CSGE602055 Operating Systems
CSF2600505 Sistem Operasi
Week 10: I/O & Programming

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Sendirian Berhad

https://os.vlsm.org/Slides/os10.pdf
Always check for the latest revision!

REV392 30-Aug-2022

OS222[3]): Operating Systems Schedule 2022 - 2

Week	Topic[1])	OSC10[2])
Week 00	Overview (1), Assignment of Week 00	Ch. 1, 2
Week 01	Overview (2), Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	Security, Protection, Privacy, & C-language.	Ch. 16, 17.
Week 03	File System & FUSE	Ch. 13, 14, 15.
Week 04	Addressing, Shared Lib, & Pointer	Ch. 9.
Week 05	Virtual Memory	Ch. 10.
Week 06	Concurrency: Processes & Threads	Ch. 3, 4.
Week 07	Synchronization & Deadlock	Ch. 6, 7, 8.
Week 08	Scheduling + W06/W07	Ch. 5.
Week 09	Storage, Firmware, Bootloader, & Systemd	Ch. 11.
Week 10	I/O & Programming	Ch. 12.

[1]) For schedule, see https://os.vlsm.org/#idx02

[2]) Silberschatz et. al.: **Operating System Concepts**, 10^{th} Edition, 2018.

[3]) This information will be on **EVERY** page two (2) of this course material.

STARTING POINT — https://os.vlsm.org/

- **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10^{th} Edition, 2018. (See https://www.os-book.com/OS10/).
- **Resources** (https://os.vlsm.org/#idx03)
  - **SCELE OS222** — https://scele.cs.ui.ac.id/course/view.php?id=3398. The enrollment key is **XXX**.
  - **Download Slides and Demos from GitHub.com** — (https://github.com/os2xx/os/) os00.pdf (W00), os01.pdf (W01), os02.pdf (W02), os03.pdf (W03), os04.pdf (W04), os05.pdf (W05), os06.pdf (W06), os07.pdf (W07), os08.pdf (W08), os09.pdf (W09), os10.pdf (W10).
  - **Problems** 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).
  - **LFS** — http://www.linuxfromscratch.org/lfs/view/stable/
  - **OSP4DISS** — https://osp4diss.vlsm.org/
  - **This is How Me Do It!** — https://doit.vlsm.org/001.html
    - PS: "Me" rhymes better than "I", duh!

Agenda

Agenda (2)

13. 54-write
14. 55-write
15. 57-dup
16. 58-dup2
17. 59a-IO
18. 59b-IO
19. 59c-IO
20. 71-os171
21. 72-os172
22. 73-os181
23. 74-os182
24. 75-os191
25. 76-os192

Week 10 I/O & Programming: Topics[1]

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

[1] Source: ACM IEEE CS Curricula 2013

Week 10 I/O & Programming: Learning Outcomes[1]

- 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]

[1] Source: ACM IEEE CS Curricula 2013

OSC10 (Silberschatz) Chapter 12

- OSC10 Chapter 12: I/O Systems
  - Overview
  - I/O Hardware
  - Application I/O Interface
  - Kernel I/O Subsystem
  - Transforming I/O Requests to Hardware Operations
  - STREAMS
  - Performance

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)

I/O (1)

- 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 (2)

- 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

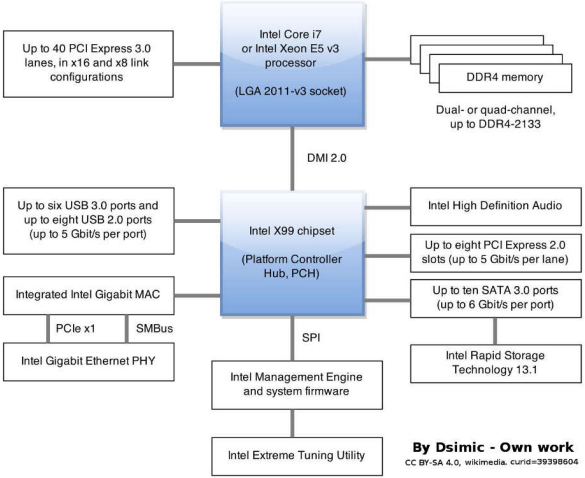

Figure: PCH: Platform Controller Hub

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 x DDR2 (DDR2 = 2 x DDR (DDR = 2 x 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 bytes[1]

