

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 10: I/O & Programming

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<https://os.vlsm.org/>

Always check for the latest revision!

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A [08-10, Rm 3114, Mo/We] — B/M [10:10-12, Rm 3114, Mo/We] — C [13-15, Rm 3114, Mo/We]

D [10-12, Rm 2307(Mo), Rm 3113(We)] — E [08-10, Rm 2307(Mo), Rm 3113(We)]

Week	Schedule	Topic	OSC10
Week 00	27 Jan - 02 Feb 2020	Overview 1, Virtualization & Scripting	Ch. 1, 2, 18.
Week 01	03 Feb - 09 Feb 2020	Overview 2, Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	10 Feb - 16 Feb 2020	Security, Protection, Privacy, & C-language	Ch. 16, 17
Week 03	17 Feb - 23 Feb 2020	File System & FUSE	Ch. 13, 14, 15
Week 04	24 Feb - 01 Mar 2020	Addressing, Shared Lib, & Pointer	Ch. 9
Week 05	02 Mar - 08 Mar 2020	Virtual Memory	Ch. 10
Reserved	09 Mar - 13 Mar 2020	Q & E	
MidTerm	14 Mar 2020 (13:00-15:30)	MidTerm (UTS)	Subject to change.
Week 06	TBA	Concurrency: Processes & Threads	Ch. 3, 4
Week 07	TBA	Synchronization & Deadlock	Ch. 6, 7, 8
Week 08	TBA	Scheduling + W06/W07	Ch. 5
Week 09a	TBA	Storage, Firmware, Bootldr, & Systemd	Ch. 11
Week 09b	TBA	Storage, Firmware, Bootldr, & Systemd	Ch. 11
Week 10	TBA	I/O & Programming	Ch. 12
Reserved	TBA	Q & A	
Final	TBA	Final (UAS)	This schedule is subject to change.
Extra	TBA	Extra assignment confirmation	

- ❑ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018. See also <http://codex.cs.yale.edu/avi/os-book/OS10/>.
- ❑ **Resources**
 - ❑ **All In One** — BADAk.cs.ui.ac.id:///extra/ (**FASILKOM only!**).
 - ❑ **Download Slides and Demos from GitHub.com**
<https://github.com/UI-FASILKOM-OS/SistemOperasi/>
 - ❑ **Problems** — <https://rms46.vlsm.org/2/>:
195.pdf (W00), 196.pdf (W01), 197.pdf (W02), 198.pdf (W03),
199.pdf (W04), 200.pdf (W05), 201.pdf (W06), 202.pdf (W07),
203.pdf (W08), 204.pdf (W09), 205.pdf (W10).
- ❑ **Try Demos**
 - ❑ Your own Ubuntu system.
 - ❑ Ubuntu on VirtualBox, or VMWare, or ...
 - ❑ Windows Subsystem for Linux (**Windows 10 only!**).
 - ❑ SSH to BADAk.cs.ui.ac.id (**FASILKOM only!**).

Agenda

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Week 10 I/O & Programming: Topics¹

- Characteristics of serial and parallel devices
- Abstracting device differences
- Buffering strategies
- Direct memory access
- Recovery from failures
- I/O Programming
- Network Programming

¹Source: ACM IEEE CS Curricula 2013

Week 10 I/O & Programming: Learning Outcomes¹

- Explain the key difference between serial and parallel devices and identify the conditions in which each is appropriate. [Familiarity]
- Identify the relationship between the physical hardware and the virtual devices maintained by the operating system. [Usage]
- Explain buffering and describe strategies for implementing it. [Familiarity]
- Differentiate the mechanisms used in interfacing a range of devices (including hand-held devices, networks, multimedia) to a computer and explain the implications of these for the design of an operating system. [Usage]
- Describe the advantages and disadvantages of direct memory access and discuss the circumstances in which its use is warranted. [Usage]
- Identify the requirements for failure recovery. [Familiarity]
- Implement a simple device driver for a range of possible devices. [Usage]
- I/O Programming [Usage]
- Network Programming [Usage]

Week 10: I/O & Programming

- Reference: (OSC10-ch12)
- Overview
- I/O Hardware
- Application I/O Interface
- Kernel I/O Subsystem
- Transforming I/O Requests to Hardware Operations
- STREAMS
- Legacy Linux I/O Scheduling Algorithm.
 - Deadline Scheduler
 - Completely Fair Queueing (CFQ)

- Direct I/O vs. Memory Mapped I/O
- Interrupts: Non Maskable (NMI) vs Maskable (MI)
- DMA: Direct Memory Access
- I/O Structure:
 - Kernel (S/W).
 - I/O (S/W: Kernel Subsystem)
 - Driver (S/W)
 - Controller (H/W)
 - Device (H/W)
- I/O Streams
 - APP
 - HEAD
 - MODULES
 - DRIVER
 - H/W.

