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SMR/643 - 6

SECOND COLLEGE ON
MICROPROCESSOR-BASED REAL-TIME CONTROL -
PRINCIPLES AND APPLICATIONS IN PHYSICS
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C LANGUAGE - BASICS

(6 - 8)

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These are preliminary lecture notes, intended only for distribution to participants.

STRUCTURES AND UNIONS

To group heterogeneous objects (PASCAL"record"):

date: day month year

```
struct date{ int day, month, year; };
struct date today, yesterday,
   tomorrow;
```

- declare **structure** *tag* `date`(its not a `typedef!`)
- declares `today, yesterday` and `tomorrow` to be variables of the type "`struct date`"

Personal record:
name
social security number
date of birth : date

```
struct vitalstat
{   char vs_name[19],vs_ssnum[11];
    struct date vs_birth_date;
} vs1;

struct vitalstat vs2;
```

- declares **structure** *tag* `vitalstat`
- declares variables `vs1 vs2` of type `struct vitalstat`

- **struct** *tag_name* { *list of declarations*}

- **struct** components can be other **structs**
  WARNING : but of different types

```
struct infinite{ int count;
          struct infinite mytail;
} /*ILLEGAL*/
```

- *tag_name* is optional

```
struct {char a[10], b[10] ;} str1,
str2;
```

ACCESSING ELEMENTS OF A STRUCTURE

```
strcpy( vs.vs_name, "John Smith");
strcpy( vs.vs_ssnum, "035400245");
vs.vs_birth_date.day=17;
vs.vs_birth_date.month=9;
vs.vs_birth_date.year=1956;
```

variable name .component name

```
if (vs.vs_birth_date.month > 12 ||
    vs.vs_birth_date.day > 31 )
   printf ( "Illegal date. \n");
```

Structure components are normal variables

ARRAYS OF STRUCTURES

Arrays of anything!

```
#include <stdio.h>
typedef struct {float re,im;} Complex;
/* placed here to be GLOBAL, that is
apply to all functions in this file */
/* reads in two complex arrays */
main()
{

   Complex v1[10], v2[10];

   for ( i=0; i<10 ; i++ )
      scanf(" %f %f %f %f " ,
         &v1[i].re , &v1[i].im,
         &v2[i].re , &v2[i].im) ;
}
```

OR

```
#include <stdio.h>
struct complex { float re,im;}  ;
main()
{

   struct complex v1[10] , v2[10] ;

   for ( i=0; i<10 ; i++ )
        scanf(" %f %f %f %f " ,
         &v1[i].re , &v1[i].im,
         &v2[i].re , &v2[i].im) ;
}
```

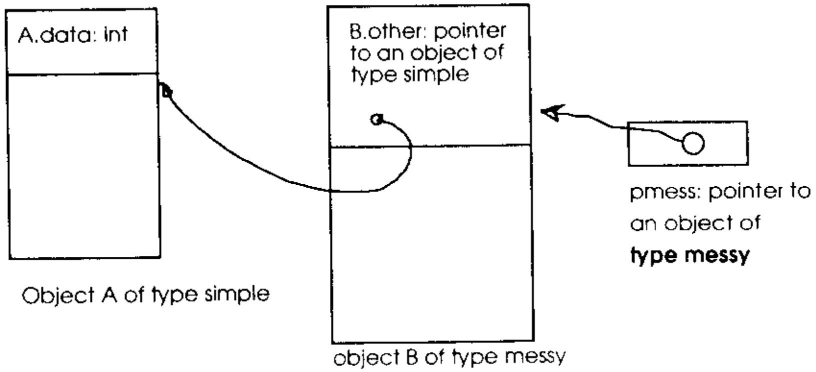
POINTERS TO STRUCTURES

pointers to anything !

```
#include <stdio.h>
typedef struct {float re,im;} Complex;

/* reads in one complex array
 * and computes its euclidean norm
 * squared */
main()
{

    Complex v1[1000];
    double cnorm2( );

    for ( i=0; i<10 ; i++ )
         scanf(" %f %f " , &v1[i].re ,
           &v1[i].im) ;
    dp=cnorm2(v1,10);
    printf (" %f \n" , dp );
}
double
cnorm2( v1,  n)
Complex v1[];
int n;
{
    double d=0;
    Complex *vend=&v1[n], *vp= v1;

    for( ; vp < vend; vp++ )
         d += (*vp).re * (*vp).re +
              (*vp).im * (*vp).im ;

    return d;
}
```

(*vp).re UGLY. CAN BE TERRIBLE :

```
struct simple { int data;
       ....
} A;
struct messy{ struct simple * other;
       ....
       } B;
struct messy * pmess;

(*(*pmess).other).data
```


