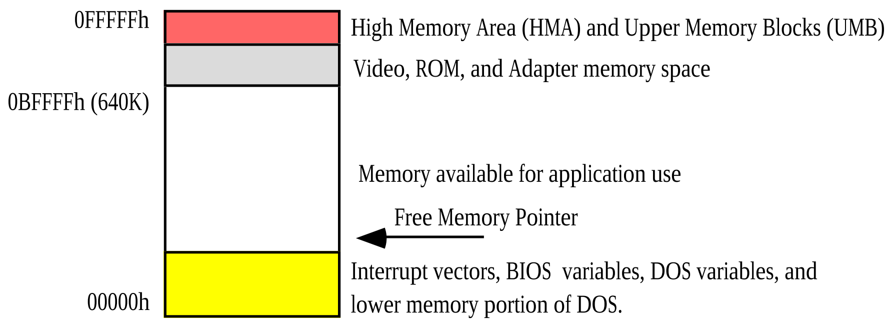
Resident Programs — Chapter 18

Most MS-DOS applications are *transient*. They load into memory, execute, terminate, and DOS uses the memory allocated to the application for the next program the user executes. Resident programs follow these same rules, except for the last. A resident program, upon termination, does not return all memory back to DOS. Instead, a portion of the program remains *resident*, ready to be reactivated by some other program at a future time.

Resident programs, also known as *terminate and stay resident programs* or *TSRs*, provide a tiny amount of *multitasking* to an otherwise single tasking operating system. Until Microsoft Windows became popular, resident programs were the most popular way to allow multiple applications to coexist in memory at one time. Although Windows has diminished the need for TSRs for background processing, TSRs are still valuable for writing *device drivers*, *antiviral tools*, and *program patches*. This chapter will discuss the issues you must deal with when writing resident programs.

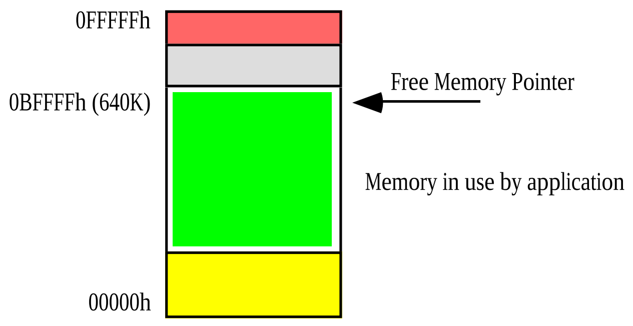
18.1 DOS Memory Usage and TSRs

When you first boot DOS, the memory layout will look something like the following:


0FFFFFh
0BFFFFh (640K)
00000h
High Memory Area (HMA) and Upper Memory Blocks (UMB)
Video, ROM, and Adapter memory space
Memory available for application use
Free Memory Pointer
Interrupt vectors, BIOS variables, DOS variables, and lower memory portion of DOS.

DOS Memory Map (no active application)

DOS maintains a *free memory pointer* that points the the beginning of the block of free memory. When the user runs an application program, DOS loads this application starting at the address the free memory pointer contains. Since DOS generally runs only a single application at a time, all the memory from the free memory pointer to the end of RAM (0BFFFFh) is available for the application's use:

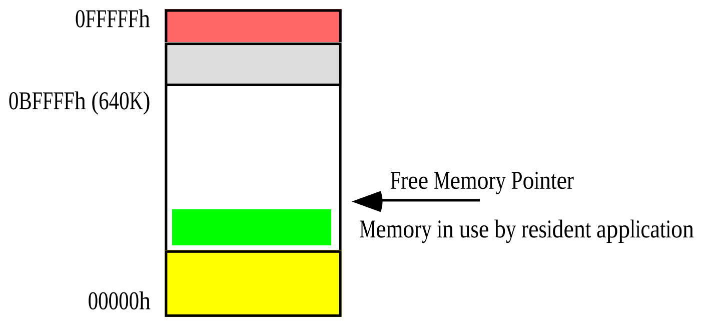


DOS Memory Map (w/active application)

When the program terminates normally via DOS function 4Ch (the Standard Library `exitpgm` macro), MS-DOS reclaims the memory in use by the application and resets the free memory pointer to just above DOS in low memory.

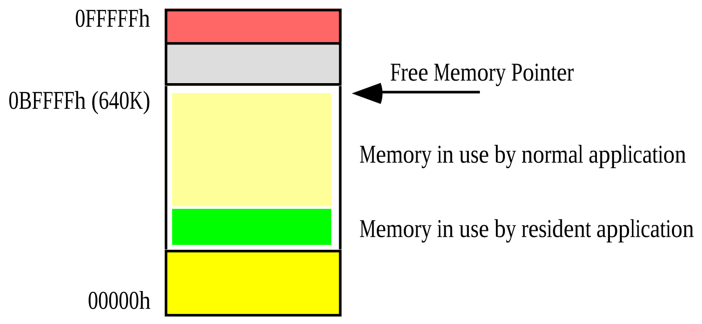
This document was created with FrameMaker 4.0.2

MS-DOS provides a second termination call which is identical to the terminate call with one exception, it does not reset the free memory pointer to reclaim all the memory in use by the application. Instead, this *terminate and stay resident* call frees all but a specified block of memory. The TSR call (ah=31h) requires two parameters, a process termination code in the al register (usually zero) and dx must contain the size of the memory block to protect, in paragraphs. When DOS executes this code, it adjusts the free memory pointer so that it points at a location dx*16 bytes above the program's PSP (see "MS-DOS, PC-BIOS, and File I/O" on page 699). This leaves memory looking like this:



DOS Memory Map (w/resident application)

When the user executes a new application, DOS loads it into memory at the new free memory pointer address, protecting the resident program in memory:


0FFFFFh
Free Memory Pointer
0BFFFFh (640K)
Memory in use by normal application
Memory in use by resident application
00000h

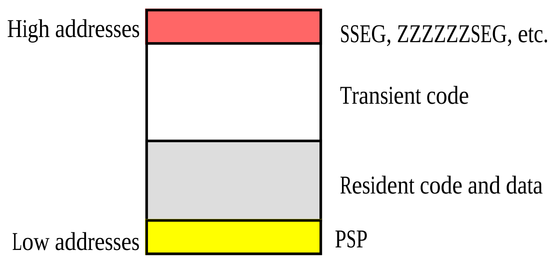
DOS Memory Map (w/resident and normal application)

When this new application terminates, DOS reclaims its memory and readjusts the free memory pointer to its location before running the application – just above the resident program. By using this free memory pointer scheme, DOS can protect the memory in use by the resident program[1].

The trick to using the terminate and stay resident call is to figure out how many paragraphs should remain resident. Most TSRs contain two sections of code: a *resident* portion and a *transient* portion. The transient portion is the data, main program, and support routines that execute when you run the program from the command line. This code will probably never execute again. Therefore, you should not leave it in memory when your program terminates. After all, every byte consumed by the TSR program is one less byte available to other application programs.

The resident portion of the program is the code that remains in memory and provides whatever functions are necessary of the TSR. Since the PSP is usually right before the first byte of program code, to effectively use the DOS TSR call, your program must be organized as follows:

1. Of course, DOS could never protect the resident program from an errant application. If the application decides to write zeros all over memory, the resident program, DOS, and many other memory areas will be destroyed.



Memory Organization for a Resident Program

To use TSRs effectively, you need to organize your code and data so that the resident portions of your program loads into lower memory addresses and the transient portions load into the higher memory addresses. MASM and the Microsoft Linker both provide facilities that let you control the loading order of segments within your code (see “MASM: Directives & Pseudo-Opcodes” on page 355). The simple solution, however, is to put all your resident code and data in a single segment and make sure that this segment appears *first* in every source module of your program. In particular, if you are using the UCR Standard Library SHELL.ASM file, you must make sure that you define your resident segments *before* the include directives for the standard library files. Otherwise MS-DOS will load all the standard library routines *before* your resident segment and that would waste considerable memory. Note that you only need to define your resident segment first, you do not have to place all the resident code and data before the includes. The following will work just fine:

```
ResidentSeg    segment    para public ‘resident’
ResidentSeg    ends

EndResident    segment    para public ‘EndRes’
EndResident    ends

               .xlist
               include    stdlib.a
               includelib stdlib.lib
               .list


ResidentSeg    segment    para public ‘resident’
               assume     cs:ResidentSeg, ds:ResidentSeg

PSP            word       ?             ;This var must be here!

; Put resident code and data here

ResidentSeg    ends


dseg           segment    para public ‘data’

; Put transient data here

dseg           ends


cseg           segment    para public ‘code’
               assume     cs:cseg, ds:dseg

; Put Transient code here.

cseg           ends
               etc.
```

The purpose of the EndResident segment will become clear in a moment. For more information on DOS memory ordering, see Chapter Six.