- I/O Interface Dimensions
 - Character-stream vs. Block;
 - Sequential vs. Random-access;
 - Sharable vs. Dedicated;
 - Parallel vs. Serial;
 - Speed;
 - Read Write – Read Only – Write Only.
 - Synchronous vs. Asynchronous;
 - Blocking vs. Non-Blocking.
- Where should a new algorithm be implemented?
 - APP?
 - Kenel?
 - Driver?
 - Controller?
 - HW?

PCH: Platform Controller Hub



Figure: PCH: Platform Controller Hub

Some Terms

- PCH: Platform Controller Hub
 - The successor of north/south-bridge architecture chipsets.
- PCIe: Peripheral Component Interconnect Express
 - 1 lane = dual simplex channel (1x); 2 lanes = 2x; etc.
 - 40 lanes = 8 GTs (GigaTransfers per second).
 - Configurations: 8x and 16x.
- DDR4 SDRAM (single/dual/quad channel(s))
 - Double Data Rate Fourth-generation Synchronous Dynamic Random-Access Memory: $2 \times \text{DDR2}$ ($\text{DDR2} = 2 \times \text{DDR}$ ($\text{DDR} = 2 \times \text{SDRAM}$)). Eg. DDR4-3200 (8x SDRAM); Memory Clock: 400 MHz; Data Rate: 3200 MT/s; Module Name PC4-25600; Peak Transfer Rate: 25600 MB/s,
- DMI 2.0 (Direct Media Interface): 4x.
- SMB: System Management Bus
- SPI: Serial Peripheral Interface, a de facto standard bus.
- SATA: Serial AT Attachment. Eg. SATA 3.2 \approx 2 GB/s.
- 1 KB (KiloByte) = 1000 bytes — 1 KiB (Kibibyte) = 1024 bytes¹

¹In IT tradition; 1 KB = 1024 bytes

- Sockets

- `atoi()`
- `accept()`
- `bind()`
- `connect()`
- `exit()`
- `fprintf()`
- `getenv()`
- `gethostbyname()`
- `htons()`
- `listen()`
- `memcpy()`
- `memset()`

- Sockets

- `perror()`
- `sizeof()`
- `socket()`
- `snprintf()`
- `strchr()`
- `strcmp()`
- `strncpy()`
- `strlen()`
- `read()`
- `write()`

10-server

```
/*
 * (c) 2007-2016 Rahmat M. Samik-Ibrahim -- This is free software
 * This program was copased from the net and hacked until it works.
 * Feel free to copy and/or modify and/or distribute it,
 * provided this notice, and the copyright notice, are preserved.
 * REV00 Tue Nov  8 11:45:35 WIB 2016
 * START Xxx Xxx XX XX:XX:XX UTC 2007
 */

char pesan[]="[FROM SERVER] ACK MESSAGE...\n";
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <unistd.h>
#include <netdb.h>
#include <sys/socket.h>
#include <arpa/inet.h>
typedef struct sockaddr      sockad;
typedef struct sockaddr_in   sockadin;
typedef struct hostent       shostent;

void error(char *msg){
    perror(msg);
    exit(0);
}
```

10-server (2)

```
int main(int argc, char *argv[]) {
    char    buffer[256];
    int     cliilen, newsockfd, nn, portno, sockfd;
    sockadin serv_addr, cli_addr;
    if (argc < 2) {
        fprintf(stderr, "ERROR, no port provided\n");
        exit(1);
    }
    sockfd = socket(AF_INET, SOCK_STREAM, 0);
    if (sockfd < 0)
        error("ERROR opening socket");
    memset(&serv_addr, 0, sizeof(serv_addr));
    portno = atoi(argv[1]);
    serv_addr.sin_family      = AF_INET;
    serv_addr.sin_addr.s_addr = INADDR_ANY;
    serv_addr.sin_port        = htons(portno);
    if (bind(sockfd, (sockad*)&serv_addr, sizeof(serv_addr)) < 0)
        error("ERROR on binding");
    listen(sockfd, 5);
    cliilen = sizeof(cli_addr);
    newsockfd = accept(sockfd, (sockad*)&cli_addr, (socklen_t*)&cliilen);
    if (newsockfd < 0)
        error("ERROR on accept");
    memset(buffer, 0, 256);
    nn = read(newsockfd, buffer, 255);
    if (nn < 0)
        error("ERROR reading from socket");
    printf("[FROM CLIENT]:\n %s\n", buffer);
    nn = write(newsockfd, pesan, sizeof(pesan));
    if (nn < 0)
        error("ERROR writing to socket");
    return 0;
}
```