A.data: int
B.other: pointer to an object of type simple
pmess: pointer to an object of **type messy**
Object A of type simple
object B of type messy

NEW OPERATOR ->

p->x IS **(*p).x**

EXAMPLE ABOVE: **pmess->other->data**

```
double cnorm2( v1 , n)
Complex v1[];
int n;
{
    double d=0;
    Complex *vend= &v1[n],  *vp=v1;
    for( ; vp < vend; vp++)
        d += vp->re * vp->re +
            vp->im * vp->im ;
    return d;
}
```

OPERATIONS ON STRUCTURES

- take a component (**.**)
- take the address (**&**)
- take the size (**sizeof**)

TO PASS TO FUNCTIONS: pass pointers

```
struct complex * cprod (cp1, cp2)
struct complex * cp1, *cp2;
{   struct complex product;
    product.re=cp1->re*cp2->re -
                cp1->im*cp2->im;
    product.im=cp1->re*cp2->im+
                cp1->im*cp2->re;
    return &product; /* DISASTER:
* returns pointer to local
* variable! */
}
```

Solution: use global or local static ?
Difficult! **cprod(cprod(*a,*b),*c) would not work either!**

DO NOT TRY TO RETURN AS VALUE (at least if use in of returned struct in an expression is conceivable)

```
cprod ( resultp, cp1, cp2)
struct complex *resultp, * cp1, *cp2;
{
    resultp->re=cp1->re*cp2->re -
                cp1->im*cp2->im;
    resultp->im=cp1->re*cp2->im+
                cp1->im*cp2->re;
    return ;
}
```

ANSI ONLY:

```
typedef struct(float re,im;) Complex;
Complex z1,z2;
```

- assignement:

```
z1=z2;
```

- passing as argument to functions

```
double cnorm ( Complex z1){
       return ( sqrt(z1.re * z1.re+
               z1.im * z1.im))
}
```

- being returned by a function

```
Complex csum (Complex z1,Complex z2){
    Complex s;
    s.re = z1.re + z2.re;
    s.im = z1.im + z2.im;
    return s;
}
```

- together with assignement:

```
Complex s,a,b;
Complex csum(Complex, Complex);
......
s=csum(a,b);
```

LAYOUT OF STRUCTURES IN MEMORY

Seldom useful; sometimes, with pointers...;

- Components are in sequential order, but not necessarily contiguous (holes -*padding*- possible to align objects to hardware required positions)
- No padding before first component: address of structure is address of first component

SELF-REFERENTIAL STRUCTURES

UNIONS

Like structures, but components share the same memory: only one can be *active* at any time.

Like Fortran EQUIVALENCE, Pascal variant record

```
union reint{
     float re;
     int i;
}

reint.re = 2.0; /* reint.int becomes undefined */
......
reint.i = 1; /* reint.re becomes undefined */
```

NORMALLY used inside a **struct,** togeteher with another variable holding an indicator,

```
struct {
     int type;
     union {  float r;
              int i;
     } v;
} var;

var.type = 0;
var.v.r = 1.0;
.....
var.type = 1;
var.v.i = 7;
.....
if (var.type == 0) x=var.v.r;
```

Bit fields

Not available on your compiler

```
struct {
     a: 3;
     b: 7;
     c: 2:
} s;
```

s.a is 3 bits wide;
s.b is 7 bits wide, and contiguous to s.a
s.c is 2 bits wide, contiguous to s.a

-- Each compiler can arrange bit fields in increasing or decreasing order in a computer word;

-- If a bit field would cross the boundary between two computer words, it is shifted to a new word

-- No bit field can be longer than a computer word

USAGE : sometimes to save memory
often to manipulate bit-sized objects
(hardware)

SCOPE RULES

```
#include <stdio.h>
typedef struct {float re,im;} Complex;
Complex arr[100];

main(){
   Complex x,y; /*OK:Complex global*/
   float normx = 0.0, normy = 0.0;
   int i;
   for (i = 0; i<100; i++){
      scanf(" %f %f", &arr[i].re,
&arr[i].im);
      if (norm() > normx)
         /* wrong: norm() unknown
          * assumed int
          */
        x = arr[i];
      if (norm() < normy)
        y=arr[i];
   }
}
float
norm(){
   return( arr[i].re*arr[i].re +
arr[i].im*arr[i].im);
   /* WRONG : i unknown */
}
```

i defined when norm called, but its *name* unknown outside function main

SCOPE of identifiers: where a NAME can be used

DIFFERENT BUT RELATED PROBLEM

```
main()
{ ......
   int *p, *f1();
   p=f1();
   ...
   f2(p);
}
int * f1(){
   int i=1;
   f2(&i);
   return &i;
}
f2(ip)
int *ip;
{
   printf ("%d",i);
}
```

- **i** *created* when **f1** called
  deleted when **f1** exits

- when **f2** called from **main,**
  i NO LONGER EXISTS

STORAGE CLASSES: when are variables created, deleted, initialized, etc.