Now the only problem is to figure out the size of the resident code, in paragraphs. With your code structured in the manner shown above, determining the size of the resident program is quite easy, just use the following statements to terminate the transient portion of your code (in cseg):

```
              mov       ax, ResidentSeg   ;Need access to ResidentSeg
              mov       es, ax
              mov       ah, 62h           ;DOS Get PSP call.
              int       21h
              mov       es:PSP, bx        ;Save PSP value in PSP variable.

; The following code computes the sixe of the resident portion of the code.
; The EndResident segment is the first segment in memory after resident code.
; The program's PSP value is the segment address of the start of the resident
; block. By computing EndResident-PSP we compute the size of the resident
; portion in paragraphs.

              mov       dx, EndResident   ;Get EndResident segment address.
              sub       dx, bx            ;Subtract PSP.

; Okay, execute the TSR call, preserving only the resident code.

              mov       ax, 3100h         ;AH=31h (TSR), AL=0 (return code).
              int       21h
```

Executing the code above returns control to MS-DOS, preserving your resident code in memory.

There is one final memory management detail to consider before moving on to other topics related to resident programs – accessing data within an resident program. Procedures within a resident program become active in response to a direct call from some other program or a hardware interrupt (see the next section). Upon entry, the resident routine *may* specify that certain registers contain various parameters, but one thing you cannot expect is for the calling code to properly set up the segment registers for you. Indeed, the only segment register that will contain a meaningful value (to the resident code) is the code segment register. Since many resident functions will want to access local data, this means that those functions may need to set up `ds` or some other segment register(s) upon initial entry. For example, suppose you have a function, count, that simply counts the number of times some other code calls it once it has gone resident. One would thing that the body of this function would contain a single instruction: `inc counter`. Unfortunately, such an instruction would increment the variable at `counter`'s offset in the current data segment (that is, the segment pointed at by the `ds` register). It is unlikely that `ds` would be pointing at the data segment associated with the count procedure. Therefore, you would be incrementing some word in a different segment (probably the caller's data segment). This would produce disastrous results.

There are two solutions to this problem. The first is to put all variables in the code segment (a very common practice in resident sections of code) and use a `cs:` segment override prefix on all your variables. For example, to increment the `counter` variable you could use the instruction `inc cs:counter`. This technique works fine if there are only a few variable references in your procedures. However, it suffers from a few serious drawbacks. First, the segment override prefix makes your instructions larger and slower; this is a serious problem if you access many different variables throughout your resident code. Second, it is easy to forget to place the segment override prefix on a variable, thereby causing the TSR function to wipe out memory in the caller's data segment. Another solution to the segment problem is to change the value in the `ds` register upon entry to a resident procedure and restore it upon exit. The following code demonstrates how to do this:

```
              push      ds                ;Preserve original DS value.
              push      cs                ;Copy CS's value to DS.
              pop       ds
              inc       Counter           ;Bump the variable's value.
              pop       ds                ;Restore original DS value.
```

Of course, using the cs: segment override prefix is a much more reasonable solution here. However, had the code been extensive and had accessed many local variables, loading ds with cs (assuming you put your variables in the resident segment) would be more efficient.

18.2 Active vs. Passive TSRs

Microsoft identifies two types of TSR routines: active and passive. A passive TSR is one that activates in response to an explicit call from an executing application program. An active TSR is one that responds to a hardware interrupt or one that a hardware interrupt calls.

TSRs are almost always interrupt service routines (see “80x86 Interrupt Structure and Interrupt Service Routines (ISRs)” on page 996). Active TSRs are typically hardware interrupt service routines and passive TSRs are generally trap handlers (see “Traps” on page 999). Although, in theory, it is possible for a TSR to determine the address of a routine in a passive TSR and call that routine directly, the 80x86 trap mechanism is the perfect device for calling such routines, so most TSRs use it.

Passive TSRs generally provide a callable library of routines or extend some DOS or BIOS call. For example, you might want to reroute all characters an application sends to the printer to a file. By patching into the int 17h vector (see “The PC Parallel Ports” on page 1199) you can intercept all characters destined for the printer[2]. Or you could add additional functionality to a BIOS routine by chaining into its interrupt vector. For example, you could add new function calls to the int 10h BIOS video services routine (see “MS-DOS, PC-BIOS, and File I/O” on page 699) by looking for a special value in ah and passing all other int 10h calls on through to the original handler. Another use of a passive TSR is to provide a brand new set of services through a new interrupt vector that the BIOS does not already provide. The mouse services, provided by the mouse.com driver, is a good example of such a TSR.

Active TSRs generally serve one of two functions. They either service a hardware interrupt directly, or they piggyback off the hardware interrupt so they can activate themselves on a periodic basis without an explicit call from an application. *Pop-up* programs are a good example of active TSRs. A pop-up program chains itself into the PC’s keyboard interrupt (int 9). Pressing a key activates such a program. The program can read the PC’s keyboard port (see “The PC Keyboard” on page 1153) to see if the user is pressing a special key sequence. Should this keysequence appear, the application can save a portion of the screen memory and “pop-up” on the screen, perform some user-requested function, and then restore the screen when done. Borland’s Sidekick™ program is an example of an extremely popular TSR program, though many others exist.

Not all active TSRs are pop-ups, though. Certain viruses are good examples of active TSRs. They patch into various interrupt vectors that activate them automatically so they can go about their dastardly deeds. Fortunately, some anti-viral programs are also good examples of active TSRs, they patch into those same interrupt vectors and detect the activities of a virus and attempt to limit the damage the virus may cause.

Note that a TSR may contain both active and passive components. That is, there may be certain routines that a hardware interrupt invokes and others that an application calls explicitly. However, if any routine in a resident program is active, we’ll claim that the entire TSR is active.

The following program is a short example of a TSR that provides both active and passive routines. This program patches into the int 9 (keyboard interrupt) and int 16h (keyboard trap) interrupt vectors. Every time the system generates a keyboard interrupt, the active routine (int 9) increments a counter. Since the keyboard usually generates two keyboard interrupts per keystroke, dividing this value by two produces the approximate number of keys typed since starting the TSR[3]. A passive routine, tied into the int 16h vector, returns the number of keystrokes to the calling program. The following code provides two programs, the TSR and a short application to display the number of keystrokes since the TSR started running.

```
; This is an example of an active TSR that counts keyboard interrupts
; once activated.

; The resident segment definitions must come before everything else.
```

2. Assuming the application uses DOS or BIOS to print the characters and does not talk directly to the printer port itself.
3. It is not an exact count because some keys generate more than two keyboard interrupts.

```
ResidentSeg    segment    para public 'Resident'
ResidentSeg    ends

EndResident    segment    para public 'EndRes'
EndResident    ends

               .xlist
               include    stdlib.a
               includelib stdlib.lib
               .list


; Resident segment that holds the TSR code:

ResidentSeg    segment    para public 'Resident'
               assume     cs:ResidentSeg, ds:nothing

; The following variable counts the number of keyboard interrupts

KeyIntCnt      word       0

; These two variables contain the original INT 9 and INT 16h
; interrupt vector values:

OldInt9        dword      ?
OldInt16       dword      ?


; MyInt9-      The system calls this routine every time a keyboard
;              interrupt occus. This routine increments the
;              KeyIntCnt variable and then passes control on to the
;              original Int9 handler.

MyInt9         proc       far
               inc        ResidentSeg:KeyIntCnt
               jmp        ResidentSeg:OldInt9
MyInt9         endp




; MyInt16-     This is the passive component of this TSR. An
;              application explicitly calls this routine with an
;              INT 16h instruction. If AH contains 0FFh, this
;              routine returns the number of keyboard interrupts
;              in the AX register. If AH contains any other value,
;              this routine passes control to the original INT 16h
;              (keyboard trap) handler.

MyInt16        proc       far
               cmp        ah, 0FFh
               je         ReturnCnt
               jmp        ResidentSeg:OldInt16;Call original handler.

; If AH=0FFh, return the keyboard interrupt count

ReturnCnt:     mov        ax, ResidentSeg:KeyIntCnt
               iret
MyInt16        endp


ResidentSeg    ends



cseg           segment    para public 'code'
               assume     cs:cseg, ds:ResidentSeg

Main           proc
               meminit

               mov        ax, ResidentSeg
               mov        ds, ax
```

```
              mov       ax, 0
              mov       es, ax

              print
              byte      "Keyboard interrupt counter TSR program",cr,lf
              byte      "Installing....",cr,lf,0

; Patch into the INT 9 and INT 16 interrupt vectors. Note that the
; statements above have made ResidentSeg the current data segment,
; so we can store the old INT 9 and INT 16 values directly into
; the OldInt9 and OldInt16 variables.

              cli                         ;Turn off interrupts!
              mov       ax, es:[9*4]
              mov       word ptr OldInt9, ax
              mov       ax, es:[9*4 + 2]
              mov       word ptr OldInt9+2, ax
              mov       es:[9*4], offset MyInt9
              mov       es:[9*4+2], seg ResidentSeg

              mov       ax, es:[16h*4]
              mov       word ptr OldInt16, ax
              mov       ax, es:[16h*4 + 2]
              mov       word ptr OldInt16+2, ax
              mov       es:[16h*4], offset MyInt16
              mov       es:[16h*4+2], seg ResidentSeg
              sti                         ;Okay, ints back on.

; We're hooked up, the only thing that remains is to terminate and
; stay resident.

              print
              byte      "Installed.",cr,lf,0

              mov       ah, 62h           ;Get this program's PSP
              int       21h               ; value.

              mov       dx, EndResident   ;Compute size of program.
              sub       dx, bx
              mov       ax, 3100h         ;DOS TSR command.
              int       21h
Main          endp
cseg          ends

sseg          segment   para stack 'stack'
stk           db        1024 dup ("stack ")
sseg          ends

zzzzzzseg     segment   para public 'zzzzzz'
LastBytes     db        16 dup (?)
zzzzzzseg     ends
              end       Main
```