11-client

```
/*
 * (c) 2007-2016 Rahmat M. Samik-Ibrahim -- This is free software
 * This program was copased from the net and hacked until it works.
 * Feel free to copy and/or modify and/or distribute it,
 * provided this notice, and the copyright notice, are preserved.
 * REV00 Tue Nov  8 11:45:52 WIB 2016
 * START Xxx Xxx XX XX:XX:XX UTC 2007
 */

char pesan[]="[FROM SERVER] ACK MESSAGE...\n";
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <unistd.h>
#include <netdb.h>
#include <sys/socket.h>
#include <arpa/inet.h>
typedef struct sockaddr      sockad;
typedef struct sockaddr_in   sockadin;
typedef struct hostent       shostent;

void error(char *msg){
    perror(msg);
    exit(0);
}
```

11-client (2)

```
if (argc < 3) {
    fprintf(stderr, "usage %s hostname port\n", argv[0]);
    exit(0);
}
portno = atoi(argv[2]);
sockfd = socket(AF_INET, SOCK_STREAM, 0);
if (sockfd < 0)
    error("ERROR opening socket");
server = gethostbyname(argv[1]);
if (server == NULL) {
    fprintf(stderr, "ERROR, no such host\n");
    exit(0);
}
memset(&serv_addr, 0, sizeof(serv_addr));
serv_addr.sin_family = AF_INET;
memmove(&serv_addr.sin_addr.s_addr, server->h_addr, server->h_length);
serv_addr.sin_port = htons(portno);
if(connect(sockfd, (const struct sockaddr*) &serv_addr, sizeof(serv_addr)) < 0)
    error("ERROR connecting");
printf("Enter the message: ");
memset(buffer, 0, 256);
fgets(buffer, 255, stdin);
nn = write(sockfd, buffer, strlen(buffer));
if (nn < 0)
    error("ERROR writing to socket");
memset(buffer, 0, 256);
nn = read(sockfd, buffer, 255);
if (nn < 0)
    error("ERROR reading from socket");
printf("%s\n", buffer);
return 0;
}
```

OUTPUT: 10-server – 11-client

```
>>>>> $ PS1="SERVER >> "  
SERVER >> 00-server 4444  
[FROM CLIENT]:  
  This is from client via port 4444.
```

```
SERVER >>
```

```
>>>>> $ PS1="CLIENT >> "  
CLIENT >> 01-client localhost 4444  
Enter the message: This is from client via port 4444.  
[FROM SERVER] ACK MESSAGE...
```

```
CLIENT >>
```

```
/*
* (c) 2007 Tadeus Prastowo and Rahmat M. Samik-Ibrahim.
* (c) 2017 Rahmat M. Samik-Ibrahim.
* This is free software. It was copased from the net and hacked until
* it works. Feel free to copy and/or modify and/or distribute it,
* provided this notice, and the copyright notice, are preserved.
* REV01 Wed Nov 8 20:00:02 WIB 2017
* START 2007
*
* This program serves as both a client and a server. Three modes of
* operation are available:
* - initiating mode
* - bridging mode
* - terminating mode
*
* The following are how to run thisprogram for each mode:
* - Initiating mode: client_server null ANOTHER_HOST ANOTHER_PORT
* - Bridging mode: client_server CURRENT_PORT ANOTHER_HOST ANOTHER_PORT
* - Terminating mode: client_server CURRENT_PORT null null
*
* The program having the initiating mode _MUST_ run last after all other
* instances of this program with other operational modes has been started.
*
* In initiating mode, this program just simply sends a hello message to
* another instance of this program that operates either as a bridge or
* as a terminator that this program points to as specified in
* ANOTHER_HOST and ANOTHER_PORT. After that this program will quit
* without printing out any message.
*/
```

