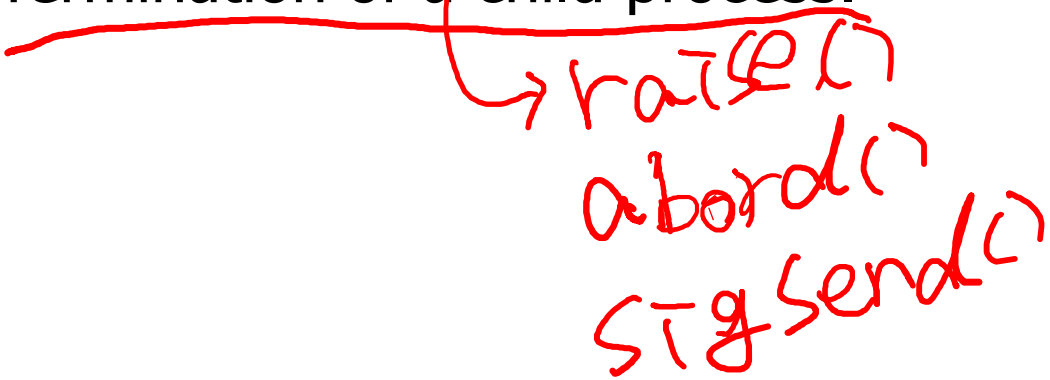
What Is Signals?

- A primitive way of doing IPC and most widely known UNIX facility.
  - Be used to inform processes of *asynchronous* events.
  - Posted by one process and received by another or the same process.
  - An asynchronous event either terminates a process or is simply being ignored.
  - Signal handling
    - Default (SIG_DFL)
    - Ignored (SIG_IGN)
    - User-defined

Signal Generation

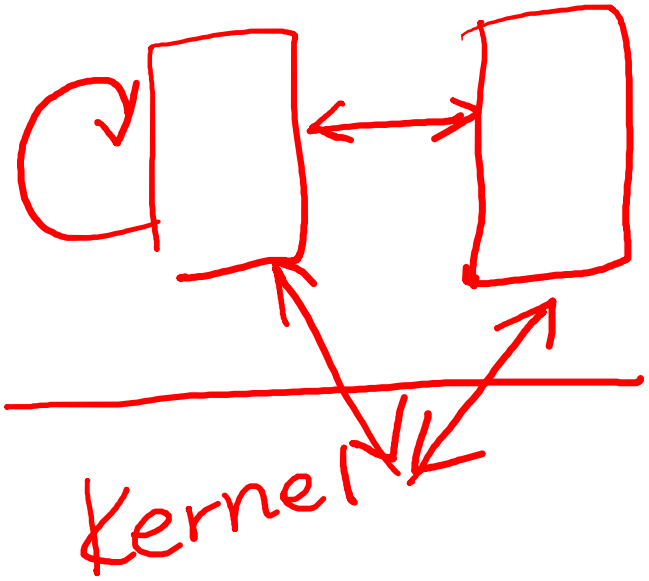
- A signal is generated when (not a complete list):
  - A hardware exception occurs.
  - Interrupt or quit from control terminal.
  - An alarm timer expires.
  - A call to kill( ).
  - Termination of a child process.





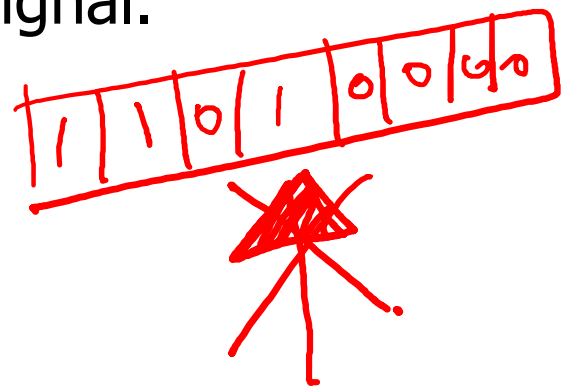
Signal Usage

- Signals can be used:
  - Intraprocess
    - With the same user ID
  - Interprocesses
  - Between kernel to any process.



