Preview

- The waitpid() System Call
- The system() System Call
- Concept of Signals
  - Linux Signals
  - The signal System Call
  - Unreliable Signals
- Signal() System Call
- The kill() and raise() System Call
- The alarm() System Call
- The pause() System Call

Process Termination

- The exit status of a child will be used for parent process termination
- When a child exits, the parent process will receive a SIGCHLD signal to indicate that one of its children has finished executing; the parent process will typically call the wait() system call at this point.
- That call will provide the parent with the child's exit status, and will cause the child to be *reaped*, or removed from the process table.

wait and waitpid() System Call

- When a process terminate either normally or abnormally, the kernel sent a signal (SIGCHD) to a parent.
- A parent can ignore the signal or call a function (wait or waitpid) to take care the signal.

```
#include <sys/wait.h>
pid_t wait (int *status);
pid_t waitpid(pid_t pid, int *status, int option);

                          Returns ID if OK, -1 on error
```

wait and waitpid() System Call

- The execution of **wait()** could have two possible situations.
  - If there are at least one child processes, the caller will be blocked until one of its child processes exits.
  - If there is no child process running, then this **wait()** has no effect at all.
- **The status is the pointer** where terminated process's status is saved.

```
/*wait.c  demonstrate wait() system call */
#include  <stdio.h>
#include  <string.h>
#include <unistd.h>
#include  <sys/types.h>
#define   MAX_COUNT  1000
#define   BUF_SIZE   100
void  main(void)
{

    pid_t   pid1, pid,  p1;
    int     status;
    int     i;
    char    buf[BUF_SIZE];
    printf("*** Parent is about to fork  ***\n");
    if ((pid1 = fork()) < 0)
    {
                    printf("Failed to fork process 1\n");
                    exit(1);
    }
    if (pid1 == 0) /* child's part */
    {
        p1= getpid();
        for (i = 1; i <MAX_COUNT; i++)
        {
            sprintf(buf,"child %d is running\n", p1);
            write(1, buf, strlen(buf));
        }
     }
     else
     {
            sprintf(buf, "*** Parent enters waiting status .....\n");
            write(1, buf, strlen(buf));
            pid = wait(&status); /*wait for child finish it's job */
            sprintf(buf, "*** Parent detects process %d was done ***\n", pid);
            write(1, buf, strlen(buf));
            printf("*** Parent exits ***\n");
            exit(0);
      }
}
```

waitpid() System Call

- If a parent create more than one child, wait returns on termination of any of children process.
- **waitpid**() system call can be used to wait for specific process to terminate.

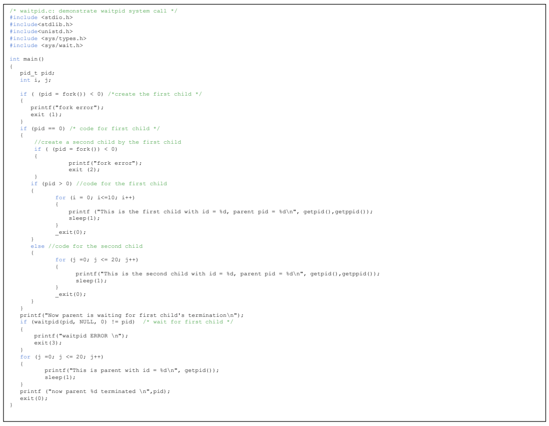
```
#include <sys/wait.h>
pid_t waitpid(pid_t pid, int *status, int option);

                          Returns ID if OK, -1 on error
```

waitpid() System Call

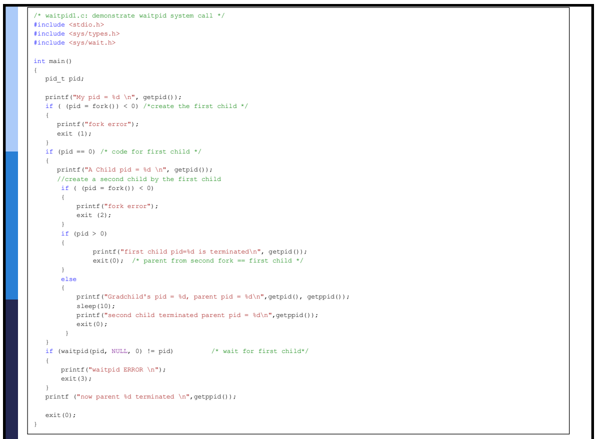
- The differences between wait() and waitpid()
  - The wait can block the caller(parent) until a child process terminates.
  - The waitpid() has option that prevents it from blocking
  - The waitpid() function doesn’t wait for the child that terminate first; it has options that control which process parent wait for.

waitpid() System Call

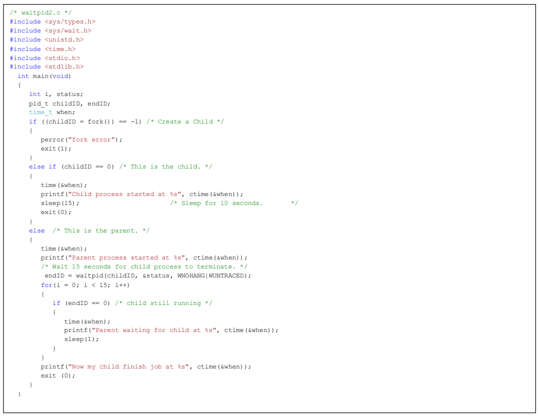
- The waitpid() system call provides three features that does not by the wait()
  - Wait for one particular process
  - Provide non blocking version of wait
  - Provides support for job control
- Options
  - 0: wait one by one until all terminated
  - WNOHANG: will not block if the child is not available immediately
  - WCONTINUED: if implementation support job control,
  - WUNTRACED : if implementation support job control,