12-clisvr (2)

```
/*
 * In bridging mode, this program just simply waits for an incoming hello
 * message in CURRENT_PORT. Once it receives a hello message, it prints
 * out the message in a certain format. Next, this program forwards the
 * modified message to another instance of this program that acts either as
 * a bridge or as a terminator that this program points to as specified
 * in ANOTHER_HOST and ANOTHER_PORT. After that this program will quit.
 *
 * In terminating mode, this program just simply waits for an incoming hello
 * message in CURRENT_PORT. Once it receives a hello message, it prints out
 * the message in a certain format, and then quits.
 *
 * The following illustrates the idea above:
 * 192.168.10.18 (alvin)
 * $ ./client_server 8888 localhost 7777
 * 192.168.10.18 (user)$
 * $ ./client_server 7777 null null
 * 192.168.12.17 (eus)$
 * $ ./client_server null 192.168.10.18 8888
 * The print out will be:
 * 192.168.10.18 (alvin):
 *   From eus to alvin: Hello
 * 192.168.10.18 (user):
 *   From eus to alvin to user: Hello
 */
```

12-clisvr (3)

```
char pesan[]="[FROM SERVER] ACK MESSAGE...\n";
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <unistd.h>
#include <netdb.h>
#include <sys/time.h>
#include <sys/socket.h>
#include <arpa/inet.h>

typedef struct sockaddr      sockad;
typedef struct sockaddr_in   sockadin;
typedef struct hostent       shostent;

void error(char *msg){
    perror(msg);
    exit(0);
}
```

12-clisvr (4)

```
#define BUFFER_SIZE 4096

int main (int argc, char *argv []) {
    int sockfd, newsockfd, portno, cliilen, count, nn, sysup;
    char  buffer[BUFFER_SIZE], temp_buffer [BUFFER_SIZE];
    char* colon_pos;
    struct sockaddr_in serv_addr, cli_addr;
    struct hostent *server;
    struct timeval tval;

    if (argc < 4) {
        fprintf (stderr,
            "\nUsage: %s this_port  next_sever next_server_port\n\n"
            "Start the chain with 'this_port' = 'null'\n\n"
            "Terminte the chain with 'next_server'='next_server_port"
            " = 'null'\n\n", argv [0]);
        exit (1);
    }
```

12-clisvr (5)

```
if (strcmp (argv [1], "null") == 0) {
    portno = atoi (argv [3]);
    sockfd = socket (AF_INET, SOCK_STREAM, 0);
    if (sockfd < 0) {
        error ("ERROR opening socket");
    }
    server = gethostbyname(argv[2]);
    if (server == NULL) {
        fprintf (stderr, "ERROR, no such host\n");
        exit (1);
    }
    memset (&serv_addr, 0, sizeof (serv_addr));
    serv_addr.sin_family = AF_INET;
    memcpy(&serv_addr.sin_addr.s_addr, server->h_addr, server->h_length);
    serv_addr.sin_port = htons(portno);
    if (connect(sockfd,(struct sockaddr *)&serv_addr,sizeof(serv_addr))< 0){
        error ("ERROR connecting");
    }
    /* Begin: action */
    memset (buffer, 0, BUFFER_SIZE);
    gettimeofday(&tval,NULL);
    sysup = 0x0000FFFF & (int) (tval.tv_sec * 1000 + tval.tv_usec / 1000);
    snprintf (buffer, BUFFER_SIZE, "From %s[%d]: Hello", getenv ("USER"), sysup);
    nn = write (sockfd, buffer, strlen (buffer));

    if (nn < 0) {
        error ("ERROR writing to socket");
    }
    /* End: action */
    exit (0);
}
```


12-clisvr (6)

```
sockfd = socket(AF_INET, SOCK_STREAM, 0);
if (sockfd < 0) {
    error ("ERROR opening socket");
}
memset(&serv_addr, 0, sizeof(serv_addr));
portno = atoi (argv [1]);
serv_addr.sin_family = AF_INET;
serv_addr.sin_addr.s_addr = INADDR_ANY;
serv_addr.sin_port = htons (portno);

if (bind (sockfd, (struct sockaddr *)&serv_addr, sizeof(serv_addr)) < 0) {
    error ("ERROR on binding");
}
listen (sockfd, 5);
clilen = sizeof (cli_addr);
newsockfd = accept (sockfd, (struct sockaddr *) &cli_addr,
                    (socklen_t *) &clilen);
if (newsockfd < 0) {
    error ("ERROR on accept");
}
memset (buffer, 0, BUFFER_SIZE);
nn = read(newsockfd, buffer, BUFFER_SIZE-1);
if (nn < 0) {
    error ("ERROR reading from socket");
}
```

