第六章　子程序结构

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主要内容：

- 过程定义伪操作
- 子程序的调用与返回
- 保存与恢复寄存器
- 子程序的参数传送
- 子程序的嵌套与递归

1. 过程定义伪操作

过程名　PROC　NEAR（FAR）

⋮

过程名　ENDP

（1）NEAR属性：调用程序和子程序在同一代码段中（段内调用）

（2）FAR属性：调用程序和子程序不在同一代码段中（段间调用）

```
code segment

main   proc   far
       ......
       call   subr1
       ......
       ret
main   endp

subr1  proc   near
       ......
       ret
subr1  endp

code ends
```

段内调用

```
segx   segment
subt    proc   far
        ......
        ret
subt    endp
        ......
        call   subt
        ......
segx   ends

segy   segment
        ......
        call   subt
        ......
segy   ends
```

段间调用

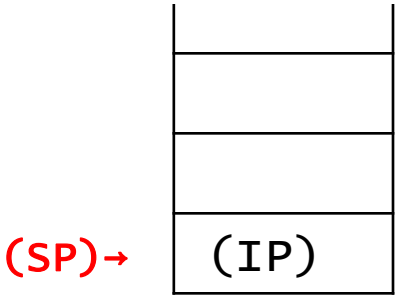
2. 子程序的调用与返回

子程序调用：隐含使用堆栈保存返回地址

call near ptr subp

(1) 保存返回地址

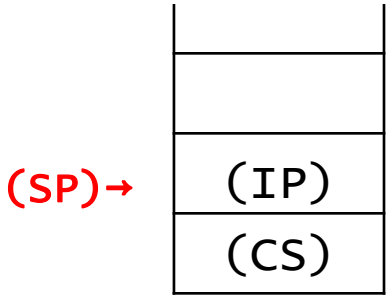
(2) 转子程序



call far ptr subp

(1) 保存返回地址

(2) 转子程序



子程序返回：ret

3. 保存与恢复寄存器

```
subt    proc    far
        push    ax
        push    bx
        push    cx
        push    dx
        ......
        ......
        pop     dx
        pop     cx
        pop     bx
        pop     ax

        ret
subt    endp
```

4. 子程序的参数传送

(1) 通过寄存器传送参数

(2) 通过存储器传送参数

(3) 通过地址表传送参数地址

(4) 通过堆栈传送参数或参数地址

(5) 多个模块之间的参数传送

例：十进制到十六进制的转换（通过寄存器传送参数）

```
decihex   segment                ; 10→16
          assume cs: decihex
main      proc    far
          push    ds
          sub     ax, ax
          push    ax
repeat:   call    decibin        ; 10→2
          call    crlf           ; 回车换行
          call    binihex        ; 2→16
          call    crlf
          jmp     repeat
          ret
main      endp
……
……
……                               ; 三个子程序
decihex   ends
          end     main
```

```
decibin  proc near
         mov  bx, 0
newchar: mov  ah, 1
         int  21h
         sub  al, 30h
         jl   exit
         cmp  al, 9
         jg   exit
         cbw
         xchg ax, bx
         mov  cx, 10
         mul  cx
         xchg ax, bx
         add  bx, ax
         jmp  newchar
   exit: ret
decibin  endp
```

```
binihex  proc  near
         mov   ch, 4
rotate:  mov   cl, 4
         rol   bx, cl
         mov   al, bl
         and   al, 0fh
         add   al, 30h
         cmp   al, 3ah
         jl    printit
         add   al, 7
printit: mov   dl, al
         mov   ah, 2
         int   21h
         dec   ch
         jnz   rotate
         ret
binihex  endp
```

```
crlf     proc  near
         mov   dl, 0dh
         mov   ah, 2
         int   21h
         mov   dl, 0ah
         mov   ah, 2
         int   21h
         ret
crlf     endp
```