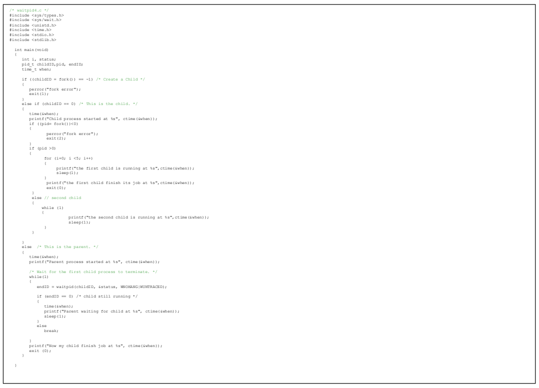
```c
/* waitpid.c: demonstrate waitpid system call */
#include <stdio.h>
#include<stdlib.h>
#include<unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

int main()
{
   pid_t pid;
   int i, j;

   if ( (pid = fork()) < 0) /*create the first child */
   {
      printf("fork error");
      exit (1);
   }
   if (pid == 0) /* code for first child */
   {
       //create a second child by the first child
       if ( (pid = fork()) < 0)
       {
                 printf("fork error");
                 exit (2);
       }
      if (pid > 0) //code for the first child
      {
             for (i = 0; i<=10; i++)
             {
                 printf ("This is the first child with id = %d, parent pid = %d\n", getpid(),getppid());
                 sleep(1);
             }
             _exit(0);
      }
      else //code for the second child
      {
             for (j =0; j <= 20; j++)
             {
                   printf("This is the second child with id = %d, parent pid = %d\n", getpid(),getppid());
                   sleep(1);
             }
             _exit(0);
      }
   }
   printf("Now parent is waiting for first child's termination\n");
   if (waitpid(pid, NULL, 0) != pid)  /* wait for first child */
   {
       printf("waitpid ERROR \n");
       exit(3);
   }
   for (j =0; j <= 20; j++)
   {
          printf("This is parent with id = %d\n", getpid());
          sleep(1);
   }
   printf ("now parent %d terminated \n",pid);
   exit(0);
}
```



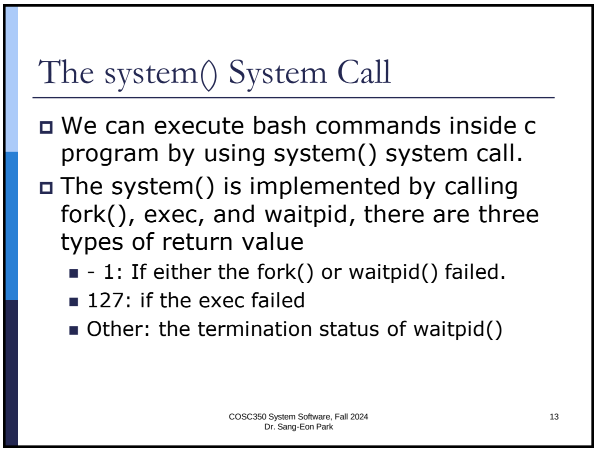
```c
/* waitpid1.c: demonstrate waitpid system call */
#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>

int main()
{
   pid_t pid;

   printf("My pid = %d \n", getpid());
   if ( (pid = fork()) < 0) /*create the first child */
   {
      printf("fork error");
      exit (1);
   }
   if (pid == 0) /* code for first child */
   {
      printf("A Child pid = %d \n", getpid());
      //create a second child by the first child
       if ( (pid = fork()) < 0)
       {
           printf("fork error");
           exit (2);
       }
       if (pid > 0)
       {
                printf("first child pid=%d is terminated\n", getpid());
                exit(0);  /* parent from second fork == first child */
       }
       else
       {
           printf("Gradchild's pid = %d, parent pid = %d\n",getpid(), getppid());
           sleep(10);
           printf("second child terminated parent pid = %d\n",getppid());
           exit(0);
        }
   }
   if (waitpid(pid, NULL, 0) != pid)          /* wait for first child*/
   {
       printf("waitpid ERROR \n");
       exit(3);
   }
   printf ("now parent %d terminated \n",getppid());

   exit(0);
}
```



```c
/* waitpid2.c */
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>
#include <time.h>
#include <stdio.h>
#include <stdlib.h>
  int main(void)
  {
     int i, status;
     pid_t childID, endID;
     time_t when;
     if ((childID = fork()) == -1) /* Create a Child */
     {
        perror("fork error");
        exit(1);
     }
     else if (childID == 0) /* This is the child. */
     {
        time(&when);
        printf("Child process started at %s", ctime(&when));
        sleep(15);                      /* Sleep for 10 seconds.       */
        exit(0);
     }
     else  /* This is the parent. */
     {
        time(&when);
        printf("Parent process started at %s", ctime(&when));
        /* Wait 15 seconds for child process to terminate. */
         endID = waitpid(childID, &status, WNOHANG|WUNTRACED);
        for(i = 0; i < 15; i++)
        {
           if (endID == 0) /* child still running */
           {
              time(&when);
              printf("Parent waiting for child at %s", ctime(&when));
              sleep(1);
           }
        }
        printf("Now my child finish job at %s", ctime(&when));
        exit (0);
     }
  }
```

