Linux/Unix Signals

- Signals are simple forms of interprocess-communication.
- Signals can be generated from a variety of sources:
  - From another process via `kill()`.
  - From the operating system (e.g., timer).
  - From within the process (e.g., system call).
  - From a fault in the process (e.g., div-by-zero).
- Processes can define how they want to handle signals:
  - Using the `signal()` library function (simple).
  - Using the `sigaction()` system call (powerful).
- Signal `SIGKILL` always terminates receiving processes.
- Only the owner of a process can send a signal to it.

Signal Handling

Default handling of a signal can be:

- **Term** ... terminate the process
- **Ign** ... ignored; the signal does nothing
- **Core** ... terminate the process and dump memory image to file named core
- **Stop** ... pause the process
- **Cont** ... continue the process (if paused)

Processes can choose to ignore a signal.

Processes can set a custom signal handler for a signal.

... except for `SIGKILL` and `SIGSTOP`, which cannot be caught, blocked, or ignored.

See `man 7 signal` for details of signals and default handling.
Operating System-Generated Signals

Signals from internal process activity, e.g.

- **SIGILL** ... illegal instruction  *(Term by default)*
- **SIGABRT** ... generated by abort() *(Core by default)*
- **SIGFPE** ... floating point exception *(Core by default)*
- **SIGSEGV** ... invalid memory reference *(Core by default)*

Signals from external process events, e.g.

- **SIGHUP** ... hangup detected on controlling terminal/process
- **SIGINT** ... interrupt from keyboard (ctrl-c) *(Term by default)*
- **SIGPIPE** ... broken pipe *(Term by default)*
- **SIGCHLD** ... child process stopped or died *(Ign by default)*
- **SIGTSTP** ... stop typed at tty (ctrl-z) *(Stop by default)*

Signal Handlers

**Signal Handler** = a function invoked in response to a signal

- knows which signal it was invoked by
- needs to ensure that invoking signal (at least) is blocked
- carries out appropriate action; may return

```c
#include <signal.h>
typedef void (*sighandler_t)(int);
sighandler_t signal(int signum, sighandler_t handler);
```

- old way to create signal handler - do not use in new code
- set how to handle a signal **signum** (e.g. **SIGINT**)
- **handler** can be one of...
  - **SIG_IGN** ... ignore signal **signum**
  - **SIG_DFL** ... use default handler for **signum**
  - a user-defined function for **signum** signals
- function type must be void *(int)*
- returns previous value of signal handler, or **SIG_ERR**
sigaction() — installing a signal handler, the new way

#include <signal.h>

int sigaction (  
    int signum,  
    const struct sigaction *act,  
    struct sigaction *oldact);

- set how to handle a signal **signum** (e.g. SIGINT)
- **act** defines how signal should be handled
- **oldact** saves a copy of how signal was handled
  - if act->sa_handler == SIG_IGN, signal is ignored
  - if act->sa_handler == SIG_DFL, default handler is used
- on success, returns 0; on error, returns -1 and sets **errno**

For much more information: man 2 sigaction

Signal Handlers

Details on **struct sigaction** ...

```c
struct sigaction {
    void (*sa_handler) (int);
    void (*sa_sigaction) (int, siginfo_t *, void *);
    sigset_t sa_mask;
    int sa_flags;
    /* ... */
};
```

- void (*sa_handler)(int)
  - pointer to a handler function, or SIG_IGN or SIG_DFL
- void (*sa_sigaction)(int, siginfo_t *, void *)
  - pointer to handler function; used if SA_SIGINFO flag is set
  - allows more context info to be passed to handler
- sigset_t sa_mask
  - a mask, where each bit specifies a signal to be blocked
- int sa_flags
  - flags to modify how signal is treated
  - (e.g., don't block signal in its own handler)

Signal Handlers

Details on **siginfo_t** ...

```c
typedef struct {
    int si_signo; /* signal number of signal being handled */
    int si_code; /* signal code - more information about why */
    pid_t si_pid; /* process ID of sending process */
    uid_t si_uid; /* user ID of owner of sending process */
    void *si_addr; /* address of faulting instruction */
    int si_status; /* exit value for process termination */
    /* ... */
} siginfo_t;
```