Here's the application that calls MyInt16 to print the number of keystrokes:

```
; This is the companion program to the keycnt TSR.
; This program calls the "MyInt16" routine in the TSR to
; determine the number of keyboard interrupts. It displays
; the approximate number of keystrokes (keyboard ints/2)
; and quits.

              .xlist
              include   stdlib.a
              includelib stdlib.lib
              .list

cseg          segment   para public 'code'
              assume    cs:cseg, ds:nothing

Main          proc
              meminit

              print
```

```
                byte      "Approximate number of keys pressed: ",0
                mov       ah, 0FFh
                int       16h
                shr       ax, 1           ;Must divide by two.
                putu
                putcr
                ExitPgm

Main            endp
cseg            ends

sseg            segment   para stack 'stack'
stk             db        1024 dup ("stack ")
sseg            ends

zzzzzzseg       segment   para public 'zzzzzz'
LastBytes       db        16 dup (?)
zzzzzzseg       ends
                end       Main
```

18.3 Reentrancy

One big problem with active TSRs is that their invocation is asynchronous. They can activate at the touch of a keystroke, timer interrupt, or via an incoming character on the serial port, just to name a few. Since they activate on a hardware interrupt, the PC could have been executing just about any code when the interrupt came along. This isn't a problem unless the TSR itself decides to call some foreign code, such as DOS, a BIOS routine, or some other TSR. For example, the main application may be making a DOS call when a timer interrupt activates a TSR, interrupting the call to DOS while the CPU is still executing code inside DOS. If the TSR attempts to make a call to DOS at this point, then this will *reenter* DOS. Of course, DOS is not reentrant, so this creates all kinds of problems (usually, it hangs the system). When writing active TSRs that call other routines besides those provided directly in the TSR, you must be aware of possible reentrancy problems.

Note that passive TSRs never suffer from this problem. Indeed, any TSR routine you call passively will execute in the caller's environment. Unless some other hardware ISR or active TSR makes the call to your routine, you do not need to worry about reentrancy with passive routines. However, reentrancy is an issue for active TSR routines and passive routines that active TSRs call.

18.3.1 Reentrancy Problems with DOS

DOS is probably the biggest sore point to TSR developers. DOS is not reentrant yet DOS contains many services a TSR might use. Realizing this, Microsoft has added some support to DOS to allow TSRs to see if DOS is currently active. After all, reentrancy is only a problem if you call DOS while it is already active. If it isn't already active, you can certainly call it from a TSR with no ill effects.

MS-DOS provides a special one-byte flag (InDOS) that contains a zero if DOS is currently active and a non-zero value if DOS is already processing an application request. By testing the InDOS flag your TSR can determine if it can safely make a DOS call. If this flag is zero, you can always make the DOS call. If this flag contains one, you may not be able to make the DOS call. MS-DOS provides a function call, *Get InDOS Flag Address*, that returns the address of the InDOS flag. To use this function, load `ah` with 34h and call DOS. DOS will return the address of the InDOS flag in `es:bx`. If you save this address, your resident programs will be able to test the InDOS flag to see if DOS is active.

Actually, there are two flags you should test, the InDOS flag and the *critical error flag* (criterr). Both of these flags should contain zero before you call DOS from a TSR. In DOS version 3.1 and later, the critical error flag appears in the byte just before the InDOS flag.

So what should you do if these flags aren't both zero? It's easy enough to say "hey, come back and do this stuff later when MS-DOS returns back to the user program." But how do you do this? For example, if a keyboard interrupt activates your TSR and you pass control on to the real keyboard handler because DOS is busy, you can't expect your TSR to be magically restarted later on when DOS is no longer active.

The trick is to patch your TSR into the timer interrupt as well as the keyboard interrupt. When the keystroke interrupt wakes your TSR and you discover that DOS is busy, the keyboard ISR can simply set a flag to tell itself to try again later; then it passes control to the original keyboard handler. In the meantime, a timer ISR you've written is constantly checking this flag you've created. If the flag is clear, it simply passes control on to the original timer interrupt handler, if the flag is set, then the code checks the InDOS and CritErr flags. If these guys say that DOS is busy, the timer ISR passes control on to the original timer handler. Shortly after DOS finishes whatever it was doing, a timer interrupt will come along and detect that DOS is no longer active. Now your ISR can take over and make any necessary calls to DOS that it wants. Of course, once your timer code determines that DOS is not busy, it should clear the "I want service" flag so that future timer interrupts don't inadvertently restart the TSR.

There is only one problem with this approach. There are certain DOS calls that can take an indefinite amount of time to execute. For example, if you call DOS to read a key from the keyboard (or call the Standard Library's `getc` routine that calls DOS to read a key), it could be *hours*, *days*, or even longer before somebody actually bothers to press a key. Inside DOS there is a loop that waits until the user actually presses a key. And until the user presses some key, the InDOS flag is going to remain non-zero. If you've written a timer-based TSR that is buffering data every few seconds and needs to write the results to disk every now and then, you will overflow your buffer with new data if you wait for the user, who just went to lunch, to press a key in DOS' command.com program.

Luckily, MS-DOS provides a solution to this problem as well – the idle interrupt. While MS-DOS is in an indefinite loop wait for an I/O device, it continually executes an `int 28h` instruction. By patching into the int 28h vector, your TSR can determine when DOS is sitting in such a loop. When DOS executes the int 28h instruction, it is safe to make any DOS call whose function number (the value in `ah`) is greater than 0Ch.

So if DOS is busy when your TSR wants to make a DOS call, you must use either a timer interrupt or the idle interrupt (int 28h) to activate the portion of your TSR that must make DOS calls. One final thing to keep in mind is that *whenever you test or modify any of the above mentioned flags, you are in a critical section*. Make sure the interrupts are off. If not, your TSR make activate two copies of itself or you may wind up entering DOS at the same time some other TSR enters DOS.

An example of a TSR using these techniques will appear a little later, but there are some additional reentrancy problems we need to discuss first.

18.3.2 Reentrancy Problems with BIOS

DOS isn't the only non-reentrant code a TSR might want to call. The PC's BIOS routines also fall into this category. Unfortunately, BIOS doesn't provide an "InBIOS" flag or a multiplex interrupt. You will have to supply such functionality yourself.

The key to preventing reentering a BIOS routine you want to call is to use a *wrapper*. A wrapper is a short ISR that patches into an existing BIOS interrupt specifically to manipulate an InUse flag. For example, suppose you need to make an int 10h (video services) call from within your TSR. You could use the following code to provide an "Int10InUse" flag that your TSR could test:

```
MyInt10         proc        far
                inc         cs:Int10InUse
                pushf
                call        cs:OldInt10
                dec         cs:Int10InUse
                iret
MyInt10         endp
```

Assuming you've initialized the Int10InUse variable to zero, the in use flag will contain zero when it is safe to execute an int 10h instruction in your TSR, it will contain a non-zero value when the interrupt 10h handler is busy. You can use this flag like the InDOS flag to defer the execution of your TSR code.

Like DOS, there are certain BIOS routines that may take an indefinite amount of time to complete. Reading a key from the keyboard buffer, reading or writing characters on the serial port, or printing characters to the printer are some examples. While, in some cases, it is possible to create a wrapper that lets your TSR activate itself while a BIOS routine is executing one of these polling loops, there is probably no benefit to doing so. For example, if an application program is waiting for the printer to take a character before it sends another to printer, having your TSR preempt this and attempt to send a character to the printer won't accomplish much (other than scramble the data sent to the print). Therefore, BIOS wrappers generally don't worry about *indefinite postponement* in a BIOS routine.