SCOPE rules must be consistent with storage classes: non-existing variables cannot be named
- Pointers allow exceptions (AARGHH)

STORAGE CLASSES

1) **auto :**
normal declarations INSIDE compound statements.
Created and initialized before execution
of the compound statement, deleted at its end;

SCOPE: from tne declaration point to the end of the compound statement;

```
#include <stdio.h>
main(){
    int q[100];
    long int s;
    long int sum( );

    {
        int i=0 ; /* i created and
 initialized */
        for ( ; i<100 ; i++)
            scanf( "%d", &q[i]) ;
    }
    /* i no longer exists and is no
       longer accessible */
       s = sum( q, 100 );
 }
 long int
 sum ( arr, n )
 int arr[], n;
 {
     long int s = 0;
     /* s created and initialized */
     int i; /* i  created */

     for ( i=0 ; i<n ; i++)
         s += arr[i];
     return s ;/* i, s deleted */
 }
```

- NOTE : the body of functions is a compound statement!

- NOTE: the closest definition is the one that is considered (hides external ones)

Ex.: in the above the reading loop could be:

```
  {
       int s=0 ;
       /* s created and initialized
       *   "main"-wide s hidden
       */
       for ( ; s<100 ; s++)
           scanf( "%d", &q[s]) ;
  }
```

2) extern :

definitions outside any function, not marked "static". Created when program starts, survive till program end. Accessible from other files, through suitable *allusions (declarations).*

SCOPE:

- for a definition, the file in which the definition occurs, from the definition to the end;
- for an allusion :
- ---if the allusion is in a compound statement, the compound statement;

- ---if outside any function, the file from the allusion down to the end;

WARNING:

storage class <=> variable
scope <=> name

The name of an **extern** variable can have local scope if allusion (declaration) is inside compound statement

Do not identify EXTERN (storage class) and GLOBAL(scope)

File a.c:

```
#include <stdio.h>
struct complex {float re,im; } ;
    /*defines the tag complex :
    global to the file a.c*/
struct complex carr[10];
    /* defines an extern array of
        10 complex */
extern struct complex big_x;
    /* declares big_x as complex ,
        defined in another file;
        allusion */
main(){
    ....
    extern int fun();
    extern int errcode;
    /* allusions */
    int test();/* allusion? */
    struct complex z;
    /* struct complex has
        file scope */
    test();
    if(carr[1].re==0.0)errcode=1;
        /* carr has file scope */
}
int
test()/*definition of test */{
    if (carr[0].re > 100.0) {
        errcode=2;
        /* wrong : errcode has
            block scope */
            big_x.re=carr[0].re;
            big_x.im=carr[0].im;
        /* big_x, carr have file scope */
    }
```

File b.c

```
    struct complex {float re,im; };
    extern struct complex carr[10] ;
    /*allusion */
    int errcode=0; /definition of
    errcode */
    int fun(int i){
        .....
    }/*definition of fun */
```

COMMENTS:

- all the function names are by default **extern**
- types and tags have no storage associate to them->no allusions-> can be local to a block or global to file;
  #include to share among files (ALWAYS!).
- allusions are identified by the keyword **extern;**

3) static

Two uses:

3.1) Variables defined inside a block, but created and initialized at program start and deleted at program end;
keep their value from call to call (unlike **auto**)

SCOPE: the compound statement in which they are defined.

```
int ff(n)
int n;{
    static int first=1;
    ...
    if (first ){
        /*something to be done on
           first call */
        first=0;
    }
    ...
}
```

auto would not work (WHY?)

3.2) Variables AND FUNCTIONS defined like **extern** ones, but whose SCOPE is file only (cannot be *alluded*)

VERY USEFUL, HIGHLY RECOMMENDED

PROTECTS AGAINST *name clashes*

INFORMATION HIDING

Problem : set of routines to manipulate a list of names. The user should simply be able to add a name to the list (addnam), delete a name from the list (delnam), search the list for a name. The name is a string.