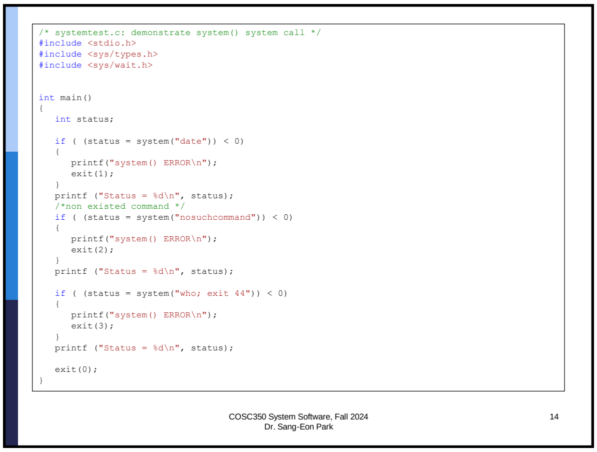


```c
/* waitpid4.c */
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>
#include <time.h>
#include <stdio.h>
#include <stdlib.h>

  int main(void)
  {
     int i, status;
     pid_t childID,pid, endID;
     time_t when;

     if ((childID = fork()) == -1) /* Create a Child */
     {
        perror("fork error");
        exit(1);
     }
     else if (childID == 0) /* This is the child. */
     {
        time(&when);
        printf("Child process started at %s", ctime(&when));
        if ((pid= fork())<0)
        {
               perror("fork error");
               exit(2);
        }
        if (pid >0)
        {
              for (i=0; i <5; i++)
              {
                   printf("the first child is running at %s",ctime(&when));
                   sleep(1);
              }
               printf("the first child finish its job at %s",ctime(&when));
               exit(0);
         }
         else // second child
         {
             while (1)
             {
                        printf("the second child is running at %s",ctime(&when));
                        sleep(1);
              }
         }

     }
     else  /* This is the parent. */
     {
        time(&when);
        printf("Parent process started at %s", ctime(&when));

        /* Wait for the first child process to terminate. */
        while(1)
        {
           endID = waitpid(childID, &status, WNOHANG|WUNTRACED);

           if (endID == 0) /* child still running */
           {
              time(&when);
              printf("Parent waiting for child at %s", ctime(&when));
              sleep(1);
           }
           else
              break;

        }
        printf("Now my child finish job at %s", ctime(&when));
        exit (0);
     }

  }
```

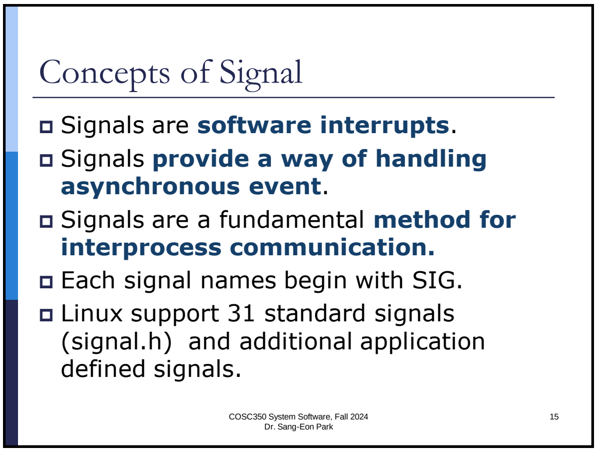


The system() System Call

- We can execute bash commands inside c program by using system() system call.
- The system() is implemented by calling fork(), exec, and waitpid, there are three types of return value
  - - 1: If either the fork() or waitpid() failed.
  - 127: if the exec failed
  - Other: the termination status of waitpid()

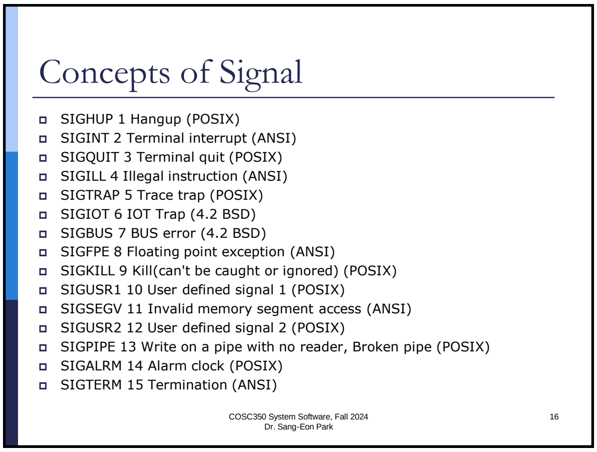


```
/* systemtest.c: demonstrate system() system call */
#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>


int main()
{
   int status;

   if ( (status = system("date")) < 0)
   {
      printf("system() ERROR\n");
      exit(1);
   }
   printf ("Status = %d\n", status);
   /*non existed command */
   if ( (status = system("nosuchcommand")) < 0)
   {
      printf("system() ERROR\n");
      exit(2);
   }
   printf ("Status = %d\n", status);

   if ( (status = system("who; exit 44")) < 0)
   {
      printf("system() ERROR\n");
      exit(3);
   }
   printf ("Status = %d\n", status);

   exit(0);
}
```