例：十六进制到十进制的转换（通过寄存器传送参数）

```
hexidec   segment                  ; 16→10
          assume cs: hexidec
main      proc    far
start:    push    ds
          sub     ax, ax
          push    ax
repeat:
          call    hexibin          ; 16→2
          call    crlf
          call    binidec          ; 2→10
          call    crlf
          jmp     repeat
          ret
main      endp
……
……
……
hexidec   ends
          end     start
```

汇编语言

```
hexibin   proc   near
          mov    bx, 0
newchar:
          mov    ah, 1
          int    21h
          sub    al, 30h
          jl     exit
          cmp    al, 10
          jl     add_to
          sub    al, 27h
          cmp    al, 0ah
          jl     exit
          cmp    al, 10h
          jge    exit
add_to:
          mov    cl, 4
          shl    bx, cl
          mov    ah, 0
          add    bx, ax
          jmp    newchar
  exit:   ret
hexibin   endp
```

```
binidec   proc   near
          mov    cx, 10000d
          call   dec_div
          mov    cx, 1000d
          call   dec_div
          mov    cx, 100d
          call   dec_div
          mov    cx, 10d
          call   dec_div
          mov    cx, 1d
          call   dec_div
          ret
binidec   endp
```

```
dec_div   proc   near
          mov    ax, bx
          mov    dx, 0
          div    cx
          mov    bx, dx
          mov    dl, al
          add    dl, 30h
          mov    ah, 2
          int    21h
          ret
dec_div   endp
```

汇编语言

例：累加数组中的元素（通过存储器传送参数）

```
data    segment
        ary     dw   1,2,3,4,5,6,7,8,9,10
        count   dw   10
        sum     dw   ?
data    ends

code    segment
main    proc    far
        assume  cs:code,ds:data
        push    ds
        sub     ax, ax
        push    ax
        mov     ax, data
        mov     ds, ax
        call    proadd
        ret
main    endp
……                  ;proadd子程序
code    ends
        end     main
```

```
proadd  proc  near
        push  ax
        push  cx
        push  si
        lea   si, ary
        mov   cx, count
        xor   ax, ax
next:   add   ax, [si]
        add   si, 2
        loop  next
        mov   sum,ax
        pop   si
        pop   cx
        pop   ax
        ret
proadd  endp
```

汇编语言

如果数据段定义如下：

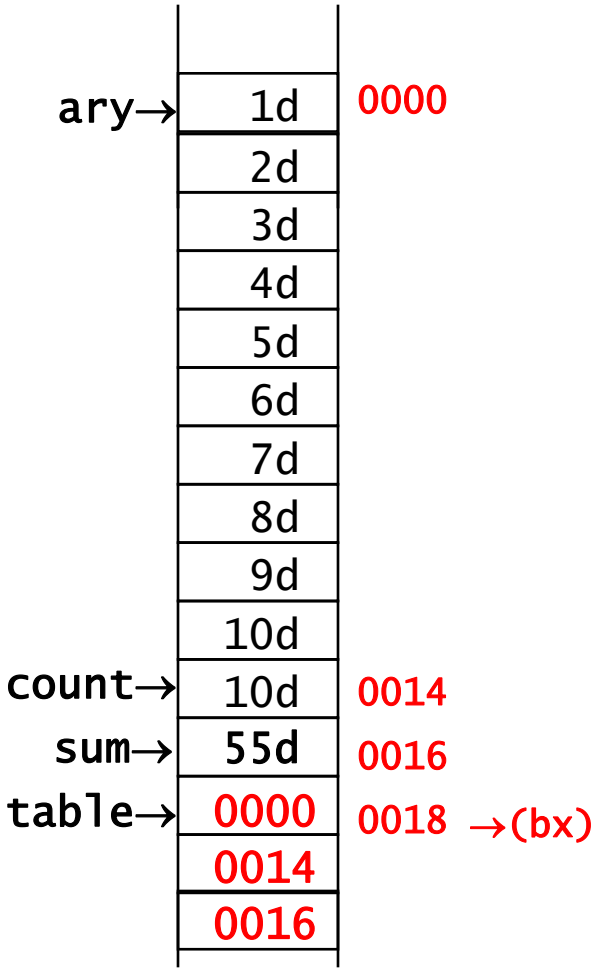
```
data   segment

       ary      dw    1,2,3,4,5,6,7,8,9,10
       count    dw    10
       sum      dw    ?

       ary1     dw    10,20,30,40,50,60,70,80,90,100
       count1   dw    10
       sum1     dw    ?

data   ends
```