Signal States

- A signal is said to be:
  - *Generated* when the event that causes the signal occurs.
  - *Delivered* when the action for a signal is taken.
  - *Pending* during the time between the generation of the signal and its delivery.
  - *Blocked* if unable to deliver due to a signal mask bit being set for the signal.



Signal Disposition

- Default action (SIG_DFL)
  - Termination in general.
- Ignored (SIG_IGN)
  - Never posted to the process.
- User-defined action
  - Needs a user-defined *signal handler*, or *signal-catching function*.
  - Most signals can be caught, or ignored except SIGKILL and SIGSTOP.

Linux Signals (1)

```
SIGHUP      1   /* Hangup (POSIX).  terminate w/ core */
SIGINT      2   /* Interrupt (ANSI).  terminate */
SIGQUIT     3   /* Quit (POSIX). terminate w/ core */
SIGILL      4   /* Illegal instruction (ANSI). terminate w/ core */
SIGTRAP     5   /* Trace trap (POSIX). terminate w/ core */
SIGABRT     6   /* Abort (ANSI). terminate w/ core */
SIGIOT      6   /* IOT trap (4.2 BSD). terminate w/ core */
SIGBUS      7   /* BUS error (4.2 BSD). terminate w/ core */
SIGFPE      8   /* Floating-point exception (ANSI). terminate w/ core */
SIGKILL     9   /* Kill, unmaskable (POSIX). terminate */
SIGUSR1     10  /* User-defined signal 1 (POSIX). terminate */
```

Linux Signals (2)

```
SIGSEGV     11  /* Segmentation violation(ANSI). terminate w/ core */
SIGUSR2     12  /* User-defined signal 2 (POSIX). terminate */
SIGPIPE     13  /* Broken pipe (POSIX). terminate */
SIGALRM     14  /* Alarm clock (POSIX). terminate */
SIGTERM     15  /* Termination (ANSI). terminate */
SIGSTKFLT   16  /* Stack fault. terminate w/ core */
SIGCLD      SIGCHLD /* Same as SIGCHLD (System V). */
SIGCHLD     17  /* Child status has changed(POSIX). ignore */
SIGCONT     18  /* Continue (POSIX). continue/ignore */
SIGSTOP     19  /* Stop, unmaskable (POSIX). stop process */
SIGTSTP     20  /* Keyboard stop (POSIX). stop process */
SIGTTIN     21  /* Background read from tty (POSIX). stop process */
SIGTTOU     22  /* Background write to tty (POSIX). stop process */
```

Linux Signals (3)

```
SIGURG      23  /* Urgent condition on socket (BSD). ignore */
SIGXCPU     24  /* CPU limit exceeded (BSD). terminate w/ core */
SIGXFSZ     25  /* File size limit exceeded (BSD). terminate w/ core */
SIGVTALRM   26  /* Virtual alarm clock (BSD). terminate */
SIGPROF     27  /* Profiling alarm clock (BSD). terminate */
SIGWINCH    28  /* Window size change (BSD,Sun). ignore */
SIGPOLL     SIGIO   /* Pollable event occurred (System V). terminate */
SIGIO       29  /* I/O now possible (BSD). terminate/ignore */
SIGPWR      30  /* Power failure restart (System V). ignore */
SIGUNUSED   31
```

Signal Sets

- Signal sets are one of the main parameters passed to system calls that deal with signals
- A list of signals you want to do something with
- To manipulate signal sets, a new data type known as sigset_t with the following five predefined functions is specified in POSIX.1:
  - sigemptyset( )
  - sigfillset( )
  - sigaddset( )
  - sigdelset( )
  - sigismember( )

sigandset
" or "
sig is emptyset

Signal Set (1)

- #include <signal.h>

  int sigemptyset(sigset_t *set);
  - Initializes the signal set given by set to empty, with all signals excluded from the set.
  - Return 0 on success and -1 on error.
- int sigfillset(sigset_t *set);
  - Initializes set to full, including all signals.
  - Return 0 on success and -1 on error.