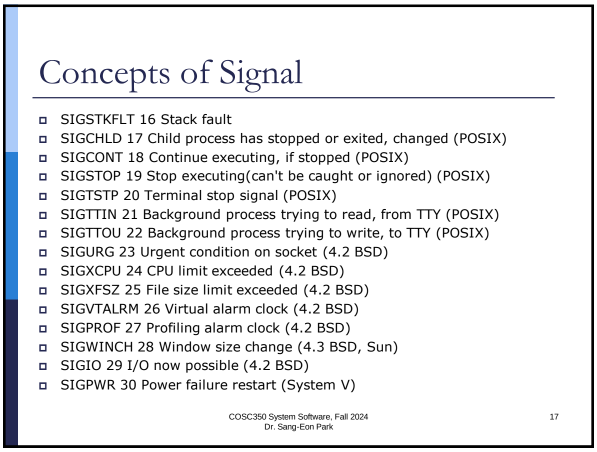
Concepts of Signal

- Signals are **software interrupts**.
- Signals **provide a way of handling asynchronous event**.
- Signals are a fundamental **method for interprocess communication.**
- Each signal names begin with SIG.
- Linux support 31 standard signals (signal.h) and additional application defined signals.



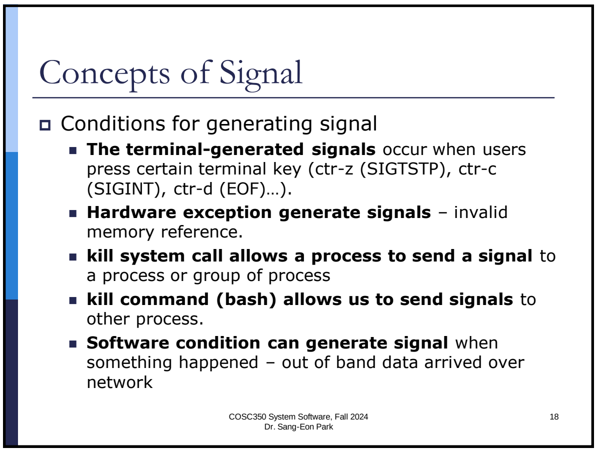
Concepts of Signal

- SIGHUP 1 Hangup (POSIX)
- SIGINT 2 Terminal interrupt (ANSI)
- SIGQUIT 3 Terminal quit (POSIX)
- SIGILL 4 Illegal instruction (ANSI)
- SIGTRAP 5 Trace trap (POSIX)
- SIGIOT 6 IOT Trap (4.2 BSD)
- SIGBUS 7 BUS error (4.2 BSD)
- SIGFPE 8 Floating point exception (ANSI)
- SIGKILL 9 Kill(can't be caught or ignored) (POSIX)
- SIGUSR1 10 User defined signal 1 (POSIX)
- SIGSEGV 11 Invalid memory segment access (ANSI)
- SIGUSR2 12 User defined signal 2 (POSIX)
- SIGPIPE 13 Write on a pipe with no reader, Broken pipe (POSIX)
- SIGALRM 14 Alarm clock (POSIX)
- SIGTERM 15 Termination (ANSI)



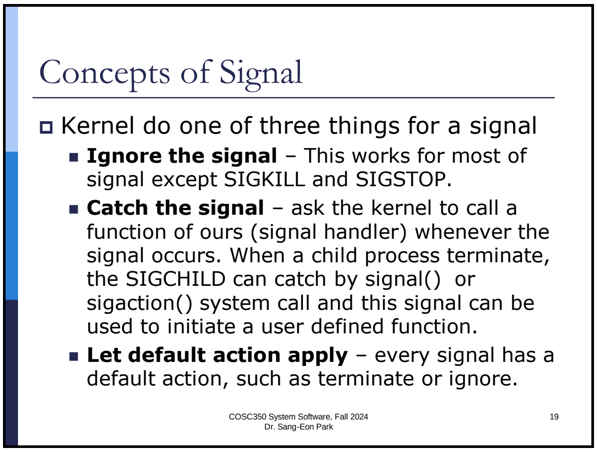
Concepts of Signal

- SIGSTKFLT 16 Stack fault
- SIGCHLD 17 Child process has stopped or exited, changed (POSIX)
- SIGCONT 18 Continue executing, if stopped (POSIX)
- SIGSTOP 19 Stop executing(can't be caught or ignored) (POSIX)
- SIGTSTP 20 Terminal stop signal (POSIX)
- SIGTTIN 21 Background process trying to read, from TTY (POSIX)
- SIGTTOU 22 Background process trying to write, to TTY (POSIX)
- SIGURG 23 Urgent condition on socket (4.2 BSD)
- SIGXCPU 24 CPU limit exceeded (4.2 BSD)
- SIGXFSZ 25 File size limit exceeded (4.2 BSD)
- SIGVTALRM 26 Virtual alarm clock (4.2 BSD)
- SIGPROF 27 Profiling alarm clock (4.2 BSD)
- SIGWINCH 28 Window size change (4.3 BSD, Sun)
- SIGIO 29 I/O now possible (4.2 BSD)
- SIGPWR 30 Power failure restart (System V)