File lname.c:

```
#include <stdio.h>
/* basic data store not directly
 accessible from outside */
static struct vsstat *listOfNames ;
/* public procedures */
addnam(name)
char *name;
{
.......
}
```

```
int delnam(name)
char *name;
{
.....
}
struct vsstat * search(name)
char *name;
{
.....
}
/* private procedures
 * NAME CLASHES impossible !
 */
static compact_list(){
.....
}
static struct vsstat *
create_entry(name)
char *name;
{
.....
}
static error (errcode)
int errcode;
{
....
}
```

4) register

Like **auto**, but suggests to the compiler to put the variable in a hardware register if possible.
Can improve optimization a lot on old compilers.
Can inhibit it with optimizing compilers

- Since registers are limited, the first variable declared **register** has higher priority for allocation, and so on;
- You cannot take the address of a register variable

```
int arr[100] , k;

{   register int *pi , s=0;
    for(pi=&arr;pi<&arr[100];pi++)
        s += *pi;
    k=s;
}
```

TYPE QUALIFIERS (ANSI ONLY)

const

```
const float m=4.0;
const int *pci;
    /* pointer to const int */
m = 5.0;  /*error */
pci = &a; /*legal*/
*pci = a; /error*/
```

- Can be used on function arguments

```
float sum(const float arr[],
          const int n);
```

volatile

A **volatile** variable can be modified by the hardware or the O.S. , outside control fom the program.
THEREFORE, any store or load operation requested by the program MUST be actually performed (no optimization allowed)

Memory-mapped I/O: output by writing to address 500

```
    char a[100] ;
    int i ;
    char *out = (char *) 500 ;

    for(i=0; i<100; i++) *out = a[i] ;
```

most optimizers would translate into

```
    *out = a[99] ;
```

BUT

```
    char a[100];
    int i;
    volatile char *out =
        (volatile char *) 500;

    for( i=0; i<100; i++) *out = a[i];
```

COMMENT: can be combined

```
    extern volatile const int clock;
```

FUNCTIONS

Glossary

declaration : the point where a name gets a type associated with it

definition : a declaration that moreover associates some memory with the name. For functions, it is the place where you give a ***body*** for the function.

formal parameters
formal arguments : the names with which a function refers to its arguments

actual parameters
actual arguments : the names or values used when the function is actually called -> the values that *formal parameters* have on entry to the functions.

FUNCTION DECLARATION

Functions must be declared before being called

ANSI style: function prototype

```
char * isprint( char c );
static struct vsstat * createnode( char
* name );
```

Synopsis:

- Optional `static`; if not present, `extern` storage class is assumed
- function type (if missing, `int` assumed)
  - cannot be **array**
  - cannot be **function**
  - CAN be pointer to array or pointer to function
- function name

- list of declarations of formal arguments, in parentheses:
  like other declarations except:
  - only legal storage class is **register**;(ANSI)
  - an array declaration is interpreted as a pointer to an object of the same type of the array elements;
  - a function declaration is interpreted as a pointer to a function;
  - no initializers

IMPORTANT USE:

```
double sqrt( double x );
...
z=sqrt(1);
```

The compiler recognizes type mismatch and performs convertion of 1 to double

```
struct vsstat *add_to_list(char * name);
.....
p = add_to_list(1.0);
```

The compiler recognizes type mismatch and signals error

Old C style

```
char * isprint( );
static struct vssstat *
createnode( );
```

No information on arguments

```
p = createnode (1.0) ;
 /* AAARRGHHH */
```

FUNCTION DEFINITION

ANSI style

function prototype as above
function body (compound statement)

```
int factorial(int n)
{
   register long int p=1;
   register int i ;

   for (i = 2; i<=n; i++) p *= i;
   return p;
}
```

Old C style (accepted also by ANSI)

static (optional)
type name **(** *list of formal arguments names***)**
formal arguments declarations
function body

```
int factorial (n)
int n;
{
    ....
}
```

---

argument declarations: as in prototypes, plus:
--- **char** and **short** are treated as **int** + conversion
--- **float** are treated as **double** + conversion
<u>DEFAULT CONVERSIONS</u>

```
void a_func( c, x )
char c;
float x;
{ .....}
```

is handled as

```
void a_func( ext_c , ext_x )
int ext_c;
double ext_x;
{
   char c;
```

```
    float ext_x;

    c = (char) ext_c;
    x = (float) ext_x;
    ......
}
```

Seldom important to know, except for cross-language development. Can impact performance.