[1] In IT tradition; 1 KB = 1024 bytes

Sockets

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

Sockets

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

10-server (01)

```
/* Copyright (C) 2007-2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.
 * REV02 Sun May  3 07:53:26 WIB 2020
 * 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;
```

10-server (02)

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

int main(int argc, char *argv[]) {
   char     buffer[256];
   int      clilen, 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");
   int enable = 1;
   if (setsockopt(sockfd, SOL_SOCKET, SO_REUSEADDR,
       &enable, sizeof(int)) < 0)
      error("setsockopt(SO_REUSEADDR) failed");
   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);
   clilen = sizeof(cli_addr);
```

10-server (03)

```
    newsockfd=accept(sockfd,(sockad*)&cli_addr,
       (socklen_t*)&clilen);
    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 (01)

```
/* Copyright (C) 2007-2018 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.
 * REV01 Wed Aug 29 20:53:11 WIB 2018
 * 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;
```

11-client (02)

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

int main(int argc, char *argv[]) {
   char      buffer[256];
   int       nn, portno, sockfd;
   sockadin  serv_addr;
   shostent* server;
   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: ");
```

11-client (03)

```
   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;
}

# TERMINAL 1 ########################################

$ ./10-server 6666
[FROM CLIENT]:
 Hello World!
$


# TERMINAL 2 ########################################

$ ./11-client localhost 6666
Enter the message: Hello World!
[FROM SERVER] ACK MESSAGE...

$
```

12-clisvr (01)

```
/*
 * Copyright (C) 2007 Tadeus Prastowo
 * Copyright (C) 2017 - 2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 * REV04 Sun May  3 07:59:57 WIB 2020
 * REV03 Wed Feb 27 19:21:44 WIB 2019
 * REV02 Wed Aug 29 20:54:25 WIB 2018
 * 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
```

12-clisvr (02)

```
 * 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
 */

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;
```

12-clisvr (03)

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

#define BUFFER_SIZE 4096

int main(int argc, char *argv []) {
   int sockfd, newsockfd, portno, clilen, count, nn, sysup;
   char buffer [BUFFER_SIZE], temp_buffer [BUFFER_SIZE], *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);
   }
   if (strcmp (argv [1], "null") == 0) {
      portno = atoi   (argv [3]);
      sockfd = socket (AF_INET, SOCK_STREAM, 0);
      if (sockfd < 0) {
         error ("ERROR opening socket");
      }
      int enable = 1;
      if (setsockopt(sockfd, SOL_SOCKET, SO_REUSEADDR,
```

12-clisvr (04)

```
   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\n%s[%d]:", getenv ("USER"), sysup);
   nn = write (sockfd, buffer, strlen (buffer));
   if (nn < 0) {
     error ("ERROR writing to socket");
   }
   /* End: action */
   exit (0);
}

sockfd = socket(AF_INET,SOCK_STREAM,0);
if (sockfd < 0) {
   error ("ERROR opening socket");
}
```

12-clisvr (05)

```
int enable = 1;
if (setsockopt(sockfd, SOL_SOCKET, SO_REUSEADDR,
   &enable, sizeof(int)) < 0)
   error("setsockopt(SO_REUSEADDR) failed");
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");
}
/* 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);
```

12-clisvr (06)

```
   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\n%s[%d]:\nEndOfMessage!", getenv ("USER"), sysup);
   /*End of modifying buffer's message*/
   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");
      }
      printf ("%s\n", buffer); // ============ Begin: action
      nn=write(sockfd,buffer,strlen(buffer));
      if (nn < 0) error ("ERROR writing to socket"); // ============ End: action
      else printf ("%s\n", buffer);
   return 0;
}
```

12-clisvr (07)

```
$ host ckilat1.vlsm.org
ckilat1.vlsm.org has address 103.43.44.16
$ ./12-clisvr 9999 null null
From
rms46[16229] to
poor[16245] to
poor[16260]:
EndOfMessage!
$
```

```
$ host ckilat2.vlsm.org
ckilat2.vlsm.org has address 103.23.20.185
$ ./12-clisvr 9998 ckilat1.vlsm.org 9999
From
rms46[16229] to
poor[16245]:
EndOfMessage!
$
```

```
$ hostname
pamulang1
$ ./12-clisvr null ckilat2.vlsm.org 9998
$ date
Sun May  3 12:17:18 WIB 2020
$
```