12-clisvr (7)

```
/* Modify buffer's message */
colon_pos = strchr (buffer, ':');
nn        = colon_pos - buffer;
memset (temp_buffer, 0, BUFFER_SIZE);
strncpy (temp_buffer, buffer, nn);
memset (buffer, 0, BUFFER_SIZE);
strncpy (buffer, temp_buffer, nn);
for (long ii=0; ii<5000000L; ii++)
    ; // delay
gettimeofday(&tval, NULL);
sysup = 0x0000FFFF &
    (int) (tval.tv_sec * 1000 + tval.tv_usec / 1000);
snprintf (buffer + nn, BUFFER_SIZE-nn,
    " to %s[%d]: Hello", getenv ("USER"), sysup);
/*End of modifying buffer's message*/
```

12-clisvr (8)

```
if (strcmp (argv [2], "null") != 0 && strcmp (argv [3], "null") != 0) {
    portno = atoi (argv [3]);
    sockfd=socket(AF_INET,SOCK_STREAM,0);
    if (sockfd < 0) {
        error ("ERROR opening socket");
    }
    server = gethostbyname (argv [2]);
    if (server == NULL) {
        fprintf (stderr, "ERROR, no such host\n");
        exit (1);
    }
    serv_addr.sin_family = AF_INET;
    memcpy (&serv_addr.sin_addr.s_addr, server->h_addr, server->h_length);
    serv_addr.sin_port = htons (portno);
    if (connect (sockfd,(struct sockaddr *)&serv_addr,sizeof (serv_addr))<0){
        error ("ERROR connecting");
    }
    /* Begin: action */
    printf ("%s\n", buffer);
    nn=write(sockfd,buffer,strlen(buffer));
    if (nn < 0) {
        error ("ERROR writing to socket");
    }
    /* End: action */
} else {
    printf ("%s\n", buffer);
}
return 0;
}
```

OUTPUT: 12-clisvr

```
TERMINAL >> PS1="TERMINAL >> "  
TERMINAL >> 02-clisvr 4000 localhost null  
From demo[23440] to demo[23450] to demo[23461]: Hello  
TERMINAL >>
```

```
MIDDLE >> PS1="MIDDLE >> "  
MIDDLE >> 02-clisvr 4001 localhost 4000  
From demo[23440] to demo[23450]: Hello  
MIDDLE >>
```

```
START >> PS1="START >> "  
START >> 02-clisvr null localhost 4001  
START >>
```

50-get-put — 51-get-put-loop

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

```
void main (void) {  
    int cc = getchar();  
    putchar(cc);  
    putchar('\n');  
}
```

```
>>>> $ 50-get-put
```

```
x
```

```
x
```

```
>>>> $ 50-get-put
```

```
abcde
```

```
a
```

```
=====  
#include <stdio.h>
```

```
void main (void) {  
    int cc;  
    while((cc = getchar()) != EOF) {  
        putchar(cc);  
    }  
}
```

```
>>>> $ 51-get-put-loop
```

```
xxxx
```

```
xxxx
```

52-open-close

```
* === umask() ===
* int open(const char* pathname, int flags, mode_t mode);
* === FLAGS: ===
* O_RDONLY      Open the file so that it is read only.
* O_WRONLY      Open the file so that it is write only.
* O_RDWR        Open the file so that it can be read from and written to.
* O_APPEND       Append new information to the end of the file.
* O_TRUNC        Initially clear all data from the file.
* O_CREAT        If the file does not exist, create it.
*                You must include the third parameter.
* O_EXCL         With O_CREAT: exists, the call will fail.
* === MODE ===
* S_IRWXU       00700 user (file owner) has read, write and execute permission
* S_IRUSR       00400 user has read permission
* S_IWUSR       00200 user has write permission
* S_IXUSR       00100 user has execute permission
*
* S_IRWXG       00070 group has read, write and execute permission
* S_IRGRP       00040 group has read permission
* S_IWGRP       00020 group has write permission
* S_IXGRP       00010 group has execute permission
*
* S_IRWXO       00007 others have read, write and execute permission
* S_IROTH       00004 others have read permission
* S_IWOTH       00002 others have write permission
* S_IXOTH       00001 others have execute permission
```