Signal Set (2)

- int sigaddset(sigset_t *set, int *signum*);
  - Add signal *signum* from *set*.
  - Return 0 on success and -1 on error.
- int sigdelset(sigset_t *set, int *signum*);
  - Delete signal *signum* from *set*.
  - Return 0 on success and -1 on error.
- int sigismember(const sigset_t *set, int *signum*);
  - Tests whether *signum* is a member of *set*.
  - Returns 1 if *signum* is a member of set, 0 if *signum* is not a member, and -1 on error.

Example #1: Signal Sets

```c
#include <stdio.h>
#include <signal.h>

int main(){
  sigset_t mask1, mask2;
  //..
  /* create empty set */
  sigemptyset(&mask1);

  /* add signals */
  sigaddset(&mask1, SIGINT);
  sigaddset(&mask1, SIGQUIT);
  //..
  /* create full set */
  sigfillset(&mask2);

  /* remove signal */
  sigdelset(&mask2, SIGCHLD);
  //..
}
```

sigaction (1)

- #include <signal.h>

  int sigaction(int *signum*, const struct sigaction **act*, struct sigaction **oldact*);
  - Change the action taken by a process on receipt of a specific signal.
  - Return 0 on success and -1 on error.
  - *signum*
    - Specifies the signal and can be any valid signal except SIGKILL and SIGSTOP.
  - If *act* is non-NULL, the new action for signal *signum* is installed from *act*.
  - If *oldact* is non-null, the previous action is saved in *oldact*.

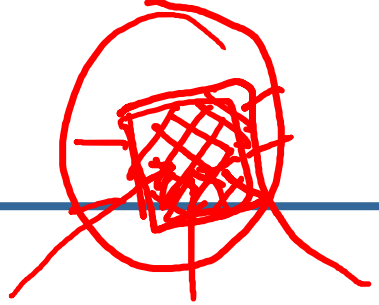
sigaction (2)

- sigaction structure

```
struct sigaction {
    union {
      void (*sa_handler)(int);
      void (*sa_sigaction)(int, siginfo_t *, void *);
    } __sigaction_handler;
    sigset_t sa_mask;
    int sa_flags;
};
```

- sa_handler
  - Specifies the action to be associated with *signum* and may be SIG_DFL for the default action.
  - SIG_IGN to ignore this signal, or a pointer to a signal handling function.

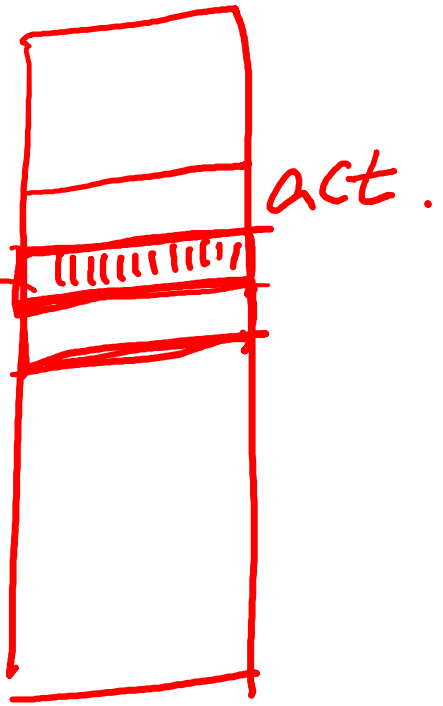
sigaction (3)



- sa_sigaction(int, siginfo_t *, void *)
  - If sa_flags is set to SA_SIGINFO, extra information will be passed to the signal handler. In this case, sa_sigaction() is used
- sa_mask
  - Gives a mask of signals which should be blocked during execution of the signal handler.
- sa_flags
  - Specifies a set of flags which modify the behavior of the signal handling process.
  - It is formed by the bitwise OR of zero or more of the following:
    - SA_NOCLDSTOP
      - » If *signum* is SIGCHLD, do not receive notification when child processes stop.
    - SA_RESETHAND
      - » Restore the signal action to the default state once the signal handler has been called.