5, 8, 9, D, E, 10, 13, 16, 17, 21, 28

If you run into problems with your TSR code and certain application programs, you may want to place wrappers around the following interrupts to see if this solves your problem: int 5, int 8, int 9, int B, int C, int D, int E, int 10, int 13, int 14, int 16, or int 17. These are common culprits when TSR problems develop.

18.3.3 Reentrancy Problems with Other Code

Reentrancy problems occur in other code you might call as well. For example, consider the UCR Standard Library. The UCR Standard Library is not reentrant. This usually isn't much of a problem for a couple of reasons. First, most TSRs do *not* call Standard Library subroutines. Instead, they provide results that normal applications can use; those applications use the Standard Library routines to manipulate such results. A second reason is that were you to include some Standard Library routines in a TSR, the application would have a *separate* copy of the library routines. The TSR might execute an strcmp instruction while the application is in the middle of an strcmp routine, *but these are not the same routines!* The TSR is not reentering the application's code, it is executing a separate routine.

However, many of the Standard Library functions make DOS or BIOS calls. Such calls do not check to see if DOS or BIOS is already active. Therefore, calling many Standard Library routines from within a TSR may cause you to reenter DOS or BIOS.

One situation does exist where a TSR could reenter a Standard Library routine. Suppose your TSR has both passive and active components. If the main application makes a call to a passive routine in your TSR and that routine call a Standard Library routine, there is the possibility that a system interrupt could interrupt the Standard Library routine and the active portion of the TSR reenter that same code. Although such a situation would be extremely rare, you should be aware of this possibility.

Of course, the best solution is to avoid using the Standard Library within your TSRs. If for no other reason, the Standard Library routines are quite large and TSRs should be as small as possible.

18.4 The Multiplex Interrupt (INT 2Fh)

When installing a passive TSR, or an active TSR with passive components, you will need to choose some interrupt vector to patch so other programs can communicate with your passive routines. You could pick an interrupt vector almost at random, say int 84h, but this could lead to some compatibility problems. What happens if someone else is already using that interrupt vector? Sometimes, the choice of interrupt vector is clear. For example, if your passive TSR is extended the int 16h keyboard services, it makes sense to patch in to the int 16h vector and add additional functions above and beyond those already provided by the BIOS. On the other hand, if you are creating a driver for some brand new device for the PC, you probably would not want to piggyback the support functions for this device on some other interrupt. Yet arbitrarily picking an unused interrupt vector is risky; how many other programs out there decided to do the same thing? Fortunately, MS-DOS provides a solution: the multiplex interrupt. Int 2Fh provides a general mechanism for installing, testing the presence of, and communicating with a TSR.

To use the multiplex interrupt, an application places an identification value in `ah` and a function number in `al` and then executes an `int 2Fh` instruction. Each TSR in the int 2Fh chain compares the value in `ah` against its own unique identifier value. If the values match, the TSR process the command specified by the value in the `al` register. If the identification values do not match, the TSR passes control to the next int 2Fh handler in the chain.

Of course, this only reduces the problem somewhat, it doesn't eliminate it. Sure, we don't have to guess an interrupt vector number at random, but we still have to choose a random identification number. After all, it seems reasonable that we must choose this number before designing the TSR and any applications that call it, after all, how will the applications know what value to load into `ah` if we dynamically assign this value when the TSR goes resident?

Well, there is a little trick we can play to dynamically assign TSR identifiers *and* let any interested applications determine the TSR's ID. By convention, function zero is the "Are you there?" call. An application should always execute this function to determine if the TSR is actually present in memory before making any service requests. Normally, function zero returns a zero in al if the TSR is *not* present, it returns 0FFh if it is present. However, when this function returns 0FFh it only tells you that *some* TSR has responded to your query; it does not guarantee that the TSR you are interested in is actually present in memory. However, by extending the convention somewhat, it is very easy to verify the presence of the desired TSR. Suppose the function zero call also returns a pointer to a unique identification string in the `es:di` registers. Then the code testing for the presence of a specific TSR could test this string when the int 2Fh call detects the presence of a TSR. the following code segment demonstrates how a TSR could determine if a TSR identified as "Randy's INT 10h Extension" is present in memory; this code will also determine the unique identification code for that TSR, for future reference:

```
; Scan through all the possible TSR IDs. If one is installed, see if
; it's the TSR we're interested in.

              mov       cx, 0FFh          ;This will be the ID number.
IDLoop:       mov       ah, cl            ;ID -> AH.
              push      cx                ;Preserve CX across call
              mov       al, 0             ;Test presence function code.
              int       2Fh               ;Call multiplex interrupt.
              pop       cx                ;Restore CX.
              cmp       al, 0             ;Installed TSR?
              je        TryNext           ;Returns zero if none there.
              strcmpl                     ;See if it's the one we want.
              byte      "Randy's INT "
              byte      "10h Extension",0
              je        Success           ;Branch off if it is ours.
TryNext:      loop      IDLoop            ;Otherwise, try the next one.
              jmp       NotInstalled      ;Failure if we get to this point.

Success:      mov       FuncID, cl        ;Save function result.
               .
               .
               .
```

If this code succeeds, the variable FuncId contains the identification value for resident TSR. If it fails, the application program probably needs to abort, or otherwise ensure that it never calls the missing TSR.

The code above lets an application easily detect the presence of and determine the ID number for a specific TSR. The next question is "How do we pick the ID number for the TSR in the first place?" The next section will address that issue, as well as how the TSR must respond to the multiplex interrupt.

18.5 Installing a TSR

Although we've already discussed how to make a program go resident (see "DOS Memory Usage and TSRs" on page 1025), there are a few aspects to installing a TSR that we need to address. First, what happens if a user installs a TSR and then tries to install it a second time without first removing the one that is already resident? Second, how can we assign a TSR identification number that won't conflict with a TSR that is already installed? This section will address these issues.

The first problem to address is an attempt to reinstall a TSR program. Although one could imagine a type of TSR that allows multiple copies of itself in memory at one time, such TSRs are few and far in-between. In most cases, having multiple copies of a TSR in memory will, at best, waste memory and, at worst, crash the system. Therefore, unless you are specifically written a TSR that allows multiple copies of itself in memory at one time, you should check to see if the TSR is installed before actually installing it. This code is identical to the code an application would use to see if the TSR is installed, the only difference is that the TSR should print a nasty message and refuse to go TSR if it finds a copy of itself already installed in memory. The following code does this:

```
              mov       cx, 0FFh
SearchLoop:   mov       ah, cl
              push      cx
              mov       al, 0
              int       2Fh
              pop       cx
              cmp       al, 0
              je        TryNext
              strcmpl
              byte      “Randy’s INT “
              byte      “10h Extension”,0
              je        AlreadyThere
TryNext:      loop      SearchLoop
              jmp       NotInstalled

AlreadyThere: print
              byte      “A copy of this TSR already exists in memory”,cr,lf
              byte      “Aborting installation process.”,cr,lf,0
              ExitPgm
               .
               .
               .
```

In the previous section, you saw how to write some code that would allow an application to determine the TSR ID of a specific resident program. Now we need to look at how to dynamically choose an identification number for the TSR, one that does not conflict with any other TSRs. This is yet another modification to the scanning loop. In fact, we can modify the code above to do this for us. All we need to do is save away some ID value that does not does not have an installed TSR. We need only add a few lines to the above code to accomplish this:

```
              mov       FuncID, 0         ;Initialize FuncID to zero.
              mov       cx, 0FFh
SearchLoop:   mov       ah, cl
              push      cx
              mov       al, 0
              int       2Fh
              pop       cx
              cmp       al, 0
              je        TryNext
              strcmpl
              byte      “Randy’s INT “
              byte      “10h Extension”,0
              je        AlreadyThere
              loop      SearchLoop
              jmp       NotInstalled

; Note:  presumably DS points at the resident data segment that contains
;        the FuncID variable. Otherwise you must modify the following to
;        point some segment register at the segment containing FuncID and
;        use the appropriate segment override on FuncID.

TryNext:      mov       FuncID, cl        ;Save possible function ID if this
              loop      SearchLoop        ; identifier is not in use.
              jmp       NotInstalled

AlreadyThere: print
```

```
              byte      “A copy of this TSR already exists in memory”,cr,lf
              byte      “Aborting installation process.”,cr,lf,0
              ExitPgm

NotInstalled: cmp       FuncID, 0        ;If there are no available IDs, this
              jne       GoodID           ; will still contain zero.
              print
              byte      “There are too many TSRs already installed.”,cr,lf
              byte      “Sorry, aborting installation process.”,cr,lf,0
              ExitPgm

GoodID:
```

If this code gets to label “GoodID” then a previous copy of the TSR is not present in memory and the FuncID variable contains an unused function identifier.