如果直接访问内存变量，那么累加数组ary和数组ary1中的元素不能用同一个子程序 proadd。

例：累加数组中的元素（通过地址表传送参数地址）

```
data   segment
       ary      dw   1,2,3,4,5,6,7,8,9,10
       count    dw   10
       sum      dw   ?
       table    dw   3   dup (?)          ; 地址表
data   ends
code   segment
main   proc    far
       assume cs:code, ds:data
       push    ds
       sub     ax, ax
       push    ax
       mov     ax, data
       mov     ds, ax
       mov     table,    offset  ary
       mov     table+2,  offset  count
       mov     table+4,  offset  sum    ; 建立地址表
       mov     bx,       offset  table  ; 地址表的地址->bx
       call    proadd
       ret
main   endp
```

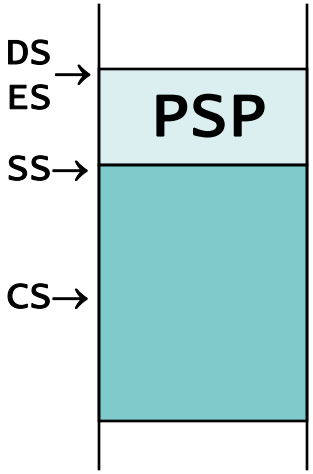
```
proadd  proc   near
        push   ax
        push   cx
        push   si
        push   di
        mov    si, [bx]
        mov    di, [bx+2]
        mov    cx, [di]
        mov    di, [bx+4]
        xor    ax, ax
next:
        add    ax, [si]
        add    si, 2
        loop   next
        mov    [di],ax
        pop    di
        pop    si
        pop    cx
        pop    ax
        ret
proadd  endp
code    ends
        end    main
```



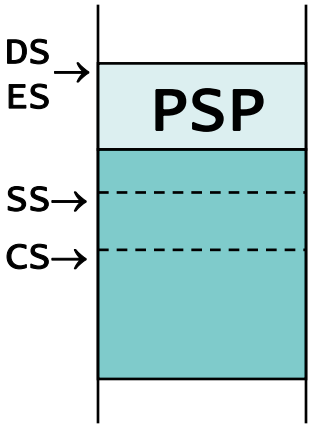
汇编语言

通过堆栈传送参数或参数地址：

```
stack   segment
        dw    100     dup (?)
        tos   label   word
stack   ends
start:
        mov     ax,   stack
        mov     ss,   ax
        mov     sp,   offset tos
        push    ds
        sub     ax,   ax
        push    ax
        ……
```



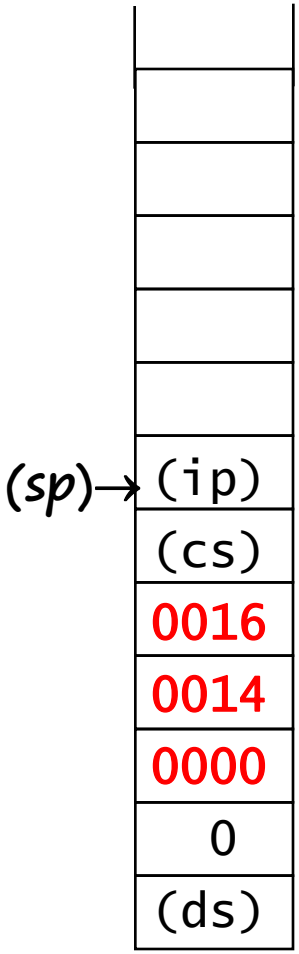

```
stack   segment     stack
        dw    100   dup (?)
        tos   label word
stack   ends
```