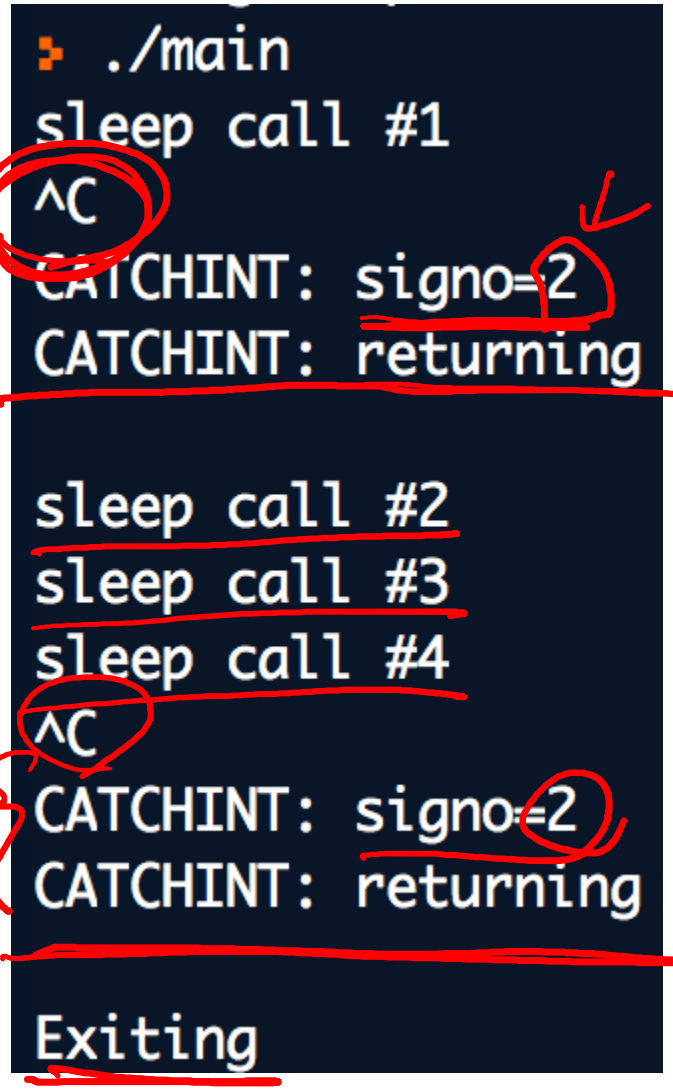
Example #2: catching SIGINT (1)

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

void catchint (int signo) {
  printf ("\nCATCHINT: signo=%d\n", signo);
  printf("CATCHINT: returning\n\n");
  return;
}

int main() {
  static struct sigaction act;
  act.sa_handler = catchint;

  sigfillset(&(act.sa_mask));
  sigaction(SIGINT, &act, NULL);

  printf ("sleep call #1\n");
  sleep (1);
```



Example #2: catching SIGINT (2)

```
  printf ("sleep call #2\n");
  sleep (1);

  printf ("sleep call #3\n");
  sleep (1);

  printf ("sleep call #4\n");
  sleep (1);