CALLING FUNCTIONS

1. evaluate expressions passed as arguments;
2. convert values according to function prototypes if any (ANSI) or according to default conversions;
3. use these values to initialize formal arguments
4. henceforth formal arguments behave like other local variables

```
void called_func( int , float );

main(){
    called_func ( 1, 2*3.5 );
}

void called_func (int iarg, float
farg){
    float tmp;
    tmp= iarg * farg;
}
```

CALL BY VALUE :

a copy of the value of the actual argument is passed, not the actual argument itself
-> function cannot modify the actual arguments
(unlike FORTRAN, Pascal **var** arguments)

```
int called_func( );

main(){
    int n=10, array[30];
    ......
    called_func ( array,10 );
}
called_func (arr,n)
int arr[],n;
{
    for(;n>=0;n--)
        printf("%d\n",arr[n]);
/*changing n is perfectly safe */
}
```

CALL BY REFERENCE:

passing the *address* of the actual argument.
Function MUST be written specially to accept it

```
float called_func(  );

main(){
    int i = 1, f;
    f=called_func ( &i , 2*3.5 );
}
float called_func (iarg,farg)
int *iarg; /* note int* */
float farg;
{
    float tmp;
    tmp= *iarg * farg;
    (*iarg )++ ; /* changes i */
    return tmp;
}
```

Arrays **are not** be passed by value:

```
void func(arr)
int arr[];
{......}
main()
{
int arr[10];
func(arr);
}
```

is identical to

```
void func(arr)
int *arr;
{ ...... }
main()
{int arr[10];
func(&arr[0]);
}
```

Functions are not be passed by value (WHAT?)

EXCURSUS : pointers to functions

Often used !

function name is constant pointer to function like array name

```
double fun(x)
double x;
{.....}
double operator(f)
double (*f)();
{/*do something with function f*/
...
}
main()
{
    double (*pf)(),s;
    /* pf pointer to function
    returning double */
    pf = fun ; /* pf = &fun wrong ;
             * pf = fun() wrong ;
             * pf = &fun() wrong ;
             * /
    s=operator(fun);
    /* same as s=operator(pf) */
    .....
}
```

Structures are passed by value (ANSI)

More on Default Conversions

If no function prototype used (Old C form of declaration or no declaration at all)

- `short` and `char` converted to `int`;
- `float` converted to `double`;

ANSI WARNING : mixing a prototyped declaration with a non-prototyped definition can cause problems

RETURNING FROM FUNCTIONS

```
void a_func(i,s)
int i;
float *s;
{
    if( !i ) return ;
    *s ++ ;
}
```

- `return`
- flow through the end

RETURNING A VALUE

```
double squareroot(x)
double x;
{
    double s;

    if ( x < 0.0 ) return 0;
    s =.../* compute square root */
    return s;
}
```

- type of returned expression automatically converted to type of function;

WARNING :
- mixing **return** *value* ; and **return;**
- mixing **return** *value*; and flow through end

is meaningless

EXCURSUS: COMPLEX DEFINITIONS

What's that

```
    int *(*(*x)())[5];
```

`*(*(*x)())[5]` is an `int`

[] has higher precedence than *

`(*(*x)())[5]` is a pointer to an `int`

`*(*x)()` is a 5-elements array of pointers to `int`

() has higher precedence than *

`(*x)()` is a pointer to a 5-elements array of pointers to `int`

`*x` is a function returning a pointer to a 5 - elements array of pointers to `int`

`x` is a pointer to a function returning .....

HORRIBLE
USE TYPEDEF

```
   typedef int *PI;
      /* a PI is pointer to int */
   typedef PI AP[5];
      /* an AP is a 5-elements array
      of PI, i.e. of pointers to int */
   typedef AP *FP() ;
      /* an FP is a function returning
      a pointer to an AP */
   FP  *x; /* x is a pointer to an FP */
```

INPUT-OUTPUT

Implemented through macros and functions, but **defined in the standard** as part of the standard library and standard header file **<stdio.h>**

GENERAL MODEL :

- **stream** : flux of *characters*
- each stream connected to an external *file* (operating system dependent)
- read or write take place at *file position indicator*
- *f.p.i.* moved after each read or write (sequential I-O)
- *f.p.i* can be manipulated directly to achieve direct access I-O
- Two basic types of streams : *text* and *binary* (ANSI)
  - *text* : sequence of lines, composed of printable characters. Programs see line separators as a single *newline* character (O.S. can use other conventions)
  - *binary:* sequence of non-interpreted characters.

THEY ARE THE SAME IN UNIX, OS/9, etc.