52-open-close (2)

```
#define FILE1 "demo-file1.txt"
#define FILE2 "demo-file2.txt"
#define FILE3 "demo-file3.txt"

#include <stdio.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>
void main(void) {
    char*   file1=FILE1;
    char*   file2=FILE2;
    char*   file3=FILE3;

    int fd; /* to hold a file descriptor */
    /* umask(0);      ***** */
    fd = open (file1, O_CREAT | O_RDWR, S_IRWXU);
    close(fd);
    fd = open (file2, O_CREAT | O_RDWR, S_IRWXU|S_IRGRP|S_IWGRP|S_IROTH);
    close(fd);
    fd = open (file3, O_CREAT | O_RDWR, 0711);
    close(fd);
    fd = open (file3, O_CREAT | O_RDWR, 0700);
    close(fd);
}

>>>> $ ls -al demo-file[234].txt
-rwxr--r-- 1 demo demo  0 Oct  5 17:49 demo-file2.txt
-rwx--x--x 1 demo demo  0 Oct  5 17:49 demo-file3.txt
-rw-r--r-- 1 demo demo 75 Oct  5 17:49 demo-file4.txt
>>>> $
```

53-file-pointer

```
#define FILE4 "demo-file4.txt"
#include <stdio.h>
#include <stdlib.h>

void main(void) {
    FILE* fp;
    int    cc;

    printf ("*** Open and listing file %s ***\n\n", FILE4);
    if ((fp=fopen(FILE4, "r")) == NULL) {
        printf("fopen error...\n");
        exit(1);
    }
    while((cc=fgetc(fp)) != EOF) {
        printf("%c", cc);
    }
    printf("\n");
    fclose(fp);
}
```

*** Open and listing file demo-file4.txt ***

Line 1: Blah Blah Blah 1
Line 2: Blah Blah Blah 2
Line 3: Blah Blah Blah 3

54-write

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>

#define FILE5    "demo-file5.txt"
static char* str1 = "AAAXBBB\n";
static char* str2 = "CCC\n";

void main(void) {
    int fd1, fd2;
    fd1 = open (FILE5, O_RDWR | O_CREAT, 0644);
    fd2 = open (FILE5, O_RDWR | O_CREAT, 0644);
    printf("File Descriptors --- fd1 = %d, fd2 = %d\n", fd1, fd2);
    write(fd1, str1, strlen(str1));
    write(fd2, str2, strlen(str2));
    close(fd1);
    close(fd2);
    printf("See output file %s\n", FILE5);
}
```

```
#####
File Descriptors --- fd1 = 3, fd2 = 4
See output file demo-file5.txt
```

```
#####
demo-file5.txt:
CCC
BBB
```

55-write

```
#define FILE6 "demo-file6.txt"
char buf1[] = "abcdefgh";
char buf2[] = "ABCDEFGH";

void main(void) {
    int fd;
    fd = creat(FILE6, 0644);
    if (fd < 0) {
        perror("creat error");
        exit(1);
    }
    if (write(fd, buf1, 8) != 8) {
        perror("buf1 write error");
        exit(1);
    } /* offset now = 8 */
    if (lseek(fd, 32, SEEK_SET) == -1) {
        perror("lseek error");
        exit(1);
    } /* offset now = 32 */
    if (write(fd, buf2, 8) != 8) {
        perror("buf2 write error");
        exit(1);
    } /* offset now = 40 */
    close(fd);
    printf("Run: hexdump -c %s\n", FILE6);
}
```

```
>>>> $ hexdump -c demo-file6.txt
00000000  a  b  c  d  e  f  g  h  \0  \0  \0  \0  \0  \0  \0  \0
00000100  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0
00000200  A  B  C  D  E  F  G  H
```

```
#include <stdio.h>
#include <errno.h>
#include <stdlib.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#define BUF_SIZE 16

void main(int argc, char* argv[])
{
    int            fdread, fdwrite;
    unsigned int  total_bytes = 0;
    ssize_t       nbytes_read, nbytes_write;
    char buf[BUF_SIZE];
    if (argc != 3) {
        printf("Usage: %s source destination\n",
            argv[0]);
        exit(1);
    }
    fdread = open(argv[1], O_RDONLY);
    if (fdread < 0) {
        perror("Failed to open source file");
        exit(1);
    }
    fdwrite = creat(argv[2], S_IRWXU);
    if (fdwrite < 0) {
        perror("Failed to open destination file");
        exit(1);
    }
}
```

56-copy (2)

```
do {
    nbytes_read = read(fdread, buf, BUF_SIZE);
    if (nbytes_read < 0) {
        perror("Failed to read from file");
        exit(1);
    }
    nbytes_write = write(fdwrite, buf, nbytes_read);
    if (nbytes_write < 0) {
        perror("Failed to write to file");
        exit(1);
    }
} while (nbytes_read > 0);
close(fdread);
close(fdwrite);
exit(0);
}

