Software Interrupts

"Most nontrivial application programs need to deal with signals"

asynchronous events

Version 7 signals -- Not reliable
   Signal could "get lost"

BSD -- changes for reliable signals
   Changes were incompatible

POSIX -- also their concept of signals
Signal Basics

Signal Names:
- SIGINT - interrupt program
- SIGSEGV - segmentation violation
- SIGTSTP - stop signal from terminal
- SIGCHLD - child status has changed
- man 7 signal

Signal causes:
- Terminal generated
  - ^C - often SIGINT
  - ^Z - often SIGTSTP
- Hardware generated
  - Divide by zero - SIGFPE (example divzero.c)
  - Bad pointer ref - SIGSEGV
  - Unaligned access - SIGBUS (example buserr.c)
More Signal causes:

- **kill system call**
  - int kill(pid_t pid, int sig);
  - pid > 0 => to that process
  - pid = 0 => to process group of sender
  - pid = -1 => All processes (except sender)
    - root -> all but system processes
    - !root -> all with same uid
  - root can signal any process
  - !root can only signal process with same uid

- **kill user level command**
  - Sometimes built into shells (bash)
  - Same as above
More Signal causes:

Other indications

- SIGURG  -- Network related
- SIGPIPE -- Write to a pipe with no reader
- SIGALRM -- "Alarm Clock" went off
- SIGCHLD -- Child change of status
What happens at "signal time"?

Signal gets "Delivered" to the process

Actions ...

☐ Ignore the signal -- nothings happens
  ☐ (Can’t ignore SIGKILL and SIGSTOP)

☐ Catch the signal
  ☐ Starts a designated function
  ☐ (Can’t catch SIGKILL and SIGSTOP)

☐ Default action
  ☐ May ignore it
  ☐ May terminate the process
  ☐ May dump core and terminate process

Again ... look at "man 7 signal"
How to use:

Simple version (unreliable):

```c
void (*signal(int sig, void (*func)(int);)(int)
```

- func -> function name  OR
  - SIG_DFL
  - SIG_IGN
- sig -> Signal Name
- return -> previous function pointer (or SIG_DFL or SIG_IGN)

Example: sig.c
Other issues:

system calls may be interrupted by signals
EINTR is an error code for an interrupted system call

Other signal related calls
- `raise(3)`
- `alarm(3) / setitimer(2)`
- `pause(3) / sigsuspend(2)`
- `abort(3)`

Use of system calls in handler!
- Save `errno` at least!
- Don’t use routines like `malloc`!
- How about `printf`?
  - Not a good idea!
"Advanced" signal interface

```c
#include <signal.h>

struct sigaction {
    void (*sa_handler)(int);
    sigset_t sa_mask;
    int sa_flags;
};

int sigaction(int sig, const struct sigaction *act, struct sigaction *oact);
```

- `sa_mask` -- a "set" of signals to "block" during handler running.
- Routines to make signal sets:
  - sigemptyset, sigfillset, sigaddset, sigdelset, sigismember
- `sa_flags` -- Controls other things
  - SA_RESTART -- restart system calls that can be restarted
  - Others ... not that important here
Example: sigaction.c

```c
int sigprocmask(int how, const sigset_t *set, sigset_t *oset);
 □ Block/unblock the current set of signals from being delivered.

int sigpending(sigset_t *set);
 □ Returns set of signals waiting (blocked) to be delivered

int sigsuspend(const sigset_t *sigmask);
 □ Wait for a signal to be delivered. sigmask normally empty.

sigsetjmp / siglongjmp
 □ setjmp and longjmp that deals with signals.
Signal Set operations

From "man sigsetops"

```c
#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);

int sigismember(sigset_t *set, int signo);
```