System-dependent; these are (a subset of) mandated fields.
#include <signal.h>
void signal_handler(int signum) {
    printf("signal number %d received\n", signum);
}

int main(void) {
    struct sigaction action = {.sa_handler = signal_handler};
    sigaction(SIGUSR1, &action, NULL);
    printf("I am process %d waiting for signal %d\n", getpid(), SIGUSR1);
    // suspend execution for 1 hour
    sleep(3600);
}

source code for wait_for_signal.c

#include <unistd.h>

unsigned int sleep(unsigned int seconds);

- sleep() suspended the caller for **seconds** of real-time
- efficient way to wait for an event such as a signal
- allows operating system to run other processes

Example: waiting for an event

#include <signal.h>

void signal_handler(int signum) {
    printf("signal number %d received\n", signum);
}

int main(void) {
    struct sigaction action = {.sa_handler = signal_handler};
    sigaction(SIGUSR1, &action, NULL);
    printf("I am process %d waiting for signal %d\n", getpid(), SIGUSR1);
    // suspend execution for 1 hour
    sleep(3600);
}

source code for wait_for_signal.c
#include <sys/types.h>
#include <signal.h>

int kill(pid_t pid, int sig);

- Send signal number `sig` to process number `pid`
- If successful, return 0; on error, return -1 and set `errno`

```c
int main(int argc, char *argv[]) {
    if (argc != 3) {
        fprintf(stderr, "Usage: %s <signal> <pid>\n", argv[0]);
        return 1;
    }
    int signal = atoi(argv[1]);
    int pid = atoi(argv[2]);
    kill(pid, signal);
}
```

Source code for `send_signal.c`

https://www.cse.unsw.edu.au/~cs1521/21T3/COMP1521 21T3 — Signals 13 / 17

Example: ignoring a signal

```c
#include <signal.h>
int main(void) {
    // catch SIGINT which is sent if user types ctrl-d
    struct sigaction action = {.sa_handler = SIG_IGN};
    sigaction(SIGINT, &action, NULL);
    while (1) {
        printf("Can't interrupt me, I'm ignoring ctrl-C\n");
        sleep(1);
    }
}
```

Source code for `ignore_control_c.c`

https://www.cse.unsw.edu.au/~cs1521/21T3/ COMP1521 21T3 — Signals 14 / 17

Example: a simple signal handler

```c
#include <signal.h>
void ha_ha(int signum) {
    printf("Ha Ha!\n"); // I/O can be unsafe in a signal handler
}

int main(void) {
    // catch SIGINT which is sent if user types ctrl-d
    struct sigaction action = {.sa_handler = ha_ha};
    sigaction(SIGINT, &action, NULL);
    while (1) {
        printf("Can't interrupt me, I'm ignoring ctrl-C\n");
        sleep(1);
    }
}
```

Source code for `laugh_at_control_c.c`

https://www.cse.unsw.edu.au/~cs1521/21T3/ COMP1521 21T3 — Signals 15 / 17
Example: another simple signal handler

```c
#include <signal.h>
int signal_received = 0;
void stop(int signum) {
    signal_received = 1;
}
int main(void) {
    // catch SIGINT which is sent if user types cntrl-C
    struct sigaction action = {.sa_handler = stop};
    sigaction(SIGINT, &action, NULL);
    while (!signal_received) {
        printf("Type ctrl-c to stop me\n");
        sleep(1);
    }
    printf("Good bye\n");
}
```

Example: catching an internal error with a signal handler

```c
#include <signal.h>
#include <stdlib.h>
void report_signal(int signum) {
    printf("Signal %d received\n", signum);
    printf("Please send help\n");
    exit(0);
}
int main(int argc, char *argv[]) {
    struct sigaction action = {.sa_handler = report_signal};
    sigaction(SIGFPE, &action, NULL);
    // this will produce a divide by zero
    // if there are no command-line arguments
    // which will cause program to receive SIGFPE
    printf("%d\n", 42/(argc - 1));
    printf("Good bye\n");
}
```