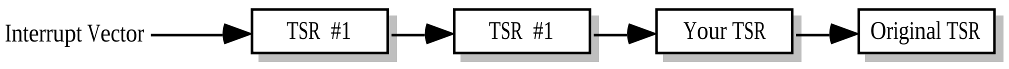
Of course, when you install your TSR in this manner, you must not forget to patch your interrupt 2Fh handler into the int 2Fh chain. Also, you have to write an interrupt 2Fh handler to process int 2Fh calls. The following is a very simple multiplex interrupt handler for the code we’ve been developing:

```
FuncID        byte      0                ;Should be in resident segment.
OldInt2F      dword     ?                ; Ditto.

MyInt2F       proc      far
              cmp       ah, cs:FuncID    ;Is this call for us?
              je        ItsUs
              jmp       cs:OldInt2F      ;Chain to previous guy, if not.

; Now decode the function value in AL:

ItsUs:        cmp       al, 0            ;Verify presence call?
              jne       TryOtherFunc
              mov       al, 0FFh         ;Return “present” value in AL.
              lesi      IDString         ;Return pointer to string in es:di.
              iret                       ;Return to caller.
IDString      byte      ““Randy’s INT “
              byte      “10h Extension”,0

; Down here, handle other multiplex requests.
; This code doesn’t offer any, but here’s where they would go.
; Just test the value in AL to determine which function to execute.

TryOtherFunc:
               .
               .
               .
              iret
MyInt2F       endp
```

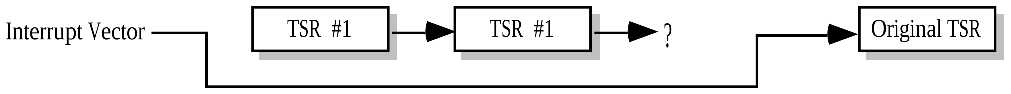
18.6 Removing a TSR

Removing a TSR is quite a bit more difficult that installing one. There are three things the removal code must do in order to properly remove a TSR from memory: first, it needs to stop any pending activities (e.g., the TSR may have some flags set to start some activity at a future time); second it needs to restore all interrupt vectors to their former values; third, it needs to return all reserved memory back to DOS so other applications can make use of it. The primary difficulty with these three activities is that it is not always possible to properly restore the interrupt vectors.

If your TSR removal code simply restores the old interrupt vector values, you may create a really big problem. What happens if the user runs some other TSRs after running yours and they patch into the same interrupt vectors as your TSR? This would produce interrupt chains that look something like the following:



If you restore the interrupt vector with your original value, you will create the following:



This effectively disables the TSRs that chain into your code. Worse yet, this only disables the interrupts that those TSRs have in common with your TSR. the other interrupts those TSRs patch into are still active. Who knows how those interrupts will behave under such circumstances?

One solution is to simply print an error message informing the user that they cannot remove this TSR until they remove all TSRs installed prior to this one. This is a common problem with TSRs and most DOS users who install and remove TSRs should be comfortable with the fact that they must remove TSRs in the reverse order that they install them.

It would be tempting to suggest a new convention that TSRs should obey; perhaps if the function number is 0FFh, a TSR should store the value in `es:bx` away in the interrupt vector specified in `cl`. This would allow a TSR that would like to remove itself to pass the address of its original interrupt handler to the previous TSR in the chain. There are only three problems with this approach: first, almost no TSRs in existence currently support this feature, so it would be of little value; second, some TSRs might use function 0FFh for something else, calling them with this value, *even if you knew their ID number*, could create a problem; finally, just because you've removed the TSR from the interrupt chain doesn't mean you can (truly) free up the memory the TSR uses. DOS' memory management scheme (the free pointer business) works like a stack. If there are other TSRs installed above yours in memory, most applications wouldn't be able to use the memory freed up by removing your TSR anyway.

Therefore, we'll also adopt the strategy of simply informing the user that they cannot remove a TSR if there are others installed in shared interrupt chains. Of course, that does bring up a good question, how can we determine if there are other TSRs chained in to our interrupts? Well, this isn't so hard. We know that the 80x86's interrupt vectors should still be pointing at our routines if we're the last TSR run. So all we've got to do is compare the patched interrupt vectors against the addresses of our interrupt service routines. If they *all* match, then we can safely remove our TSR from memory. If only one of them does not match, then we cannot remove the TSR from memory. The following code sequence tests to see if it is okay to detach a TSR containing ISRs for int 2fH and int 9:

```
; OkayToRmv-    This routine returns the carry flag set if it is okay to
;               remove the current TSR from memory. It checks the interrupt
;               vectors for int 2F and int 9 to make sure they
;               are still pointing at our local routines.
;               This code assumes DS is pointing at the resident code's
;               data segment.

OkayToRmv       proc       near
                push       es
                mov        ax, 0             ;Point ES at interrupt vector
                mov        es, ax            ; table.
                mov        ax, word ptr OldInt2F
                cmp        ax, es:[2fh*4]
                jne        CantRemove
                mov        ax, word ptr OldInt2F+2
                cmp        ax, es:[2Fh*4 + 2]
                jne        CantRemove

                mov        ax, word ptr OldInt9
                cmp        ax, es:[9*4]
                jne        CantRemove
                mov        ax, word ptr OldInt9+2
                cmp        ax, es:[9*4 + 2]
                jne        CantRemove

; We can safely remove this TSR from memory.

                stc
                pop        es
                ret
```

```
' Someone else is in the way, we cannot remove this TSR.

CantRemove:    clc
               pop       es
               ret
OkayToRmv      endp
```

Before the TSR attempts to remove itself, it should call a routine like this one to see if removal is possible.

Of course, the fact that no other TSR has chained into the same interrupts does *not* guarantee that there are not TSRs above yours in memory. However, removing the TSR in that case will not crash the system. True, you may not be able to reclaim the memory the TSR is using (at least until you remove the other TSRs), but at least the removal will not create complications.

To remove the TSR from memory requires two DOS calls, one to free the memory in use by the TSR and one to free the memory in use by the environment area assigned to the TSR. To do this, you need to make the DOS deallocation call (see "MS-DOS, PC-BIOS, and File I/O" on page 699). This call requires that you pass the segment address of the block to release in the es register. For the TSR program itself, you need to pass the address of the TSR's PSP. This is one of the reasons a TSR needs to save its PSP when it first installs itself. The other free call you must make frees the space associated with the TSR's *environment block*. The address of this block is at offset 2Ch in the PSP. So we should probably free it first. The following calls handle the job of free the memory associated with a TSR:

```
; Presumably, the PSP variable was initialized with the address of this
; program's PSP before the terminate and stay resident call.

               mov       es, PSP
               mov       es, es:[2Ch]      ;Get address of environment block.
               mov       ah, 49h           ;DOS deallocate block call.
               int       21h

               mov       es, PSP           ;Now free the program's memory
               mov       ah, 49h           ; space.
               int       21h
```

Some poorly-written TSRs provide no facilities to allow you to remove them from memory. If someone wants remove such a TSR, they will have to reboot the PC. Obviously, this is a poor design. Any TSR you design for anything other than a quick test should be capable of removing itself from memory. The multiplex interrupt with function number one is often used for this purpose. To remove a TSR from memory, some application program passes the TSR ID and a function number of one to the TSR. If the TSR can remove itself from memory, it does so and returns a value denoting success. If the TSR cannot remove itself from memory, it returns some sort of error condition.

Generally, the removal program is the TSR itself with a special parameter that tells it to remove the TSR currently loaded into memory. A little later this chapter presents an example of a TSR that works precisely in this fashion (see "A Keyboard Monitor TSR" on page 1041).

18.7 Other DOS Related Issues

In addition to reentrancy problems with DOS, there are a few other issues your TSRs must deal with if they are going to make DOS calls. Although your calls might not cause DOS to reenter itself, it is quite possible for your TSR's DOS calls to disturb data structures in use by an executing application. These data structures include the application's stack, PSP, disk transfer area (DTA), and the DOS extended error information record.

When an active or passive TSR gains control of the CPU, it is operating in the environment of the main (foreground) application. For example, the TSR's return address and any values it saves on the stack are pushed onto the application's stack. If the TSR does not use much stack space, this is fine, it need not switch stacks. However, if the TSR consumes considerable amounts of stack space because of recursive calls or the allocation of local variables, the TSR should save the application's ss and sp values and switch to a local stack. Before returning, of course, the TSR should switch back to the foreground application's stack.