例：累加数组中的元素（通过堆栈传送参数地址）

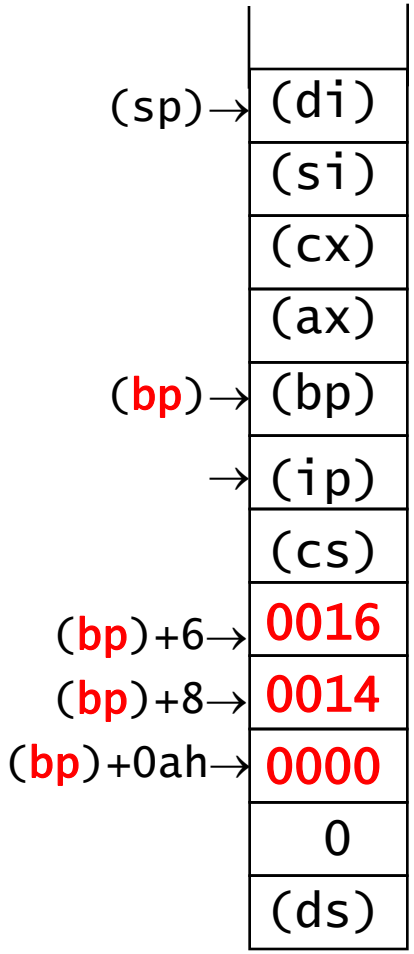
```
data    segment
        ary     dw  1,2,3,4,5,6,7,8,9,10
        count   dw  10
        sum     dw  ?
data    ends

stack   segment
                dw  100     dup (?)
               tos  label   word
stack   ends
```

```
code1 segment
main  proc    far
      assume  cs:code1, ds:data, ss:stack
start:
      mov     ax,  stack
      mov     ss,  ax
      mov     sp,  offset  tos
      push    ds
      sub     ax,  ax
      push    ax
      mov     ax,  data
      mov     ds,  ax
      mov     bx,  offset  ary
      push    bx
      mov     bx,  offset  count
      push    bx
      mov     bx,  offset  sum
      push    bx

      call    far  ptr     proadd

      ret
main  endp
code1 ends
```



汇编语言

```
code2     segment
  assume  cs:code2

proadd    proc   far

  push    bp
  mov     bp, sp

  push    ax
  push    cx
  push    si
  push    di

  mov     si,[bp+0ah]
  mov     di,[bp+8]
  mov     cx,[di]
  mov     di,[bp+6]

  xor     ax,  ax
next:
  add     ax,  [si]
  add     si,  2
  loop    next
  mov     [di],ax

  pop     di
  pop     si
  pop     cx
  pop     ax

  pop     bp

  ret     6

proadd    endp

code2     ends
          end start
```



汇编语言

结构伪操作 STRUC：

定义一种可包含不同类型数据的结构模式

格式：　结构名　STRUC

字段名1　DB　?

字段名2　DW　?

字段名3　DD　?

……

结构名　ENDS

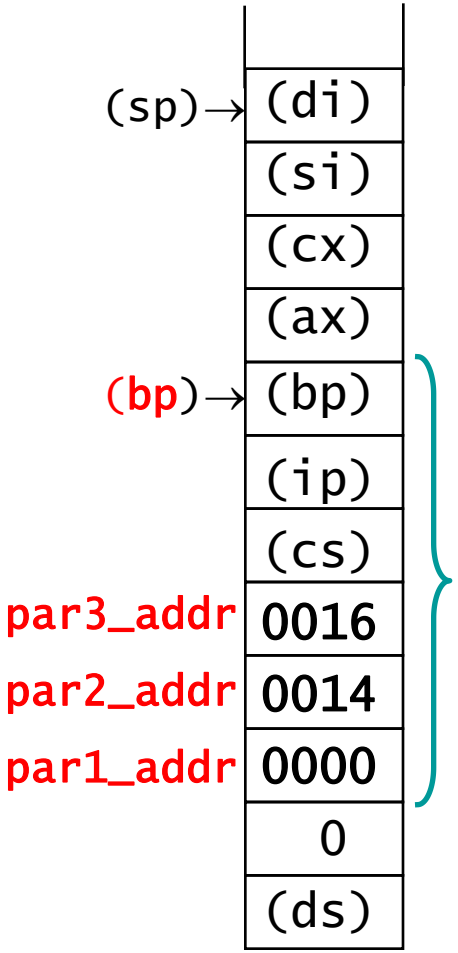
例：学生个人信息

```
STUDENT_DATA    STRUC
                NAME    DB    5    DUP (?)
                ID      DW    0
                AGE     DB    ?
                DEP     DB    10   DUP (?)
STUDENT_DATA    ENDS
```