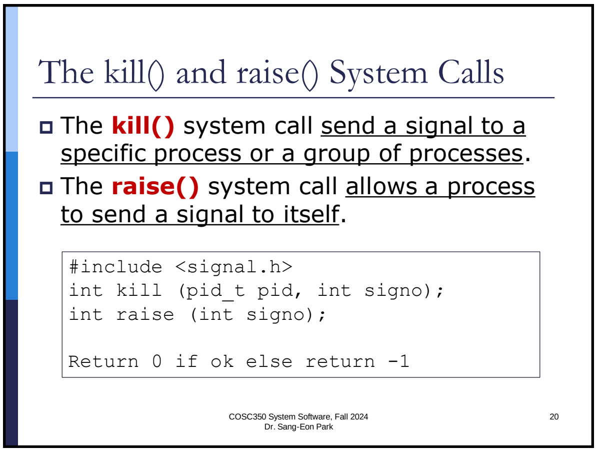
Concepts of Signal

- Conditions for generating signal
  - **The terminal-generated signals** occur when users press certain terminal key (ctr-z (SIGTSTP), ctr-c (SIGINT), ctr-d (EOF)…).
  - **Hardware exception generate signals** – invalid memory reference.
  - **kill system call allows a process to send a signal** to a process or group of process
  - **kill command (bash) allows us to send signals** to other process.
  - **Software condition can generate signal** when something happened – out of band data arrived over network



Concepts of Signal

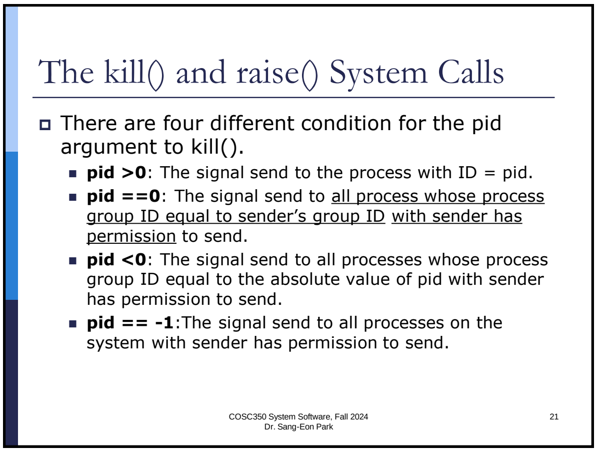
- Kernel do one of three things for a signal
  - **Ignore the signal** – This works for most of signal except SIGKILL and SIGSTOP.
  - **Catch the signal** – ask the kernel to call a function of ours (signal handler) whenever the signal occurs. When a child process terminate, the SIGCHILD can catch by signal() or sigaction() system call and this signal can be used to initiate a user defined function.
  - **Let default action apply** – every signal has a default action, such as terminate or ignore.



The kill() and raise() System Calls

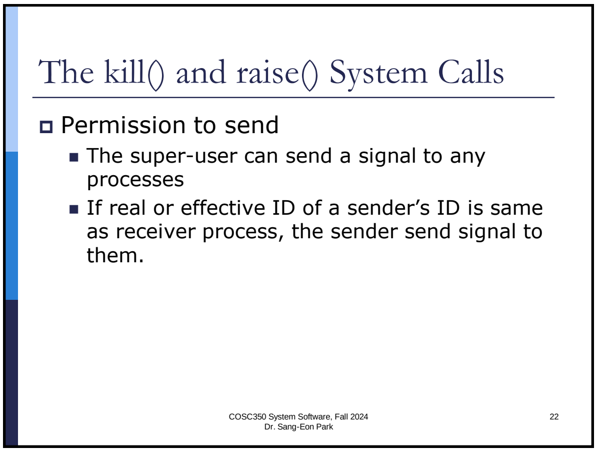
- The **kill()** system call send a signal to a specific process or a group of processes.
- The **raise()** system call allows a process to send a signal to itself.

```
#include <signal.h>
int kill (pid_t pid, int signo);
int raise (int signo);

Return 0 if ok else return -1
```



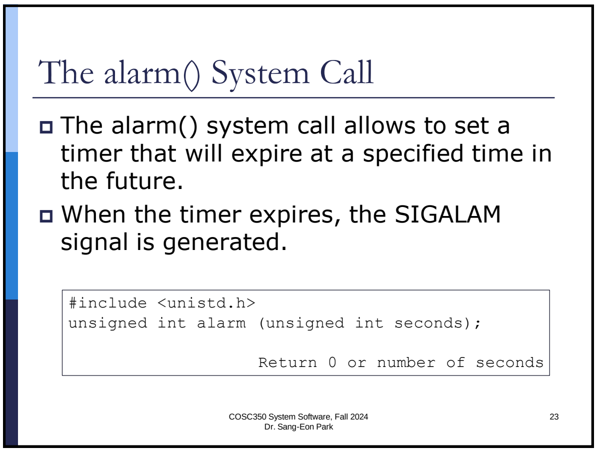
The kill() and raise() System Calls

- There are four different condition for the pid argument to kill().
  - **pid >0**: The signal send to the process with ID = pid.
  - **pid ==0**: The signal send to all process whose process group ID equal to sender's group ID with sender has permission to send.
  - **pid <0**: The signal send to all processes whose process group ID equal to the absolute value of pid with sender has permission to send.
  - **pid == -1**:The signal send to all processes on the system with sender has permission to send.



The kill() and raise() System Calls

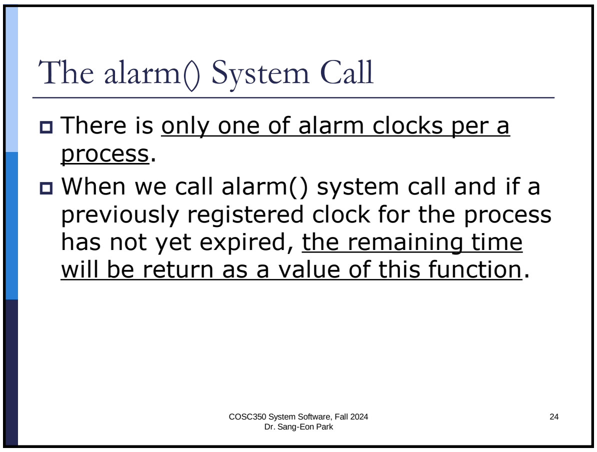
- Permission to send
  - The super-user can send a signal to any processes
  - If real or effective ID of a sender's ID is same as receiver process, the sender send signal to them.