#####

>>>> $ ./56-copy demo-file4.txt demo-copy.txt
>>>> $ ls -al demo-file4.txt demo-copy.txt
-rwx----- 1 demo demo 75 Oct  5 18:12 demo-copy.txt
-rw-r--r-- 1 demo demo 75 Oct  5 17:49 demo-file4.txt
>>>> $
```

57-dup

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>
#define FILE1 "demo-file7.txt"
```

```
static char* str1 = "AAAXBBB\n";
static char* str2 = "CCC\n";
```

Coming Soon

```
void
{
    int fd1, fd2;
    fd1 = open (FILE1, O_RDWR | O_CREAT, 0644);
    fd2 = dup(fd1);
    printf("File Descriptors --- fd1 = %d, fd2 = %d\n", fd1, fd2);
    write(fd1, str1, strlen(str1));
    write(fd2, str2, strlen(str2));
    close(fd1);
    close(fd2);
    printf("**** Please check file %s *****\n", FILE1);
    printf("**** Compare with 54-write\n");
}
```

```
#####
```

```
>>>> $ 57-dup
```

```
File Descriptors --- fd1 = 3, fd2 = 4
```

```
**** Please check file demo-file7.txt ****
```

```
**** Compare with 54-write
```

```
>>>> $ cat demo-file7.txt
```

```
AAAXBBB
```

```
CCC
```

```
>>>> $
```

58-dup2

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>
#include <string.h>
#define FILE1 "demo-file8.txt"

static char* str1 = "AAAXBBB\n";
static char* str2 = "CCC\n";

void main(void) {
    int fd1, fd2;
    fd1 = open (FILE1, O_RDWR | O_CREAT, 0644);
    dup2(fd1, fd2);
    printf("File Descriptors --- fd1 = %d, fd2 = %d\n", fd1, fd2);
    write(fd1, str1, strlen(str1));
    write(fd2, str2, strlen(str2));
    close(fd1);
    close(fd2);
    printf("**** Please check file %s *****\n", FILE1);
    printf("**** Compare with 54-write\n");
}
```

```
#####
>>>> $ 58-dup2
File Descriptors --- fd1 = 3, fd2 = 0
**** Please check file demo-file8.txt ****
**** Compare with 54-write
>>>> $ cat demo-file8.txt
AAAXBBB
CCC
>>>> $
```

```

#include <stdio.h>
#include .....
#define FILE1 "demo-file9.txt"

void main(void) {
    int fd1, fd2;
    char strvar[100];
    printf ("***** Please check file %s ***** \n", FILE1);
/* BLOCK *****
    close(STDERR_FILENO);
    close(STDOUT_FILENO);
    BLOCK ***** */
    fd1 = open (FILE1, O_RDWR | O_CREAT | O_TRUNC, 0644);
    fd2 = dup(fd1);
    printf(          "AAAAA print to standard output!!\n");
    fprintf(stdout, "BBBBB print to standard output!!\n");
    fprintf(stderr, "CCCCC print to standard error!!!\n");
    sprintf(strvar, "DDDDD print to fd1=%d!!!\n", fd1);
    dprintf(fd1,      "%s", strvar);
    dprintf(fd2,      "EEEEE print to fd2=%d!!!\n", fd2);
    close(fd1);
    close(fd2);
}

>>>> $ 59-io ; echo "~~~~~";cat demo-file9.txt
***** Please check file demo-file9.txt *****
AAAAA print to standard output!!
BBBBB print to standard output!!
CCCCC print to standard error!!!
~~~~~
DDDDD print to fd1=3!!!
EEEEE print to fd2=4!!!

```

59-io (2)

```
#include <stdio.h>
#include .....
#define FILE1 "demo-file9.txt"

void main(void) {
    int fd1, fd2;
    char strvar[100];
    printf ("***** Please check file %s *****\n", FILE1);
    close(STDERR_FILENO);
/* BLOCK *****
    close(STDOUT_FILENO);
    BLOCK ***** */
    fd1 = open (FILE1, O_RDWR | O_CREAT | O_TRUNC, 0644);
    fd2 = dup(fd1);
    printf(          "AAAAA print to standard output!!\n");
    fprintf(stdout, "BBBBB print to standard output!!\n");
    fprintf(stderr, "CCCCC print to standard error!!!\n");
    sprintf(strvar, "DDDDD print to fd1=%d!!!\n", fd1);
    dprintf(fd1,      "%s", strvar);
    dprintf(fd2,      "EEEEE print to fd2=%d!!!\n", fd2);
    close(fd1);
    close(fd2);
}

>>>> $ 59-io ; echo "~~~~~";cat demo-file9.txt
***** Please check file demo-file9.txt *****
AAAAA print to standard output!!
BBBBB print to standard output!!
~~~~~
CCCCC print to standard error!!!
DDDDD print to fd1=2!!!
EEEEE print to fd2=3!!!
```


59-io (3)