- streams can be *buffered*; buffering can be
  - block : data passed to/from O.S. when buffer full (file copying);
  - line : data passed to/from O.S. when end of line met (terminal I-O); ANSI
  - no buffer : data passed to/from O.S. immediately (screen editing).
- I-O operations are *syncronous* : program waits until completed

A key distinction:

O.S. services (calls):

read write lseek open close

Language constructs (stream-oriented)

`fread, fwrite, fseek, fopen, fclose`

- Old C programs often used system calls to do "binary" I-O (buffered unformatted)
- Better to avoid: portability
- With old compilers, could be unavoidable (fread, fwrite missing)

Therefore: in Unix and O.S. 9, O.S. uses "file numbers" (small integers) to identify files (`open(filename)` returns a filenumber, `read`, `write` require passing a filenumber, etc.) One field of the structure FILE identifying the C stream is the corresponding O.S. file number.

```
fileno (fp)
FILE *fp;
```

returns the file number attached to the stream fp; etc.

stdio.h

contains the definitions of the required types and macros, plus the prototypes of the functions, and the definitions of 3 standard streams.
Of general interest:

FILE **typedef:** the type of a `struct` containing stream control information.

EOF macro. A negative integral constant, used to signal end of file condition

stdin

stdout

stderr 3 objects of type **(FILE *)**,associated to the standard input (usually keyboard), standard output (usually screen) and standard error (usually screen). Open at program start.

NULL (char *) 0. ANSI moved it to **stddef.h**

ERROR HANDLING

- all I-O functions return error codes ;
- moreover error conditions and end-of-file on read are also recorded in a member of any FILE object;
- tested through **feof()** and **ferror()**, reset through **clearerr()**

- additional error information through system-defined extern `errno`, O.S. dependent

Ex.

```
/* this function tests error status
 * and resets it
 * it returns 0 if no error
 * 1 if end-of file
 * 2 if error
 * 3 if both
 */
#include <stdio.h>
#define EOF_FLAG 1
#define ERR_FLAG 2

char stream_stat( fp )
FILE *fp;
{
    char stat =0;

    if(ferror(fp))stat|= ERR_FLAG ;
    if(feof(fp))  stat|= EOF_FLAG ;
    clearerr(fp) ;
    return stat ;
}
```

DIRECT FILE MANIPULATION

ANSI

```
int remove ( const char *filename );
```

deletes the file. Returns 0 if success.

```
int rename ( const char *old, const
char *new);
```

changes file name. Valid file names are implementation dependent.

```
char * tmpnam(char *ε);
```

create a file name that is unique. On your compiler, analogous to **mktemp.**

```
FILE *tmpfile(void);
```

opens a temporary file which will be automatically deleted at program termination and has no name.

OPENING AND CLOSING

associate a *stream* with a *file*

fopen (***file_name*** , ***access_mode***)

returns a pointer to a **FILE** object or **NULL** (if failed)

```
FILE * fopen(file_name,access_mode)
char * file_name;
char * access_mode;
```

ACCESS MODES

for text streams

"r"	read only
"r+"	read-write (must exist)
"w"	write only. If existing, truncated to zero,else created
"w+"	write and read. If existing, truncated to 0,else created
"a"	append. Write only, but at the end of an existing file. Created if not existing.
"a+"	append and read . Created if not existing

binary streams (ANSI)

"rb", "r+b" etc.

Ex.

```
/* open with error message */
#include <stdio.h>
FILE *
openfile(fname, access)
char *fname, *access;
{
FILE *fp;
if((fp=fopen(fname,access))==NULL)
       fprintf( stderr,
"Error opening %s with access mode %s"
               ,fname,access);
return fp;
}
```

- WARNING : `(fp = fopen()) == NULL`
  parenthesis required! common mistake
- **fprintf** : like **printf** on a stream different from
  stdout

Ex:
Open file "pippo" for reading and writing; if it does'nt exist, create, if it exists, do not truncate

```
if((fp=fopen("pippo","r+"))==NULL)
       fp = fopen( "pippo", "w+");
```

reopen:
associates an open stream with a different file and/or with a different mode

```
FILE *
freopen( filename, mode, stream)
char *filename, *mode;
FILE * stream;
```

often used with standard streams

```
/*if flag set, output to disk file
"outfil"*/
....
int disk_flag;
.....
if ( disk_flag &&
freopen("outfil","w",stdout)==NULL)
       fprintf(stderr,
          "Error reopening");
....
```

IMPORTANT WARNING

Streams open for both read and write:

between a read and a write you MUST insert
a **fflush**, **fseek** or **rewind**

- - exception: write after read that hits End of File

---

fclose:

disassociates a stream from its file and makes the stream unusable

```
    int fclose(stream)
    FILE *stream;
```

NOTE : files are automatically closed at program termination

READING AND WRITING

formatted

unformatted : 1 character at a time
1 line at a time
1 block at a time

FORMATTED READ

```
    int scanf( format,...)
    char *format;

    int fscanf( stream, format, ...)
    FILE * stream;
    char *format;

    int sscanf ( in_string, format,...)
    char * in_string, * format;
```