Figure: Client Server

54-write (01)

```
/*
 * Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 *
 * TAKE NOTE()
 * O_RDWR open for reading and writing
 * O_CREAT indicates that the call to open() has a mode argument,
 * if the file being opened already exist O_CREAT has no effect
 * if the file being opened does not exist it is created
 * if O_CREAT is specified and the file did not previously exist a sucessful open
 * () sets the access time, change time, and modification time for the file
 *
 * if succesful, dup() returns a new file descriptor
 * if unsucessful, dup() returs -1 and sets errno to EBADF or EMFILE
 *
 * REV09 Tue Nov 26 11:38:34 WIB 2019
 * REV08 Wed Aug 29 20:55:23 WIB 2018
 * REV07 Thu Oct  5 17:56:09 WIB 2017
 * REV02 Sun Oct 16 20:50:52 WIB 2016
 * START Xxx Apr 25 XX:XX:XX WIB 2015
 */

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

54-write (02)

```
#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);
}
# ####################################
$ ./54-write
File Descriptors --- fd1 = 3, fd2 = 4
See output file demo-file5.txt

$ cat demo-file5.txt
CCC
BBB

$
```

55-write (01)

```
/*
 * Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 *
 * TAKE NOTE (MA)
 * Program ini akan membuat file baru dengan isi
 * buf1 pada 8 char pertama, dan buf2 pada 8 char terakhir
 *
 * Line 31 akan membuat program menulis 8 char
 * dari variabel char buf1 ke file yang didefine pada Line 19
 *
 * Line 35 akan membuat offset menjadi 32,
 * yang maksudnya adalah pointernya lompat ke huruf ke 32
 * Sehingga ketika menulis lg, akan dimulai pada huruf ke 33
 *
 * REV06 Tue Nov 26 11:39:10 WIB 2019
 * REV05 Wed Aug 29 20:55:23 WIB 2018
 * REV04 Wed Oct 18 17:54:25 WIB 2017
 * REV02 Thu Mar  9 21:21:28 WIB 2017
 * START Xxx Apr 25 XX:XX:XX WIB 2015
 * USE "hexdump FILE1"
 */

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/types.h>
```

54-write (02)

```
#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
0000000   a   b   c   d   e   f   g   h  \0  \0  \0  \0  \0  \0  \0  \0
0000010  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0  \0
0000020   A   B   C   D   E   F   G   H
```

57-dup (01)

```
/*
 * Copyright (C) 2016-2019 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 *
 * TAKE NOTE(TA)
 * O_RDWR open for reading and writing
 * O_CREAT indicates that the call to open() has a mode argument,
 * if the file being opened already exist O_CREAT has no effect
 * if the file being opened does not exist it is created
 * if O_CREAT is specified and the file did not previously exist a sucessful open
 * () sets the access time, change time, and modification time for the file
 *
 * if succesful, dup() returns a new file descriptor
 * if unsucessful, dup() returs -1 and sets errno to EBADF or EMFILE
 *
 * REV07 Tue Nov 26 11:39:10 WIB 2019
 * START Xxx Apr 25 XX:XX:XX WIB 2015
 * dup(fd) duplicates fd
 * fd2=dup(fd1)  <---> dup2(fd1, fd2)
 */

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

57-dup (02)

```
#define FILE1 "demo-file7.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);
   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");
}
# #####
$ ./54-write
File Descriptors --- fd1 = 3, fd2 = 4
See output file demo-file5.txt
$ ./57-dup
File Descriptors --- fd1 = 3, fd2 = 4
**** Please check file demo-file7.txt *****
**** Compare with 54-write
$ cat demo-file5.txt
CCC
BBB
$ cat demo-file7.txt
AAAXBBB
CCC
$
```

58-dup2 (01)

```
/*
 * Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.
 * REV07 Tue May  7 18:46:12 WIB 2019
 * REV04 Thu Mar  9 21:22:36 WIB 2017
 * REV02 Sun Oct 16 20:52:15 WIB 2016
 * START Xxx Apr 25 XX:XX:XX WIB 2015
 *
 * fd2=dup2(fd1, NEWFD)
 *
 */

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

58-dup2 (02)

```
#define FILE1 "demo-file8.txt"
#define NEWFD 10
static char* str1 = "AAAXBBB\n";
static char* str2 = "CCC\n";
void main(void) {
   int fd1, fd2;
   fd1 = open (FILE1, O_RDWR | O_CREAT, 0644);
   fd2=dup2(fd1, NEWFD);
   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 = 10
**** Please check file demo-file8.txt *****
**** Compare with 54-write
$ cat demo-file8.txt
AAAXBBB
CCC
$ cat demo-file5.txt
CCC
BBB
$
```

59a-IO