Likewise, if the TSR execute's DOS' *get psp address* call, DOS returns the address of the foreground application's PSP, not the TSR's PSP[4]. The PSP contains several important address that DOS uses in the event of an error. For example, the PSP contains the address of the termination handler, ctrl-break handler, and critical error handler. If you do not switch the PSP from the foreground application to the TSR's and one of the exceptions occurs (e.g., someone hits control-break or a disk error occurs), the handler associated with the application may take over. Therefore, when making DOS calls that can result in one of these conditions, you need to switch PSPs. Likewise, when your TSR returns control to the foreground application, it must restore the PSP value. MS-DOS provides two functions that get and set the current PSP address. The DOS *Set PSP* call (ah=51h) sets the current program's PSP address to the value in the bx register. The DOS *Get PSP* call (ah=50h) returns the current program's PSP address in the bx register. Assuming the transient portion of your TSR has saved it's PSP address in the variable PSP, you switch between the TSR's PSP and the foreground application's PSP as follows:

```
; Assume we've just entered the TSR code, determined that it's okay to
; call DOS, and we've switch DS so that it points at our local variables.

              mov       ah, 51h          ;Get application's PSP address
              int       21h
              mov       AppPSP, bx       ;Save application's PSP locally.
              mov       bx, PSP          ;Change system PSP to TSR's PSP.
              mov       ah, 50h          ;Set PSP call
              int       21h
               .
               .                         ;TSR code
               .
              mov       bx, AppPSP       ;Restore system PSP address to
              mov       ah, 50h          ; point at application's PSP.
              int       21h

        « clean up and return from TSR »
```

Another global data structure that DOS uses is the *disk transfer area*. This buffer area was used extensively for disk I/O in DOS version 1.0. Since then, the main use for the DTA has been the find first file and find next file functions (see "MS-DOS, PC-BIOS, and File I/O" on page 699). Obviously, if the application is in the middle of using data in the DTA and your TSR makes a DOS call that changes the data in the DTA, you will affect the operation of the foreground process. MS-DOS provides two calls that let you get and set the address of the DTA. The *Get DTA Address* call, with ah=2Fh, returns the address of the DTA in the es:bx registers. The *Set DTA* call (ah=1Ah) sets the DTA to the value found in the ds:dx register pair. With these two calls you can save and restore the DTA as we did for the PSP address above. The DTA is usually at offset 80h in the PSP, the following code preserve's the foreground application's DTA and sets the current DTA to the TSR's at offset PSP:80.

```
; This code makes the same assumptions as the previous example.

              mov       ah, 2Fh          ;Get application DTA
              int       21h
              mov       word ptr AppDTA, bx
              mov       word ptr AppDTA+2, es

              push      ds
              mov       ds, PSP          ;DTA is in PSP
              mov       dx, 80h          ; at offset 80h
              mov       ah, 1ah          ;Set DTA call.
              int       21h
              pop       ds
               .
               .                         ;TSR code.
               .
```

4. This is another reason the transient portion of the TSR must save the PSP address in a resident variable for the TSR.

```
              push      ds
              mov       dx, word ptr AppDTA
              mov       ds, word ptr AppDTA+2
              mov       ax, 1ah          ;Set DTA call.
              int       21h
```

The last issue a TSR must deal with is the extended error information in DOS. If a TSR interrupts a program immediately after DOS returns to that program, there may be some error information the foreground application needs to check in the DOS extended error information. If the TSR makes any DOS calls, DOS may replace this information with the status of the TSR DOS call. When control returns to the foreground application, it may read the extended error status and get the information generated by the TSR DOS call, not the application's DOS call. DOS provides two asymmetrical calls, *Get Extended Error* and *Set Extended Error* that read and write these values, respectively. The call to Get Extended Error returns the error status in the ax, bx, cx, dx, si, di, es, and ds registers. You need to save the registers in a data structure that takes the following form:

```
ExtError      struct
eeAX          word      ?
eeBX          word      ?
eeCX          word      ?
eeDX          word      ?
eeSI          word      ?
eeDI          word      ?
eeDS          word      ?
eeES          word      ?
              word      3 dup (0)        ;Reserved.
ExtError      ends
```

The Set Extended Error call requires that you pass an address to this structure in the ds:si register pair (which is why these two calls are asymmetrical). To preserve the extended error information, you would use code similar to the following:

```
; Save assumptions as the above routines here. Also, assume the error
; data structure is named ERR and is in the same segment as this code.

              push      ds               ;Save ptr to our DS.
              mov       ah, 59h          ;Get extended error call
              mov       bx, 0            ;Required by this call
              int       21h

              mov       cs:ERR.eeDS, ds
              pop       ds               ;Retrieve ptr to our data.
              mov       ERR.eeAX, ax
              mov       ERR.eeBX, bx
              mov       ERR.eeCX, cx
              mov       ERR.eeDX, dx
              mov       ERR.eeSI, si
              mov       ERR.eeDI, di
              mov       ERR.eeES, es
               .
               .                         ;TSR code goes here.
               .
              mov       si, offset ERR   ;DS already points at correct seg.
              mov       ax, 5D0Ah        ;5D0Ah is Set Extended Error code.
              int       21h

         « clean up and quit »
```

18.8 A Keyboard Monitor TSR

The following program extends the keystroke counter program presented a little earlier in this chapter. This particular program monitors keystrokes and each minute writes out data to a file listing the date, time, and approximate number of keystrokes in the last minute.

This program can help you discover how much time you spend typing versus thinking at a display screen[5].

```
; This is an example of an active TSR that counts keyboard interrupts
; once activated. Every minute it writes the number of keyboard
; interrupts that occurred in the previous minute to an output file.
; This continues until the user removes the program from memory.
;
;
; Usage:
;       KEYEVAL filename    -         Begins logging keystroke data to
;                                     this file.
;
;       KEYEVAL REMOVE      -         Removes the resident program from
;                                     memory.
;
;
; This TSR checks to make sure there isn't a copy already active in
; memory. When doing disk I/O from the interrupts, it checks to make
; sure DOS isn't busy and it preserves application globals (PSP, DTA,
; and extended error info). When removing itself from memory, it
; makes sure there are no other interrupts chained into any of its
; interrupts before doing the remove.
;
; The resident segment definitions must come before everything else.

ResidentSeg   segment    para public 'Resident'
ResidentSeg   ends

EndResident   segment    para public 'EndRes'
EndResident   ends

              .xlist
              .286
              include    stdlib.a
              includelib stdlib.lib
              .list


; Resident segment that holds the TSR code:

ResidentSeg   segment    para public 'Resident'
              assume     cs:ResidentSeg, ds:nothing

; Int 2Fh ID number for this TSR:

MyTSRID       byte       0

; The following variable counts the number of keyboard interrupts

KeyIntCnt     word       0

; Counter counts off the number of milliseconds that pass, SecCounter
; counts off the number of seconds (up to 60).

Counter       word       0
SecCounter    word       0

; FileHandle is the handle for the log file:

FileHandle    word       0

; NeedIO determines if we have a pending I/O opearation.

NeedIO        word       0

; PSP is the psp address for this program.

PSP           word       0
```