The alarm() System Call

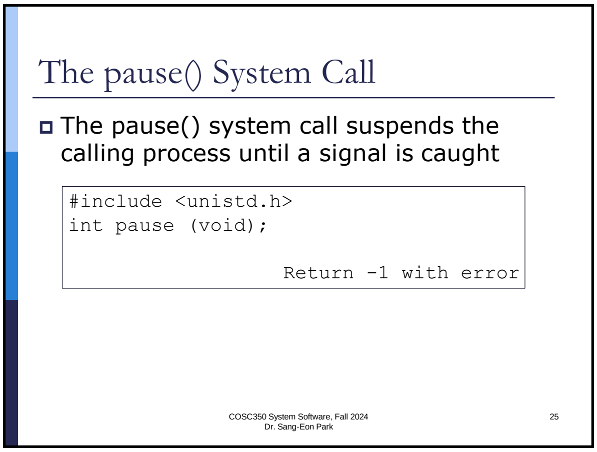
- The alarm() system call allows to set a timer that will expire at a specified time in the future.
- When the timer expires, the SIGALAM signal is generated.

```
#include <unistd.h>
unsigned int alarm (unsigned int seconds);

                        Return 0 or number of seconds
```



The alarm() System Call

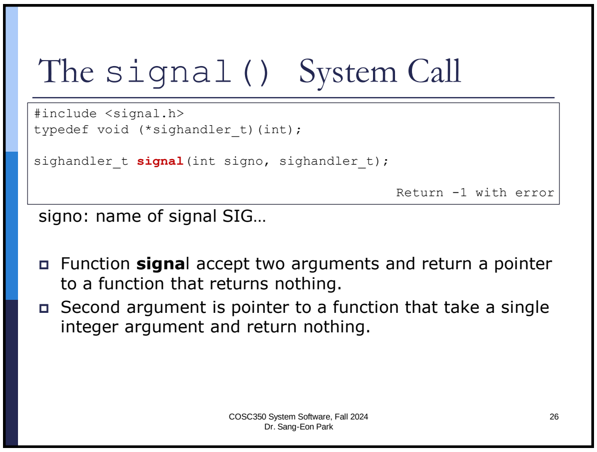
- There is only one of alarm clocks per a process.
- When we call alarm() system call and if a previously registered clock for the process has not yet expired, the remaining time will be return as a value of this function.



The pause() System Call

- The pause() system call suspends the calling process until a signal is caught

```
#include <unistd.h>
int pause (void);

                        Return -1 with error
```

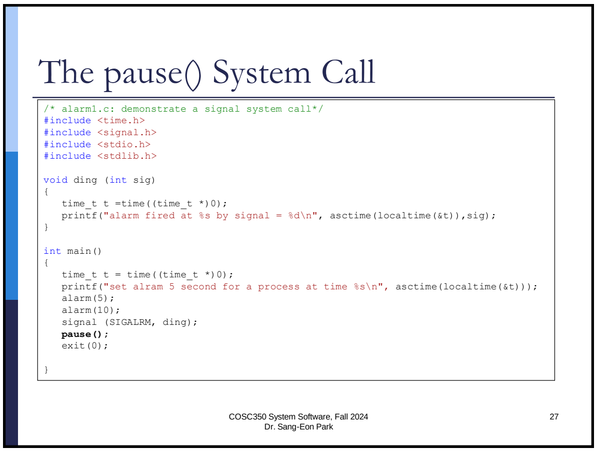


The signal () System Call

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

sighandler_t signal(int signo, sighandler_t);

                                         Return -1 with error
```

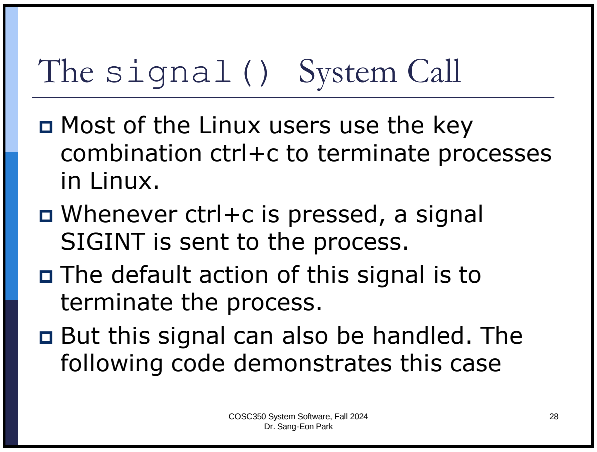
signo: name of signal SIG…

- Function **signa**l accept two arguments and return a pointer to a function that returns nothing.
- Second argument is pointer to a function that take a single integer argument and return nothing.



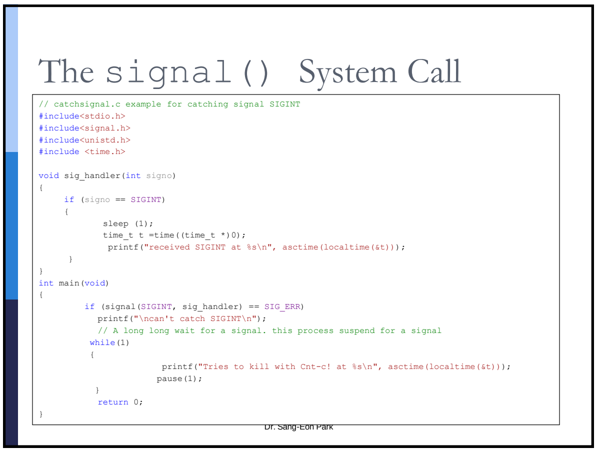
The pause() System Call