```
$ cat 59a-io.c
// Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
#define FILE1 "59a-io-demo.txt"
void main(void) {
   int fd1, fd2;
   char strvar[100];
   printf ("***** Please check file %s ***** *****\n", FILE1);
   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);
}
# ########
$ ./59a-io
***** Please check file 59a-io-demo.txt ***** *****
AAAAA print to standard output!!
BBBBB print to standard output!!
CCCCC print to standard error!!!
$ cat 59a-io-demo.txt
DDDDD print to fd1=3!!!
EEEEE print to fd2=4!!!
$
```

59b-IO

```
// Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
// #include ETC ETC
#define FILE1 "59b-io-demo.txt"
void main(void) {
   int fd1, fd2;
   char strvar[100];
   printf ("***** Please check file %s ***** *****\n", FILE1);
   close(STDERR_FILENO);
   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);
}
# ########
$
$ ./59b-io
***** Please check file 59b-io-demo.txt ***** *****
AAAAA print to standard output!!
BBBBB print to standard output!!
$ cat 59b-io-demo.txt
CCCCC print to standard error!!!
DDDDD print to fd1=2!!!
EEEEE print to fd2=3!!!
$
```

59c-IO

```
// Copyright (C) 2015-2019 Rahmat M. Samik-Ibrahim
// #include ETC ETC
#define FILE1 "59c-io-demo.txt"

void main(void) {
   int fd1, fd2;
   char strvar[100];
   printf ("***** Please check file %s ***** *****\n", FILE1);
   close(STDERR_FILENO);
   close(STDOUT_FILENO);
   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);
}
# ######
$ ./59c-io
***** Please check file 59c-io-demo.txt ***** *****
$ cat 59c-io-demo.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!!!
```

70-os161

```
// Copyright (C) 2015-2020 Rahmat M. Samik-Ibrahim
// #include ETC ETC

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

#define FILE "70-os161-demo.txt"

char *string = "ABCD\n";
void main(void) {
   int fileDescriptor;
   printf("See also file %s\n", FILE);
   close(STDOUT_FILENO);
   fileDescriptor = open (FILE, O_RDWR|O_CREAT|O_TRUNC, 0644);
   printf ( "%s", string);
   write(fileDescriptor, string, strlen(string));
}

# ######

$ ./70-os161
See also file 70-os161-demo.txt

$ cat 70-os161-demo.txt
ABCD
ABCD
```

71-os171

```
// Copyright (C) 2017-2020 Rahmat M. Samik-Ibrahim
// #include ETC ETC

static char* str1 = "AABB\n";
static char* str2 = "CCDD\n";
static char* str3 = "EEFF\n";

void main(void) {
   int fd1, fd2, fd3;
   printf("See also file %s\n", FILE);
   /* STDIN=0, STDOUT=1, STDERR=2, therefore
      fd1, fd2, fd3  will be 3, 4, and 5 */
   fd1 = open (FILE, O_TRUNC | O_RDWR | O_CREAT, 0644);
   fd2 = open (FILE, O_TRUNC | O_RDWR | O_CREAT, 0644);
   fd3 = dup(fd2);
   printf("fd1 = %d, fd2 = %d, fd3 = %d\n", fd1, fd2, fd3);
   write(fd1, str1, strlen(str1));
   write(fd2, str2, strlen(str2));
   write(fd3, str3, strlen(str3));
   close(fd1);
   close(fd2);
   close(fd3);
}
# ######
$ ./71-os171
See also file 71-os171-demo.txt
fd1 = 3, fd2 = 4, fd3 = 5
$ cat 71-os171-demo.txt
CCDD
EEFF
```

72-os172

```
// Copyright (C) 2017-2020 Rahmat M. Samik-Ibrahim
#define FILE "72-os172-demo.txt"
void main(void) {
   int fd1, fd2;
   printf("See also file %s\n", FILE);
   fd1 = open (FILE, O_RDWR | O_CREAT | O_TRUNC, 0644);
   fd2 = dup(fd1);
   write (fd1, "0123456789\n", 5);
   write (fd2, "abcdefghij\n", 5);
   close(fd1);
   close(fd2);
}
# ######
$X$ ./72-os172
See also file 72-os172-demo.txt
$X$ cat 72-os172-demo.txt
01234abcde$X$
```

73-os181