例：累加数组中的元素（通过堆栈传送参数地址）

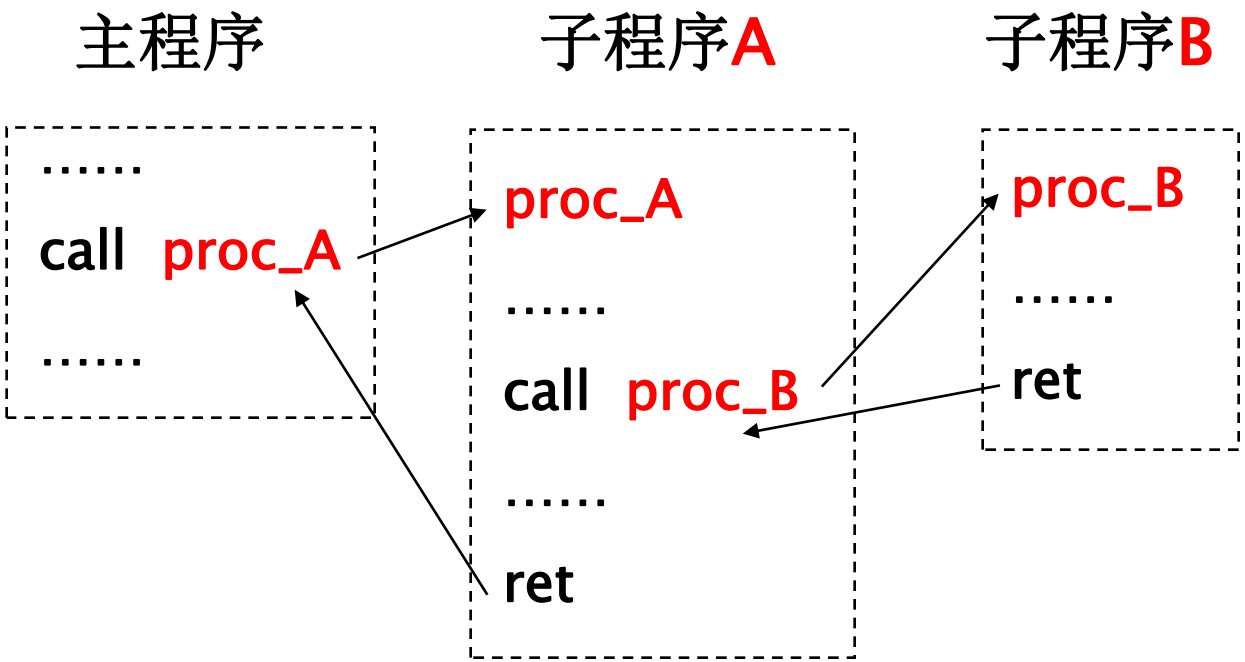
```
code2   segment
        assume   cs:code2

        stack_strc          struc
              save_bp       dw      ?
              save_cs_ip    dw      2 dup(?)
              par3_addr     dw      ?
              par2_addr     dw      ?
              par1_addr     dw      ?
        stack_strc          ends

proadd    proc   far
          ……
          ……
proadd    endp

code2     ends
          end    start
```

```
proadd   proc   far
         push   bp
         mov    bp, sp
         push   ax
         push   cx
         push   si
         push   di
         mov    si, [bp].par1_addr
         mov    di, [bp].par2_addr
         mov    cx, [di]
         mov    di, [bp].par3_addr
         xor    ax, ax
next:
         add    ax, [si]
         add    si, 2
         loop   next
         mov    [di],ax
         pop    di
         pop    si
         pop    cx
         pop    ax
         pop    bp
         ret    6
proadd   endp
```