Input-Output

fclose:

disassociates a stream from its file and makes the stream unusable

int fclose(stream)
FILE *stream;

NOTE : files are automatically closed at program termination

READING AND WRITING

formatted

unformatted : 1 character at a time
1 line at a time
1 block at a time

FORMATTED READ

int scanf(format,...)
char *format;

int fscanf(stream, format, ...)
FILE * stream;
char *format;

int sscanf (in_string, format,...)
char * in_string, * format;

NOTE : **scanf** IS **fscanf(stdin, ...)**

sscanf does conversion but not input,
using in_string as the source of characters
(FORTRAN INTERNAL FILE)

NOTE : arguments must be POINTERS to variables

ANSI INPUT FORMAT STRING

can contain three types of objects:

white space: skip input until next non-blank
ordinary character : next character in input MUST
match that character (seldom used)
conversion specifier:
LOOK IN THE MANUAL

function returns :

- EOF if EOF encountered before any conversion, OR
- number of successful conversions

UNFORMATTED INPUT-OUTPUT

ONE CHARACTER AT A TIME

Already met

```
int getchar( );
int putchar(c)
char c;
```

- refer to **stdin / stdout**

MORE GENERAL

```
int getc(fp)
FILE *fp;
int putc(c, fp)
char c ;
FILE *fp ;
```

special:

```
int ungetc(c, fp)
int c ;
FILE * fp;
```

- return EOF if error (getc/putc/ungetc) or end-of file (getc);
- otherwise return the character read or written

WARNING : in binary mode, EOF is a legal return value for getc,putc and ungetc: use ferror or feof to test for error!

- They are macros (defined in **stdio.h**)
- therefore expanded by preprocessor
- FAST

Note: `putchar(c)` is `putc( c , stdout )`
`getchar()` is `getc (stdin)`

--- WARNING

```
putc ( 'x' , fp[j++] ) ;
```

Macro expansion : more than one occurence of `fp[j++]` -> RESULTS UNDEFINED

For these cases, FUNCTION VERSION

```
int fgetc( fp)
FILE *fp ;
int fputc( c, fp)
char c ;
FILE *fp ;
```

Ex.:

```
#include <stdio.h>

#define FAIL 0
#define SUCCESS 1

int copyfile (infile,outfile)
char *infile, * outfile;
{
    FILE *fp1, *fp2;
    int c;

    if((fp1=fopen(infile,"rb"))==NULL)
        return FAIL;
    if((fp2=fopen(outfile,"wb"))==NULL)
    {   fclose (fp1);
        return FAIL;
    }
    while(c=getc(fp1), !feof(fp1)){
        putc( c , fp2 );
        if(ferror(fp2){
            fclose(fp1);
            fclose(fp2);
            return FAIL
        }
```

- note cleanup in case of failure
- **feof** needed in binary mode:

  getc returns EOF at End of File

  EOF is <0 -> not a letter, <u>if in text mode</u>

  COULD BE 8-bit pattern (often -1)

Example above could be slow (too many tests).

```
while(1){
    register int c;
    while((c=getc(fp1))!=EOF &&
           putc(c, fp2)!=EOF);
    /* EOF detected : why? */
    if(feof(fp1))break;/*finished*/
    if(ferror(fp1)||ferror(fp2)||
        /* if we are here, c==EOF but
         * no real EOF on fp1
         * therefore try to put it out
         */ (putc(c,fp2), ferror(fp2)){
           fclose(fp1);
           fclose(fp2);
           return FAIL;
    }
}
```

- why **c** needed? why not

```
    while(!feof(fp1))putc(getc(fp1), fp2);
```

?

Beware of off-by-one errors !!

ungetc:

pushes back the last character read
Ex.:

```
    /*skip until first non-blank */
    #include <stdio.h>
    #include <ctype.h>

    void
    bskip(fp)
    FILE *fp;
    {
        int c;
        while ( isspace(c=getc(fp)) );
        ungetc(c , fp) ;
    }
```

- only one character
- only after read
- it's not I-O: external file not changed
- **rewind** and other *f.p.i.* manipulations will cause the pushback to be forgotten

ONE LINE AT A TIME

MEANINGFUL ONLY IN TEXT MODE

```
char * fgets ( s,max_length)
char * s ;
int max_length;
FILE *stream;
int fputs ( s, fp)
char * s;
FILE *fp;
```