  printf ("Exiting\n");
  return 0;
}
```

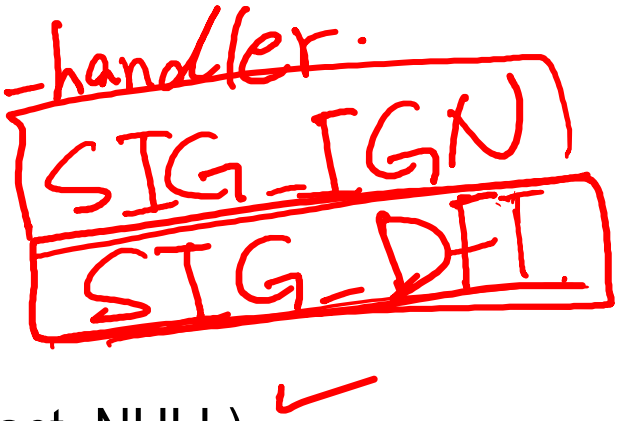


Example #3: ignoring SIGINT

- Just replace the following line in the example #2 program
  - act.sa_handler = catchint;

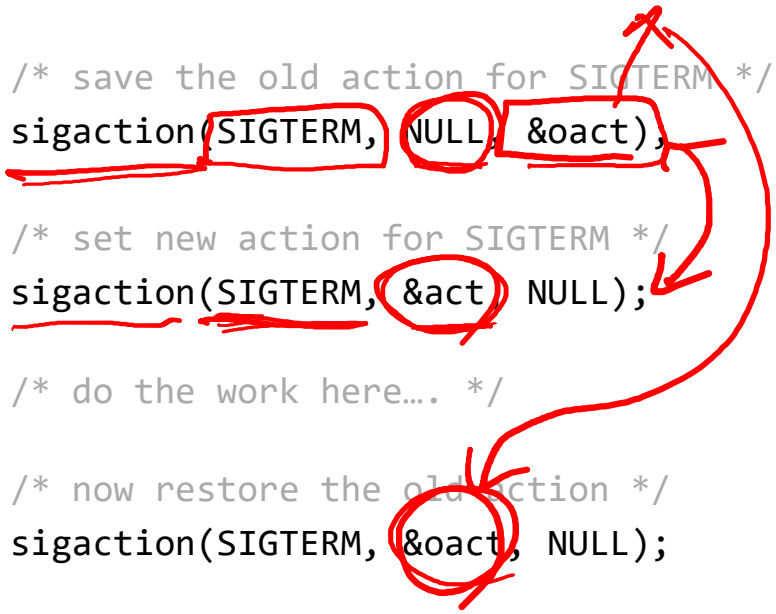
  With:
  - act.sa_handler = SIG_IGN;

  And then call sigaction(SIGINT, &act, NULL)



Example #4: restoring a previous action

```
#include <signal.h>

  static struct sigaction act, oact;

  /* save the old action for SIGTERM */
  sigaction(SIGTERM, NULL, &oact);

  /* set new action for SIGTERM */
  sigaction(SIGTERM, &act, NULL);

  /* do the work here…. */

  /* now restore the old action */
  sigaction(SIGTERM, &oact, NULL);
```

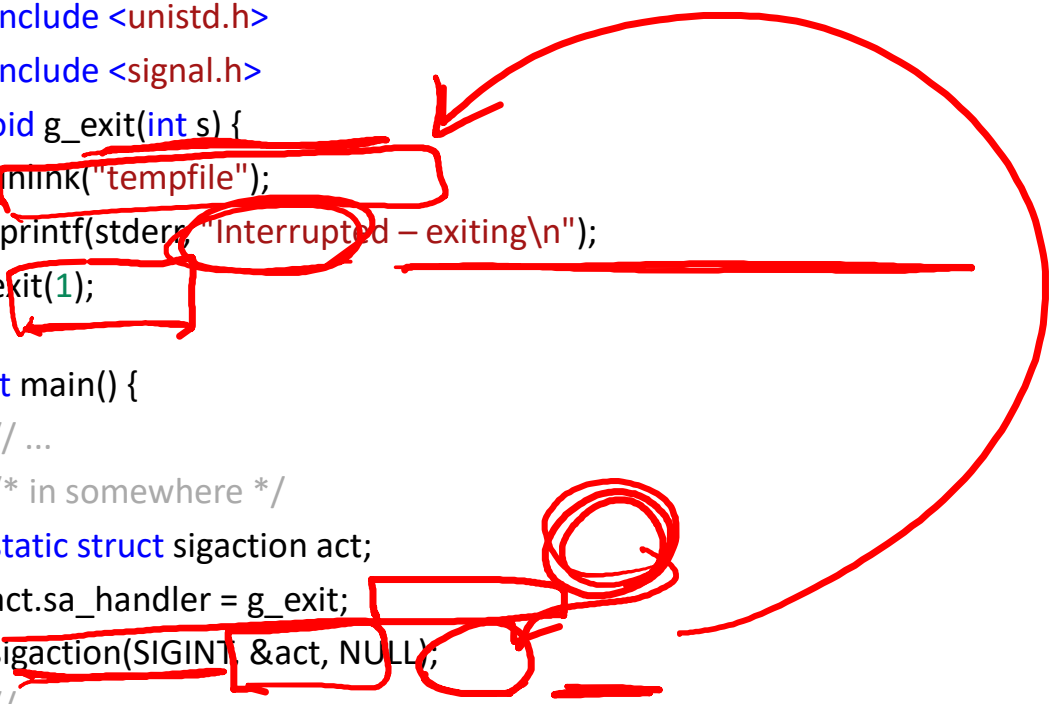


sigaction (SIGTERM, &act, &oact);

Example #5: graceful exit

- Suppose a program uses a temporary workfile