5. 子程序的嵌套与递归

子程序的嵌套：



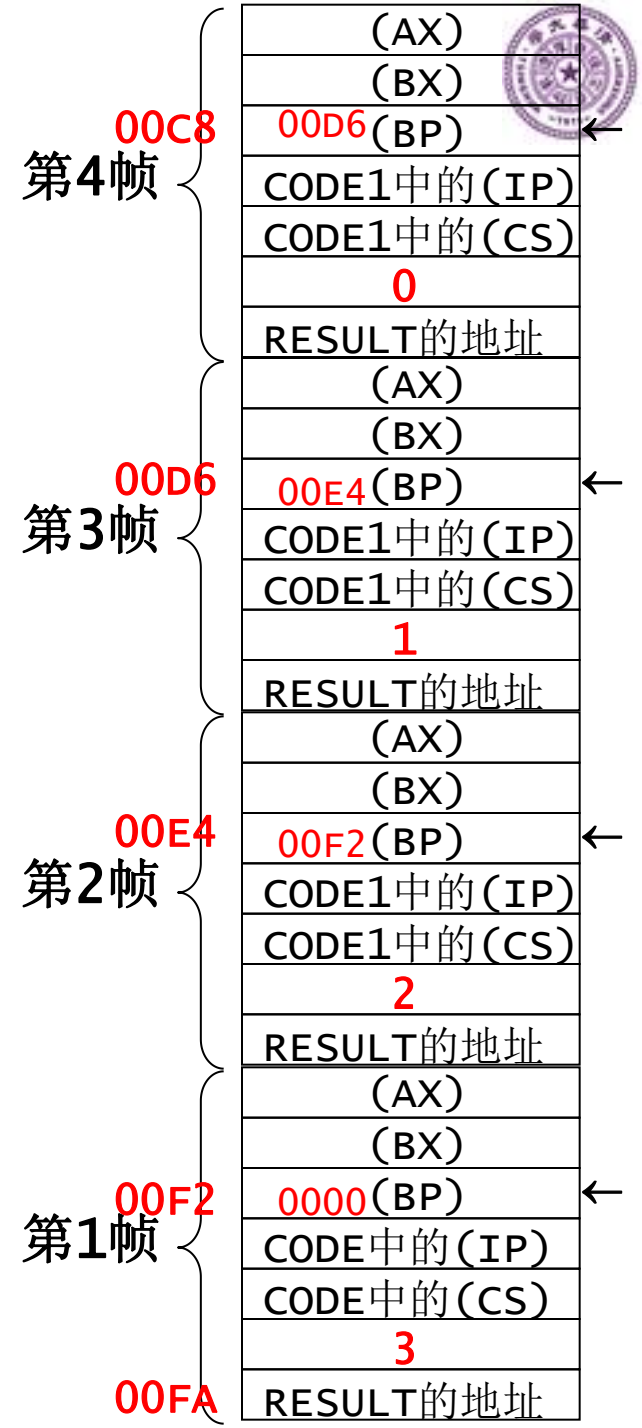
递归子程序：n!