```
// Copyright (C) 2017-2020 Rahmat M. Samik-Ibrahim
// #include ETC ETC

#define FLAGS O_RDWR|O_TRUNC|O_CREAT
#define FILE "73-os181-demo.txt"
static char* str1 = "AAAAAAAAAA";
static char* str2 = "BBBBB";
void main(void) {
   int fd1, fd2, fd3;
   printf("See also file %s\n", FILE);
   /* STDIN=0, STDOUT=1, STDERR=2,
      fd1,fd2,fd3  will be 3,4,and 5 */
   fd1=open(FILE, FLAGS, 0644);
   fd2=open(FILE, FLAGS, 0644);
   fd3=dup(fd1);
   dprintf(fd1,"%s",        str1);
   dprintf(fd2,"X%dX%dX%dX",fd1,fd2,fd3);
   dprintf(fd3,"%s",        str2);
   close(fd1);
   close(fd2);
   close(fd3);
}
# #######

$X$ ./73-os181
See also file 73-os181-demo.txt

$X$ cat 73-os181-demo.txt
X3X4X5XAAABBBBB$X$
```

74-os182

```
// Copyright (C) 2018-2020 Rahmat M. Samik-Ibrahim
#define FLAGS O_RDWR|O_CREAT|O_TRUNC
#define MODES 0644
#define FILE3 "74-os182-demo3.txt"
#define FILE4 "74-os182-demo4.txt"
void main(void) {
   printf("See %s and %s\n", FILE3, FILE4);
   int fd3 = open (FILE3,FLAGS,MODES);
   int fd4 = open (FILE4,FLAGS,MODES);
   dprintf(fd3, "fd%d\n", fd3);
   dprintf(fd4, "fd%d\n", fd4);
   close(STDOUT_FILENO); // STDOUT = 1
   int fd1 = dup(fd3);
   close(STDERR_FILENO); // STDERR = 2
   int fd2 = dup(fd4);
   dprintf(fd1, "fd%d\n", fd1);
   dprintf(fd2, "fd%d\n", fd2);
   close (fd1);
   close (fd2);
   close (fd3);
   close (fd4);
}
$ ./74-os182
See 74-os182-demo3.txt and 74-os182-demo4.txt
$ cat 74-os182-demo3.txt
fd3
fd1
$ cat 74-os182-demo4.txt
fd4
fd2
```

75-os191

```
// Copyright (C) 2019-2020 Rahmat M. Samik-Ibrahim
// #include ETC ETC

#define FILE    "75-os191-demo.txt"
#define STRING1 "AAABBBCCC"
#define STRING2 "DDDEEEFFF"
#define STRING3 "GGGHHHIII"

void main(void) {
   printf("See %s\n", FILE);
   int fd1=open(FILE,
       O_CREAT|O_TRUNC|O_RDWR, 0644);
   int fd2=open(FILE,
       O_CREAT|O_TRUNC|O_RDWR, 0644);
   int fd3=open(FILE,
       O_CREAT|O_TRUNC|O_RDWR, 0644);
   write (fd1,STRING1, 9);
   write (fd2,STRING2, 6);
   write (fd3,STRING3, 3);
   close(fd1);
   close(fd2);
   close(fd3);
}

### ##########
$X$ ./75-os191
See 75-os191-demo.txt

$X$ cat 75-os191-demo.txt
GGGEEECCC$X$
```

76-os192

```
// Copyright (C) 2019-2020 Rahmat M. Samik-Ibrahim
// #include ETC ETC

#define FILE    "76-os192-demo.txt"

void main(void) {
   printf("See %s\n", FILE);
   printf ("OUT=%d\n", STDOUT_FILENO);
   close(STDOUT_FILENO);
   int fd1 = open (FILE, O_RDWR |
             O_CREAT | O_TRUNC, 0644);
   int fd2 = dup2(fd1, 9);
   printf(         "A\n");
   fprintf(stdout, "B\n");
   dprintf(fd2,    "fd1=%d\nfd2=%d\n",
                           fd1, fd2);
}

# #########

$ ./76-os192
See 76-os192-demo.txt
OUT=1

$ cat 76-os192-demo.txt
A
B
fd1=1
fd2=9
$
```

IEEE/ACM 2013

- 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.