5. This program is intended for your personal enjoyment only, it is not intended to be used for unethical purposes such as monitoring employees for evaluation purposes.

```
; Variables to tell us if DOS, INT 13h, or INT 16h are busy:

InInt13         byte        0
InInt16         byte        0
InDOSFlag       dword       ?

; These variables contain the original values in the interrupt vectors
; we've patched.

OldInt9         dword       ?
OldInt13        dword       ?
OldInt16        dword       ?
OldInt1C        dword       ?
OldInt28        dword       ?
OldInt2F        dword       ?


; DOS data structures:

ExtErr          struct
eeAX            word        ?
eeBX            word        ?
eeCX            word        ?
eeDX            word        ?
eeSI            word        ?
eeDI            word        ?
eeDS            word        ?
eeES            word        ?
                word        3 dup (0)
ExtErr          ends



XErr            ExtErr      {}             ;Extended Error Status.
AppPSP          word        ?              ;Application PSP value.
AppDTA          dword       ?              ;Application DTA address.


; The following data is the output record. After storing this data
; to these variables, the TSR writes this data to disk.

month           byte        0
day             byte        0
year            word        0
hour            byte        0
minute          byte        0
second          byte        0
Keystrokes      word        0
RecSize         =           $-month






; MyInt9-       The system calls this routine every time a keyboard
;               interrupt occus. This routine increments the
;               KeyIntCnt variable and then passes control on to the
;               original Int9 handler.

MyInt9          proc        far
                inc         ResidentSeg:KeyIntCnt
                jmp         ResidentSeg:OldInt9
MyInt9          endp




; MyInt1C-      Timer interrupt. This guy counts off 60 seconds and then
;               attempts to write a record to the output file. Of course,
;               this call has to jump through all sorts of hoops to keep
;               from reentering DOS and other problematic code.
```

```
MyInt1C         proc        far
                assume      ds:ResidentSeg

                push        ds
                push        es
                pusha                           ;Save all the registers.
                mov         ax, ResidentSeg
                mov         ds, ax

                pushf
                call        OldInt1C

; First things first, let's bump our interrupt counter so we can count
; off a minute. Since we're getting interrupted about every 54.92549
; milliseconds, let's shoot for a little more accuracy than 18 times
; per second so the timings don't drift too much.

                add         Counter, 549        ;54.9 msec per int 1C.
                cmp         Counter, 10000      ;1 second.
                jb          NotSecYet
                sub         Counter, 10000
                inc         SecCounter
NotSecYet:


; If NEEDIO is not zero, then there is an I/O operation in progress.
; Do not disturb the output values if this is the case.

                cli                             ;This is a critical region.
                cmp         NeedIO, 0
                jne         SkipSetNIO

; Okay, no I/O in progress, see if a minute has passed since the last
; time we logged the keystrokes to the file. If so, it's time to start
; another I/O operation.

                cmp         SecCounter, 60      ;One minute passed yet?
                jb          Int1CDone
                mov         NeedIO, 1           ;Flag need for I/O.
                mov         ax, KeyIntCnt       ;Copy this to the output
                shr         ax, 1               ; buffer after computing
                mov KeyStrokes, ax              ; # of keystrokes.
                mov         KeyIntCnt, 0        ;Reset for next minute.
                mov         SecCounter, 0

SkipSetNIO:     cmp         NeedIO, 1           ;Is the I/O already in
                jne         Int1CDone           ; progress? Or done?

                call        ChkDOSStatus        ;See if DOS/BIOS are free.
                jnc         Int1CDone           ;Branch if busy.

                call        DoIO                ;Do I/O if DOS is free.

Int1CDone:      popa                            ;Restore registers and quit.
                pop         es
                pop         ds
                iret
MyInt1C         endp
                assume      ds:nothing


; MyInt28-      Idle interrupt. If DOS is in a busy-wait loop waiting for
;               I/O to complete, it executes an int 28h instruction each
;               time through the loop. We can ignore the InDOS and CritErr
;               flags at that time, and do the I/O if the other interrupts
;               are free.

MyInt28         proc        far
                assume      ds:ResidentSeg

                push        ds
                push        es
                pusha                           ;Save all the registers.
```

```
              mov      ax, ResidentSeg
              mov      ds, ax

              pushf                      ;Call the next INT 28h
              call     OldInt28          ; ISR in the chain.

              cmp      NeedIO, 1         ;Do we have a pending I/O?
              jne      Int28Done

              mov      al, InInt13       ;See if BIOS is busy.
              or       al, InInt16
              jne      Int28Done

              call     DoIO              ;Go do I/O if BIOS is free.

Int28Done:    popa
              pop      es
              pop      ds
              iret
MyInt28       endp
              assume   ds:nothing


; MyInt16-    This is just a wrapper for the INT 16h (keyboard trap)
;             handler.

MyInt16       proc     far
              inc      ResidentSeg:InInt16

; Call original handler:

              pushf
              call     ResidentSeg:OldInt16

; For INT 16h we need to return the flags that come from the previous call.

              pushf
              dec      ResidentSeg:InInt16
              popf
              retf     2                 ;Fake IRET to keep flags.
MyInt16       endp


; MyInt13-    This is just a wrapper for the INT 13h (disk I/O trap)
;             handler.

MyInt13       proc     far
              inc      ResidentSeg:InInt13
              pushf
              call     ResidentSeg:OldInt13
              pushf
              dec      ResidentSeg:InInt13
              popf
              retf     2                 ;Fake iret to keep flags.
MyInt13       endp


; ChkDOSStatus-        Returns with the carry clear if DOS or a BIOS routine
;                      is busy and we can’t interrupt them.

ChkDOSStatus  proc     near
              assume   ds:ResidentSeg
              les      bx, InDOSFlag
              mov      al, es:[bx]       ;Get InDOS flag.
              or       al, es:[bx-1]     ;OR with CritErr flag.
              or       al, InInt16       ;OR with our wrapper
              or       al, InInt13       ; values.
              je       Okay2Call
              clc
              ret

Okay2Call:    clc
              ret
ChkDOSStatus  endp
```

```
              assume    ds:nothing


; PreserveDOS-Gets a copy’s of DOS’ current PSP, DTA, and extended
;             error information and saves this stuff. Then it sets
;             the PSP to our local PSP and the DTA to PSP:80h.

PreserveDOS   proc      near
              assume    ds:ResidentSeg

              mov       ah, 51h           ;Get app’s PSP.
              int       21h
              mov       AppPSP, bx        ;Save for later

              mov       ah, 2Fh           ;Get app’s DTA.
              int       21h
              mov       word ptr AppDTA, bx
              mov       word ptr AppDTA+2, es

              push      ds
              mov       ah, 59h           ;Get extended err info.
              xor       bx, bx
              int       21h

              mov       cs:XErr.eeDS, ds
              pop       ds
              mov       XErr.eeAX, ax
              mov       XErr.eeBX, bx
              mov       XErr.eeCX, cx
              mov       XErr.eeDX, dx
              mov       XErr.eeSI, si
              mov       XErr.eeDI, di
              mov       XErr.eeES, es

; Okay, point DOS’s pointers at us:

              mov       bx, PSP
              mov       ah, 50h           ;Set PSP.
              int       21h

              push      ds                ;Set the DTA to
              mov       ds, PSP           ; address PSP:80h
              mov       dx, 80h
              mov       ah, 1Ah           ;Set DTA call.
              int       21h
              pop       ds

              ret
PreserveDOS   endp
              assume    ds:nothing



; RestoreDOS- Restores DOS’ important global data values back to the
;             application’s values.

RestoreDOS    proc      near
              assume    ds:ResidentSeg

              mov       bx, AppPSP
              mov       ah, 50h           ;Set PSP
              int       21h

              push      ds
              lds       dx, AppDTA
              mov       ah, 1Ah           ;Set DTA
              int       21h
              pop       ds
              push      ds

              mov       si, offset XErr   ;Saved extended error stuff.
              mov       ax, 5D0Ah         ;Restore XErr call.
              int       21h
              pop       ds
              ret
RestoreDOS    endp
              assume    ds:nothing


; DoIO-       This routine processes each of the I/O operations
;             required to write data to the file.

DoIO          proc      near
              assume    ds:ResidentSeg

              mov       NeedIO, 0FFh      ;A busy flag for us.

; The following Get Date DOS call may take a while, so turn the
; interrupts back on (we're clear of the critical section once we
; write 0FFh to NeedIO).

              sti
              call      PreserveDOS       ;Save DOS data.

              mov       ah, 2Ah           ;Get Date DOS call
              int       21h
              mov       month, dh
              mov       day, dl
              mov       year, cx

              mov       ah, 2Ch           ;Get Time DOS call
              int       21h
              mov       hour, ch
              mov       minute, cl
              mov       second, dh

              mov       ah, 40h           ;DOS Write call
              mov       bx, FileHandle    ;Write data to this file.
              mov       cx, RecSize       ;This many bytes.
              mov       dx, offset month  ;Starting at this address.
              int       21h               ;Ignore return errors (!).
              mov       ah, 68h           ;DOS Commit call
              mov       bx, FileHandle    ;Write data to this file.
              int       21h               ;Ignore return errors (!).

              mov       NeedIO, 0         ;Ready to start over.
              call      RestoreDOS

PhasesDone:   ret
DoIO          endp
              assume    ds:nothing



; MyInt2F-    Provides int 2Fh (multiplex interrupt) support for this
;             TSR. The multiplex interrupt recognizes the following
;             subfunctions (passed in AL):
;
;             00- Verify presence.      Returns 0FFh in AL and a pointer
;                                       to an ID string in es:di if the