```
/* exit from program gracefully */
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <signal.h>
void g_exit(int s) {
  unlink("tempfile");
  fprintf(stderr, "Interrupted – exiting\n");
  exit(1);
}
int main() {
  // ...
  /* in somewhere */
  static struct sigaction act;
  act.sa_handler = g_exit;
  sigaction(SIGINT, &act, NULL);
  // ...
  return 0;
}
```



Signal Handler

- void (*signal(int *signo*, void (**handler*)(int)))(int)
  - Signal handler can be set by user process.
- signal( ) is said to be unreliable.
  - Signals can get lost.
- Further superseded by sigaction( ) in the latest implementations of various versions of UNIX systems.

signal (1)

- #include <signal.h>

  void (*signal(int *signum*, void (**handler*)(int)))(int);

  - Installs a new signal handler for the signal with number *signum*.
  - The signal handler is set to *handler* which may be a user specified function, or one of the following:
    - SIG_IGN: Ignore the signal.
    - SIG_DFL: Reset the signal to its default behavior.

signal (2)

- The integer argument that is handed over to the signal handler routine is the *signal number*.
- It is possible to use one signal handler for several signals.
- Return value
  - The previous value (address) of the signal handler, or SIG_ERR on error.

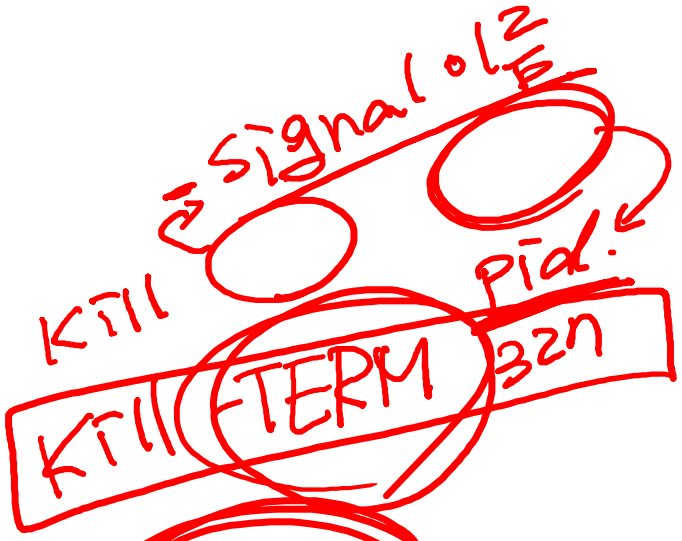
Example #6: signal (1)

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

static void sig_usr(int signo) {
  if (signo == SIGUSR1)
    printf("received SIGUSR1\n");
  else if (signo == SIGUSR2)
    printf("received SIGUSR2\n");
  else {
    fprintf(stderr, "recevied signal %d\n", signo);
    fflush(stderr);
    abort();
  }
 return;
}
```

Example #6: signal (2)

```c
int main(void) {
  if (signal(SIGUSR1, sig_usr) == SIG_ERR) {
    perror("can't catch SIGUER1");
    exit(1);
  }
  if (signal(SIGUSR2, sig_usr) == SIG_ERR) {
    perror("can't catch SIGUER2");
    exit(1);
  }

  for(;;)
    pause();
}
```

signal(SIGTERM, sig_usr)




```
$ ./main &
[1] 327
$ kill -USR1 327
$ received SIGUSR1
kill -USR2 327
$ received SIGUSR2
kill 327
```