```
#include <stdio.h>
#include .....
#define FILE1 "demo-file9.txt"

void main(void) {
    int fd1, fd2;
    char strvar[100];
    printf ("***** Please check file %s *****\n", FILE1);
    close(STDERR_FILENO);
    close(STDOUT_FILENO);
    /* BLOCK *****
    BLOCK ***** */
    fd1 = open (FILE1, O_RDWR | O_CREAT | O_TRUNC, 0644);
    fd2 = dup(fd1);
    printf(          "AAAAA print to standard output!!\n");
    fprintf(stdout, "BBBBB print to standard output!!\n");
    fprintf(stderr, "CCCCC print to standard error!!!\n");
    sprintf(strvar, "DDDDD print to fd1=%d!!!\n", fd1);
    dprintf(fd1,      "%s", strvar);
    dprintf(fd2,      "EEEEE print to fd2=%d!!!\n", fd2);
    close(fd1);
    close(fd2);
}

>>>> $ 59-io ; echo "~~~~~";cat demo-file9.txt
**** Please check file demo-file9.txt ****
~~~~~

AAAAA print to standard output!!
BBBBB print to standard output!!
CCCCC print to standard error!!!
DDDDD print to fd1=1!!!
EEEEE print to fd2=2!!!
```

60-readwrite

```
#define FILE1 "demo-fileA.txt"
#define OLOOP 10
#define ILOOP 3650
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <time.h>
#include <fcntl.h>
#include <dirent.h>
void rwfile (char* fname);
void dirfile(char* dname);
void error (char* msg);
/* MAIN ===== */
void main(void) {
    printf("Listing current directory...\n");
    dirfile(".");
    printf("Testing read-write speed...\n");
    rwfile(FILE1);
}
/* DIRFILE ===== */
void dirfile(char* dname) {
    DIR* ddir;
    struct dirent* dp;
    printf(" ");
    ddir = opendir(dname);
    if (ddir != NULL) {
        while ((dp=readdir(ddir))!= NULL)
            printf("%s ", dp->d_name);
        closedir(ddir); }
    printf("\n\n"); }
```

60-readwrite (2)

```
/* ERROR ===== */
void error(char* msg){
    perror(msg);
    exit(0); }
/* RWFILE ===== */
void rwfile(char* fname) {
    time_t tt;
    int    fd, ii, jj;
    char    buf[] = "Achtung... Achtung... AAAA BBBB CCCC DDDD\n";
    time(&tt);
    for (ii=0;ii<OLOOP;ii++) {
        if ((fd=creat(fname,00644)) < 0 )
            error("RWFILE: can not create file\n");
        for (jj=0;jj<ILOOP;jj++) {
            write(fd,buf,sizeof(buf)-1);
            fsync(fd); }
        close(fd);
        putchar('.') ;
        fflush(NULL); }
    tt=time(NULL)-tt;
    putchar('\n');
    printf("Total time: %d seconds\n", (int) tt);
}

#####
>>>> $ time 60-readwrite
Listing current directory...
      .shsh 52-open-close.c demo-file4.txt 02-pointers.c ...
Testing read-write speed...
.....
Total time: 10 seconds
real    0m9.998s  -----  user    0m0.024s  -----  sys      0m0.576s
```

• 18 Knowledge Areas

AL - Algorithms and Complexity	AR - Architecture and Organization
CN - Computational Science	DS - Discrete Structures
GV - Graphics and Visualization	HCI - Human-Computer Interaction
IAS - Information Assurance and Security	IM - Information Management
IS - Intelligent Systems	NC - Networking and Communications
OS - Operating Systems	PBD - Platform-based Development
PD - Parallel and Distributed Computing	PL - Programming Languages
SDF - Software Development Fundamentals	SE - Software Engineering
SF - Systems Fundamentals	SP - Social Issues and Professional Practice

• OS - Operating Systems (IEEE/ACM 2013)

- OS/Overview of Operating Systems (T1:2)
- OS/Operating System Principles (T1:2)
- OS/Concurrency (T2:3)
- OS/Scheduling and Dispatch (T2:3)
- OS/Memory Management (T2:3)
- OS/Security and Protection (T2:2)
- OS(Electives): Virtual Machines, Device Management, File Systems, Real Time and Embedded Systems, Fault Tolerance, System Performance Evaluation.

The End

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