```
/* alarm1.c: demonstrate a signal system call*/
#include <time.h>
#include <signal.h>
#include <stdio.h>
#include <stdlib.h>

void ding (int sig)
{
   time_t t =time((time_t *)0);
   printf("alarm fired at %s by signal = %d\n", asctime(localtime(&t)),sig);
}

int main()
{
   time_t t = time((time_t *)0);
   printf("set alram 5 second for a process at time %s\n", asctime(localtime(&t)));
   alarm(5);
   alarm(10);
   signal (SIGALRM, ding);
   pause();
   exit(0);

}
```



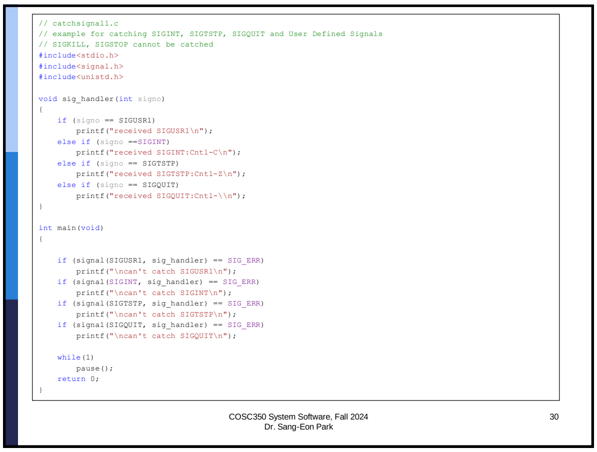
The signal () System Call

- Most of the Linux users use the key combination ctrl+c to terminate processes in Linux.
- Whenever ctrl+c is pressed, a signal SIGINT is sent to the process.
- The default action of this signal is to terminate the process.
- But this signal can also be handled. The following code demonstrates this case

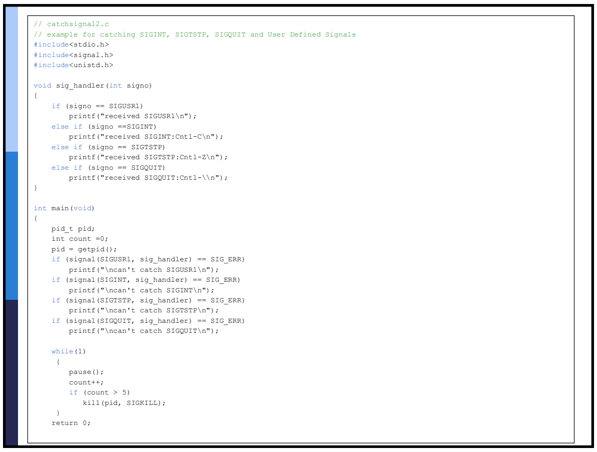


The signal () System Call

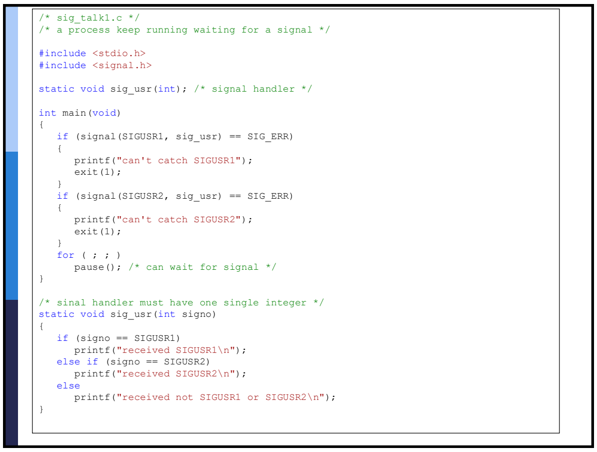
```
// catchsignal.c example for catching signal SIGINT
#include<stdio.h>
#include<signal.h>
#include<unistd.h>
#include <time.h>

void sig_handler(int signo)
{
     if (signo == SIGINT)
     {
             sleep (1);
             time_t t =time((time_t *)0);
              printf("received SIGINT at %s\n", asctime(localtime(&t)));
      }
}
int main(void)
{
         if (signal(SIGINT, sig_handler) == SIG_ERR)
           printf("\ncan't catch SIGINT\n");
           // A long long wait for a signal. this process suspend for a signal
          while(1)
          {
                         printf("Tries to kill with Cnt-c! at %s\n", asctime(localtime(&t)));
                        pause(1);
           }
           return 0;
}
```



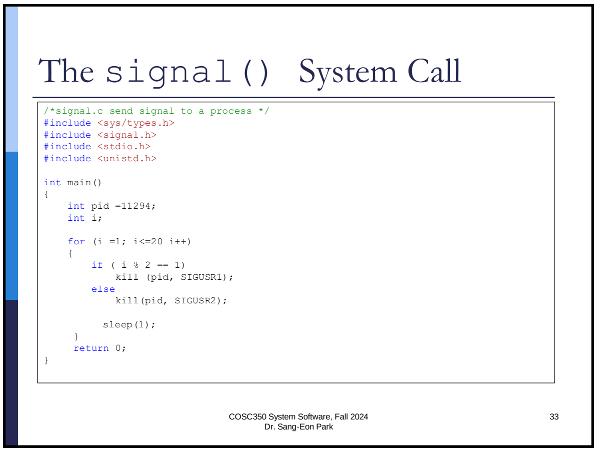
```
// catchsignal1.c
// example for catching SIGINT, SIGTSTP, SIGQUIT and User Defined Signals
// SIGKILL, SIGSTOP cannot be catched
#include<stdio.h>
#include<signal.h>
#include<unistd.h>