例：计算 n!

```
frame    struc
         save_bp       dw    ?
         save_cs_ip    dw    2 dup(?)
         n             dw    ?
         result_addr   dw    ?
frame    ends

data     segment
         n_v           dw    3
         result        dw    ?
data     ends

stack    segment
         dw    128     dup (?)
         tos   label   word
stack    ends
```

```
code   segment
main   proc   far
       assume  cs:code, ds:data, ss:stack
start:
       mov    ax, stack
       mov    ss, ax
       mov    sp, offset tos
       push   ds
       sub    ax, ax
       push   ax
       mov    ax, data
       mov    ds, ax
       mov    bx, offset result
       push   bx
       mov    bx, n_v
       push   bx

       call   far ptr  fact

       ret
main   endp
code   ends
```

```
code1   segment
        assume  cs:code1
fact    proc    far
        push    bp
        mov     bp, sp
        push    bx
        push    ax

        mov     bx, [bp].result_addr
        mov     ax, [bp].n
        cmp     ax, 0
        je      done
        push    bx
        dec     ax
        push    ax
        call    far ptr fact
        mov     bx, [bp].result_addr
        mov     ax, [bx]
        mul     [bp].n
        jmp     short   return
done:   mov     ax,1
return:
        mov     [bx], ax
        pop     ax
        pop     bx
        pop     bp
        ret     4
fact    endp
code1   ends
```



汇编语言

```
C:\ASM>debug n.exe
-r
AX=0000  BX=0000  CX=015D  DX=0000  SP=0000  BP=0000  SI=0000  DI=0000
DS=0CEF  ES=0CEF  SS=0CFF  CS=0D10  IP=0000   NV UP EI PL NZ NA PO NC
0D10:0000 B8000D        MOV     AX,0D00
-u
0D10:0000 B8000D        MOV     AX,0D00
0D10:0003 8ED0          MOV     SS,AX
0D10:0005 BC0001        MOV     SP,0100
0D10:0008 1E            PUSH    DS
0D10:0009 2BC0          SUB     AX,AX
0D10:000B 50            PUSH
0D10:000C B8FF0C        MOV
0D10:000F 8ED8          MOV
0D10:0011 BB0200        MOV
0D10:0014 53            PUSH
0D10:0015 8B1E0000      MOV
0D10:0019 53            PUSH
0D10:001A 9A0000120D    CALL
0D10:001F CB            RETF
```

```
-u
0D10:0020 55            PUSH    BP
0D10:0021 8BEC          MOV     BP,SP
0D10:0023 53            PUSH    BX
0D10:0024 50            PUSH    AX
0D10:0025 8B5E08        MOV     BX,[BP+08]
0D10:0028 8B4606        MOV     AX,[BP+06]
0D10:002B 3D0000        CMP     AX,0000
0D10:002E 7412          JZ      0042
0D10:0030 53            PUSH    BX
0D10:0031 48            DEC     AX
0D10:0032 50            PUSH    AX
0D10:0033 9A0000120D    CALL    0D12:0000
0D10:0038 8B5E08        MOV     BX,[BP+08]
0D10:003B 8B07          MOV     AX,[BX]
0D10:003D F76606        MUL     WORD PTR [BP+06]
-
```

