

- signal are simple form 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 owner of a processes can send signal to it

Default handling of 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 signal.

Except SIGKILL and SIGSTOP cannot be caught, blocked, or ignored.

See `man 7 signal` for details of signals and default handling.

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Operating System-Generated Signals

Signals from internal process activity, e.g.

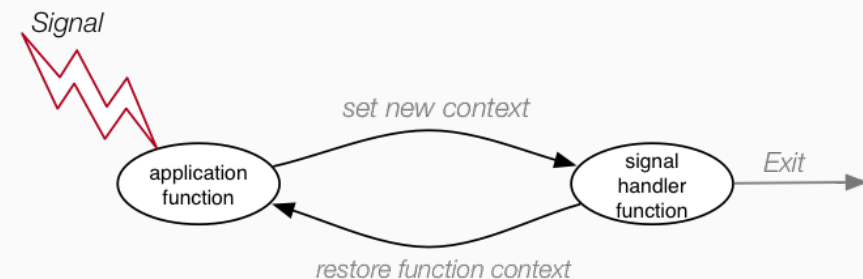
- SIGILL ... illegal instruction (**Term** by default)
- SIGABRT ... generated by `abort()` (**Core** by default)
- SIGFPE ... floating point exception (**Core** by default)
- SIGSEGV ... invalid memory reference (**Core** by default)

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



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```
#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`

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```
#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`

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Signal Handlers

Details on `struct sigaction` ...

- `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)

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Signal Handlers

Details on `siginfo_t` ...

- `si_signo` ... signal being handled
- `si_errno` ... any `errno` value associated with signal
- `si_pid` ... process ID of sending process
- `si_uid` ... user ID of owner of sending process
- `si_status` ... exit value for process termination
- etc. etc. etc.

For more details: `bits/types/siginfo_t.h` (system-dependent)

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```
#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(), SIG
    // loop waiting for signal
    // bad consumes CPU/electricity/battery
    // sleep would be better
    while (1) {
    }
}
```

source code for busy_wait_for_signal.c

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```
#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 an signal
- allows operating system to run other processes

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```
#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(), SIG
    // suspend execution for 1 hour
    sleep(3600);
}
```

source code for wait_for_signal.c

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```
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

```
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

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```
#include <signal.h>
int main(void) {
    // catch SIGINT which is sent if user types cntrl-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

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```
#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 cntrl-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

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```
#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");
}
```

source code for stop_with_control_c.c

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```
#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");
}
```

source code for catch_error.c

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