void sig_handler(int signo)
{
    if (signo == SIGUSR1)
        printf("received SIGUSR1\n");
    else if (signo ==SIGINT)
        printf("received SIGINT:Cntl-C\n");
    else if (signo == SIGTSTP)
        printf("received SIGTSTP:Cntl-Z\n");
    else if (signo == SIGQUIT)
        printf("received SIGQUIT:Cntl-\\n");
}

int main(void)
{

    if (signal(SIGUSR1, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGUSR1\n");
    if (signal(SIGINT, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGINT\n");
    if (signal(SIGTSTP, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGTSTP\n");
    if (signal(SIGQUIT, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGQUIT\n");

    while(1)
        pause();
    return 0;
}
```



```
// catchsignal2.c
// example for catching SIGINT, SIGTSTP, SIGQUIT and User Defined Signals
#include<stdio.h>
#include<signal.h>
#include<unistd.h>

void sig_handler(int signo)
{
    if (signo == SIGUSR1)
        printf("received SIGUSR1\n");
    else if (signo ==SIGINT)
        printf("received SIGINT:Cntl-C\n");
    else if (signo == SIGTSTP)
        printf("received SIGTSTP:Cntl-Z\n");
    else if (signo == SIGQUIT)
        printf("received SIGQUIT:Cntl-\\n");
}

int main(void)
{
    pid_t pid;
    int count =0;
    pid = getpid();
    if (signal(SIGUSR1, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGUSR1\n");
    if (signal(SIGINT, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGINT\n");
    if (signal(SIGTSTP, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGTSTP\n");
    if (signal(SIGQUIT, sig_handler) == SIG_ERR)
        printf("\ncan't catch SIGQUIT\n");

    while(1)
     {
        pause();
        count++;
        if (count > 5)
           kill(pid, SIGKILL);
     }
    return 0;
```



```
/* sig_talk1.c */
/* a process keep running waiting for a signal */

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

static void sig_usr(int); /* signal handler */

int main(void)
{
   if (signal(SIGUSR1, sig_usr) == SIG_ERR)
   {
      printf("can't catch SIGUSR1");
      exit(1);
   }
   if (signal(SIGUSR2, sig_usr) == SIG_ERR)
   {
      printf("can't catch SIGUSR2");
      exit(1);
   }
   for ( ; ; )
      pause(); /* can wait for signal */
}

/* sinal handler must have one single integer */
static void sig_usr(int signo)
{
   if (signo == SIGUSR1)
      printf("received SIGUSR1\n");
   else if (signo == SIGUSR2)
      printf("received SIGUSR2\n");
   else
      printf("received not SIGUSR1 or SIGUSR2\n");
}
```



The signal() System Call

```
/*signal.c send signal to a process */
#include <sys/types.h>
#include <signal.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
    int pid =11294;
    int i;

    for (i =1; i<=20 i++)
    {
        if ( i % 2 == 1)
            kill (pid, SIGUSR1);
        else
            kill(pid, SIGUSR2);

          sleep(1);
     }
     return 0;
}
```

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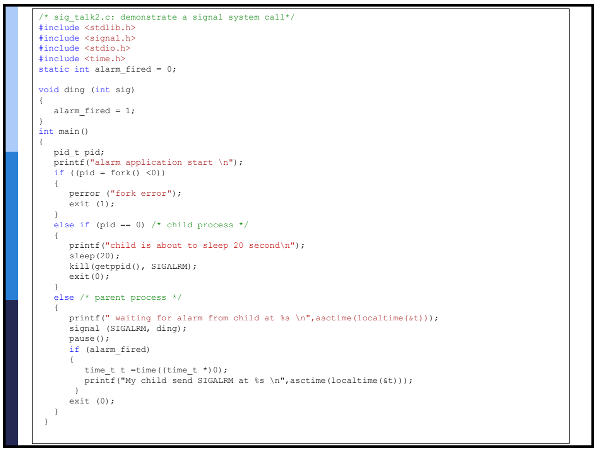

```
/* sig_talk2.c: demonstrate a signal system call*/
#include <stdlib.h>
#include <signal.h>
#include <stdio.h>
#include <time.h>
static int alarm_fired = 0;

void ding (int sig)
{
   alarm_fired = 1;
}
int main()
{
   pid_t pid;
   printf("alarm application start \n");
   if ((pid = fork() <0))
   {
      perror ("fork error");
      exit (1);
   }
   else if (pid == 0) /* child process */
   {
      printf("child is about to sleep 20 second\n");
      sleep(20);
      kill(getppid(), SIGALRM);
      exit(0);
   }
   else /* parent process */
   {
      printf(" waiting for alarm from child at %s \n",asctime(localtime(&t)));
      signal (SIGALRM, ding);
      pause();
      if (alarm_fired)
      {
         time_t t =time((time_t *)0);
         printf("My child send SIGALRM at %s \n",asctime(localtime(&t)));
       }
      exit (0);
   }
 }
```