ES 0CEFH
DS 0CFFH
SS 0D00H
CS 0D10H

汇编语言

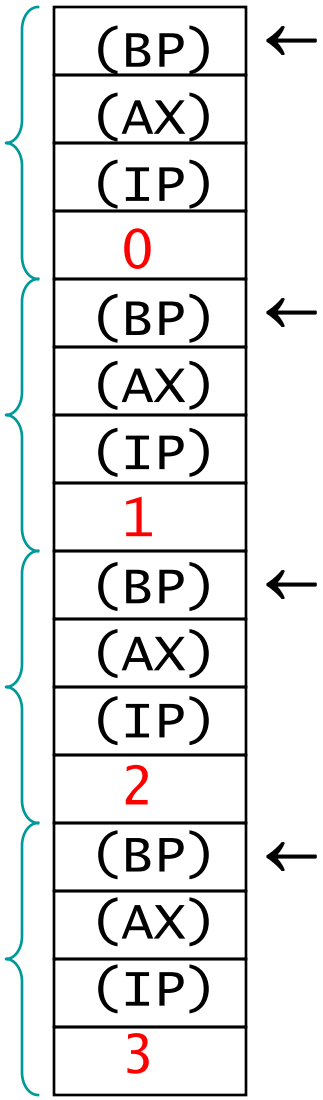
code中的CS和IP 0D10H 001FH
code1中的CS和IP 0D12H 0018H

```
-r
AX=0001  BX=0002  CX=015D  DX=0000  SP=00C4  BP=00C8  SI=00
DS=0CFF  ES=0CEF  SS=0D00  CS=0D12  IP=0027   NV UP EI PL
0D12:0027 58              POP     AX
-dss:80
0D00:0080  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
0D00:0090  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
0D00:00A0  00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00
0D00:00B0  00 00 00 00 00 00 00 00-00 00 01 00 C8 00 27 00
0D00:00C0  12 0D EB 06 00 00 02 00-D6 00 18 00 12 0D 00 00
0D00:00D0  02 00 01 00 02 00 E4 00-18 00 12 0D 01 00 02 00
0D00:00E0  02 00 02 00 F2 00 18 00-12 0D 02 00 02 00 FF 0C
0D00:00F0  03 00 00 00 1F 00 10 0D-03 00 02 00 00 00 EF 0C
-
```

00C8		(AX)
		(BX)
	00D6	(BP)
		CODE1中的(IP)
		CODE1中的(CS)
		0
		RESULT的地址
00D6		(AX)
		(BX)
	00E4	(BP)
		CODE1中的(IP)
		CODE1中的(CS)
		1
		RESULT的地址
00E4		(AX)
		(BX)
	00F2	(BP)
		CODE1中的(IP)
		CODE1中的(CS)
		2
		RESULT的地址
00F2		(AX)
		(BX)
	0000	(BP)
		CODE中的(IP)
		CODE中的(CS)
		3
00FA		RESULT的地址

例：计算n!

```
fact    proc   near
        push   ax
        push   bp
        mov    bp, sp
        mov    ax, [bp+6]
        cmp    ax, 0
        jne    fact1
        inc    ax
        jmp    exit
fact1:  dec    ax
        push   ax
        call   fact
        pop    ax
        mul    word ptr[bp+6]
exit:   mov    [bp+6], ax
        pop    bp
        pop    ax
        ret
fact    endp
```



主程序：

```
mov   bx,
n_v
push  bx
call  fact
pop   result
```

多个模块之间的参数传送：

局部符号：在本模块中定义，在本模块中引用的符号

外部符号：在某一模块中定义，在另一模块中引用的符号

PUBLIC 符号　　EXTRN 符号:类型

; proadd1.asm

```
extrn   proadd : far
……
……
code1   segment
start:
        ……
        call   far ptr proadd
        ……
code1   ends
        end    start
```

; proadd2.asm

```
public   proadd
……
……
code2    segment
proadd   proc   far
         ……
         ret
proadd   endp
code2    ends
         end
```

例：

```
; proadd1.asm

extrn   proadd : far
data    segment   common
        ary       dw   1,2,3,4,5,6,7,8,9,10
        count     dw   10
        sum       dw   ?
data    ends
code1   segment
main    proc      far
        assume    cs:code1, ds:data
start:  push      ds
        sub       ax, ax
        push      ax
        mov       ax, data
        mov       ds, ax
        call      far ptr proadd
        ret
main    endp
code1   ends
        end       start
```

```
; proadd2.asm

public  proadd
data    segment  common
        ary      dw  1,2,3,4,5,6,7,8,9,10
        count    dw  10
        sum      dw  ?
data    ends
code2   segment
proadd  proc   far
        assume cs:code2,ds:data
        mov    ax, data
        mov    ds, ax
        push   ax
        push   cx
        push   si
        lea    si, ary
        mov    cx, count
        xor    ax, ax
next:   add    ax, [si]
        add    si, 2
        loop   next
        mov    sum,ax
        pop    si
        pop    cx
        pop    ax
        ret
proadd  endp
code2   ends
        end
```