- and their stripped down versions (**stdin-stdout)**

```
char gets ( s )
char * s ;
int fputs ( s )
char * s ;
```

fgets

- reads until EOF or newline or **max_len-1** characters
- puts them in s
- adds a null at the end
- returns **s** or **NULL** if read error or EOF before anything read
- WARNING : input newline is included in s !

gets

- almost like **fgets** on **stdin** , but discards the newline (history...)

fputs

- writes **s** (as it is!) to **fp** discarding the terminating null
- returns 0 if successful, non-zero on error

puts

- almost as **fputs** on **stdout**, but adds a newline

NOTE: often implemented through calls to **fgetc/fputc ->** not faster than direct use of **getc/putc.**

ONE BLOCK AT A TIME

MAINLY BINARY
ANSI

```
#include <stdio.h>

    size_t fread( void * block, size_t
         size, size_t nelem, FILE
         *stream);

    size_t fwrite(const void * block,
         size_t size, size_t nelem,
         FILE *stream);
```

- `size_t` is a `typedef` in `stdio.h`: usually `unsigned int` or `unsigned long int`
- `nelem` elements of size `size` are transferred
  - WARNING : this is not the same as transferring **nelem * size** bytes !!
- return number of elements transferred
  - if returned < `nelem` on output, error
    on input, EOF or error (`feof`);

NOTE : implementation dependent. Can be very fast, or use **fgetc/fputc** and be very slow.

RANDOM ACCESS

Getting the current f.p.i.
Setting f.p.i. to beginning-of-file
Setting f.p.i. to an arbitrary value

Getting the current f.p.i.

```
long ftell (stream)
FILE *stream;
```

- returns the current *f.p.i.* as a `long int.`
-- binary: number of characters from start
-- text : "magic" (to be used only with `fseek`)
-- **-1L** if failure

Setting f.p.i. to beginning-of-file

```
rewind (stream)
FILE *stream;
```

Setting f.p.i. to an arbitrary value

```
int fseek( stream,offset,base_sel)
FILE * stream ;
long offset ;
int base_sel;
```

- positions the *f.p.i.* at a distance `offset` from a **`base`**:

--- **`base_sel`** selects the base:

`base_sel == SEEK_SET`
base is beginning of file

`base_sel == SEEK_CURR`
base is current *f.p.i.*

`base_sel == SEEK_END`
base is end of file

--- **`SEEK_SET, SEEK_CURR, SEEK_END`** macros defined in `stdio.h` (in old compilers, 0, 1, 2)

--- `offset` can positive or negative

--- if in **text** mode, `base` must be `SEEK_SET` and `offset` must be the output of `ftell`

--- in binary mode, `SEEK_END` could give strange results if system pads bynary files

COMMENT

`fseek/ftell` could not work if file length cannot be encoded in a `long int`

for this general case, 2 other functions ANSI only

```
int fgetpos( FILE *stream, fpos_t
*pos);

int fsetpos ( FILE *stream, const
fpos_t *pos);
```

FILE BUFFERING

File buffering: data are passed to-from the file only in chunks of fixed size (from 512 B to a few kB)

unbuffered : minimum latency
if file I-O used for control purposes
buffered : maximum I-O efficiency (less calls to O.S., device, etc)

WARNING : C buffering concerns passing data to O.S., NOT to device (O.S. can buffer by itself, or not, O.S. dependent)

By default, files buffered (buffer size implementation dependent)

`stderr` unbuffered

```
    #include <stdio.h>

    char c_arr [ BUFSIZE ];

    main(){

        FILE *fp;
        /* declarations */

        setbuf ( stderr, c_arr );
        /* stderr becomes buffered,
        c_arr is buffer */
         setbuf ( stdout, NULL);
        /* stdout becomes unbuffered */

        .....
    }
```

- `BUFSIZE` defined in `stdio.h`
(called `BUFSIZ` in your compiler)
- must be used after `fopen` and before any I-O operation

```
int fflush( stream)
FILE * stream;
```

- if stream is buffered, write content of buffer to O.S.
- if `stream == NULL`, applies to all open streams;
- returns 0 (success) or EOF (failure)

ANSI ONLY

```
    int setvbuf ( FILE * stream ,char
    *buf , int mode , size_t buf_size);
```

- arbitrary size of buffer and buffering mode
- mode can be

`_IOFBF`	Full buffering
`_IOLBF`	Line buffering
`_IONBF`	No buffering

- `setbuf ( stream, buf );`
  is (almost)
  `setvbuf(stream,buf,_IOFBF,BUFSIZE);`

and

- `setbuf ( stream , NULL ) ;`
  is (almost)
  `setvbuf(stream, NULL ,_IONBF ,0) ;`

SELDOM USED, BUT IMPORTANT