;                                       TSR ID (in AH) matches this
;                                       particular TSR.
;
;             01- Remove.               Removes the TSR from memory.
;                                       Returns 0 in AL if successful,
;                                       1 in AL if failure.

MyInt2F       proc      far
              assume    ds:nothing

              cmp       ah, MyTSRID       ;Match our TSR identifier?
              je        YepItsOurs
              jmp       OldInt2F

; Okay, we know this is our ID, now check for a verify vs. remove call.

YepItsOurs:   cmp       al, 0             ;Verify Call
              jne       TryRmv
```

```
                mov     al, 0ffh        ;Return success.
                lesi    IDString
                iret                    ;Return back to caller.

IDString        byte    “Keypress Logger TSR”,0

TryRmv:         cmp     al, 1           ;Remove call.
                jne     IllegalOp

                call    TstRmvable    ;See if we can remove this guy.
                je      CanRemove     ;Branch if we can.
                mov     ax, 1         ;Return failure for now.
                iret

; Okay, they want to remove this guy *and* we can remove it from memory.
; Take care of all that here.

                assume  ds:ResidentSeg

CanRemove:      push    ds
                push    es
                pusha
                cli                     ;Turn off the interrupts while
                mov     ax, 0           ; we mess with the interrupt
                mov     es, ax          ; vectors.
                mov     ax, cs
                mov     ds, ax

                mov     ax, word ptr OldInt9
                mov     es:[9*4], ax
                mov     ax, word ptr OldInt9+2
                mov     es:[9*4 + 2], ax

                mov     ax, word ptr OldInt13
                mov     es:[13h*4], ax
                mov     ax, word ptr OldInt13+2
                mov     es:[13h*4 + 2], ax

                mov     ax, word ptr OldInt16
                mov     es:[16h*4], ax
                mov     ax, word ptr OldInt16+2
                mov     es:[16h*4 + 2], ax

                mov     ax, word ptr OldInt1C
                mov     es:[1Ch*4], ax
                mov     ax, word ptr OldInt1C+2
                mov     es:[1Ch*4 + 2], ax

                mov     ax, word ptr OldInt28
                mov     es:[28h*4], ax
                mov     ax, word ptr OldInt28+2
                mov     es:[28h*4 + 2], ax

                mov     ax, word ptr OldInt2F
                mov     es:[2Fh*4], ax
                mov     ax, word ptr OldInt2F+2
                mov     es:[2Fh*4 + 2], ax


; Okay, with that out of the way, let’s close the file.
; Note: INT 2F shouldn’t have to deal with DOS busy because it’s
; a passive TSR call.

                mov     ah, 3Eh         ;Close file command
                mov     bx, FileHandle
                int     21h

; Okay, one last thing before we quit- Let’s give the memory allocated
; to this TSR back to DOS.

                mov     ds, PSP
                mov     es, ds:[2Ch]    ;Ptr to environment block.
                mov     ah, 49h         ;DOS release memory call.
                int     21h
```

```
              mov       ax, ds           ;Release program code space.
              mov       es, ax
              mov       ah, 49h
              int       21h

              popa
              pop       es
              pop       ds
              mov       ax, 0            ;Return Success.
              iret


; They called us with an illegal subfunction value. Try to do as little
; damage as possible.

IllegalOp:    mov       ax, 0            ;Who knows what they were thinking?
              iret
MyInt2F       endp
              assume    ds:nothing




; TstRmvable- Checks to see if we can remove this TSR from memory.
;             Returns the zero flag set if we can remove it, clear
;             otherwise.

TstRmvable    proc      near
              cli
              push      ds
              mov       ax, 0
              mov       ds, ax

              cmp       word ptr ds:[9*4], offset MyInt9
              jne       TRDone
              cmp       word ptr ds:[9*4 + 2], seg MyInt9
              jne       TRDone

              cmp       word ptr ds:[13h*4], offset MyInt13
              jne       TRDone
              cmp       word ptr ds:[13h*4 + 2], seg MyInt13
              jne       TRDone

              cmp       word ptr ds:[16h*4], offset MyInt16
              jne       TRDone
              cmp       word ptr ds:[16h*4 + 2], seg MyInt16
              jne       TRDone

              cmp       word ptr ds:[1Ch*4], offset MyInt1C
              jne       TRDone
              cmp       word ptr ds:[1Ch*4 + 2], seg MyInt1C
              jne       TRDone

              cmp       word ptr ds:[28h*4], offset MyInt28
              jne       TRDone
              cmp       word ptr ds:[28h*4 + 2], seg MyInt28
              jne       TRDone

              cmp       word ptr ds:[2Fh*4], offset MyInt2F
              jne       TRDone
              cmp       word ptr ds:[2Fh*4 + 2], seg MyInt2F
TRDone:       pop       ds
              sti
              ret
TstRmvable    endp
ResidentSeg   ends



cseg          segment   para public ‘code’
              assume    cs:cseg, ds:ResidentSeg
```

```
; SeeIfPresent-          Checks to see if our TSR is already present in memory.
;                        Sets the zero flag if it is, clears the zero flag if
;                        it is not.

SeeIfPresent  proc       near
              push       es
              push       ds
              push       di
              mov        cx, 0ffh          ;Start with ID 0FFh.
IDLoop:       mov        ah, cl
              push       cx
              mov        al, 0             ;Verify presence call.
              int        2Fh
              pop        cx
              cmp        al, 0             ;Present in memory?
              je         TryNext
              strcmpl
              byte       “Keypress Logger TSR”,0
              je         Success

TryNext:      dec        cl                ;Test USER IDs of 80h..FFh
              js         IDLoop
              cmp        cx, 0             ;Clear zero flag.
Success:      pop        di
              pop        ds
              pop        es
              ret
SeeIfPresent  endp



; FindID-     Determines the first (well, last actually) TSR ID available
;             in the multiplex interrupt chain. Returns this value in
;             the CL register.
;
;             Returns the zero flag set if it locates an empty slot.
;             Returns the zero flag clear if failure.

FindID        proc       near
              push       es
              push       ds
              push       di

              mov        cx, 0ffh          ;Start with ID 0FFh.
IDLoop:       mov        ah, cl
              push       cx
              mov        al, 0             ;Verify presence call.
              int        2Fh
              pop        cx
              cmp        al, 0             ;Present in memory?
              je         Success
              dec        cl                ;Test USER IDs of 80h..FFh
              js         IDLoop
              xor        cx, cx
              cmp        cx, 1             ;Clear zero flag
Success:      pop        di
              pop        ds
              pop        es
              ret
FindID        endp



Main          proc
              meminit

              mov        ax, ResidentSeg
              mov        ds, ax

              mov        ah, 62h           ;Get this program’s PSP
              int        21h               ; value.
              mov        PSP, bx

; Before we do anything else, we need to check the command line
; parameters. We must have either a valid filename or the
; command “remove”. If remove appears on the command line, then remove
; the resident copy from memory using the multiplex (2Fh) interrupt.
; If remove is not on the command line, we’d better have a filename and
; there had better not be a copy already loaded into memory.

              argc
              cmp       cx, 1              ;Must have exactly 1 parm.
              je        GoodParmCnt
              print
              byte      “Usage:”,cr,lf
              byte      “ KeyEval filename”,cr,lf
              byte      “or KeyEval REMOVE”,cr,lf,0
              ExitPgm


; Check for the REMOVE command.

GoodParmCnt:  mov       ax, 1
              argv
              stricmpl
              byte      “REMOVE”,0
              jne       TstPresent

              call      SeeIfPresent
              je        RemoveIt
              print
              byte      “TSR is not present in memory, cannot remove”
              byte      cr,lf,0
              ExitPgm

RemoveIt:     mov       MyTSRID, cl
              printf
              byte      “Removing TSR (ID #%d) from memory...”,0
              dword     MyTSRID

              mov       ah, cl
              mov       al, 1              ;Remove cmd, ah contains ID
              int       2Fh
              cmp       al, 1              ;Succeed?
              je        RmvFailure
              print
              byte      “removed.”,cr,lf,0
              ExitPgm

RmvFailure:   print
              byte      cr,lf
              byte      “Could not remove TSR from memory.”,cr,lf
              byte      “Try removing other TSRs in the reverse order “
              byte      “you installed them.”,cr,lf,0
              ExitPgm



; Okay, see if the TSR is already in memory. If so, abort the
; installation process.

TstPresent:   call      SeeIfPresent
              jne       GetTSRID
              print
              byte      “TSR is already present in memory.”,cr,lf
              byte      “Aborting installation process”,cr,lf,0
              ExitPgm


; Get an ID for our TSR and save it away.

GetTSRID:     call      FindID
              je        GetFileName
              print
              byte      “Too many resident TSRs, cannot install”,cr,lf,0
              ExitPgm
```

```
; Things look cool so far, check the filename and open the file.

GetFileName:  mov       MyTSRID, cl
              printf
              byte      “Keypress logger TSR program”,cr,lf
              byte      “TSR ID = %d”,cr,lf
              byte      “Processing file:”,0
              dword     MyTSRID

              puts
              putcr

              mov       ah, 3Ch           ;Create file command.
              mov       cx, 0             ;Normal file.
              push      ds
              push      es                ;Point ds:dx at name
              pop       ds
              mov       dx, di
              int       21h               ;Open the file
              jnc       GoodOpen
              print
              byte      “DOS error #”,0
              puti
              print
              byte      “ opening file.”,cr,lf,0
              ExitPgm

GoodOpen:     pop       ds
              mov       FileHandle, ax    ;Save file handle.


InstallInts:  print
              byte      “Installing interrupts...”,0


; Patch into the INT 9, 13h, 16h, 1Ch, 28h, and 2Fh interrupt vectors.
; Note that the statements above have made ResidentSeg the current data
; segment, so we can store the old values directly into
; the OldIntxx variables.

              cli                         ;Turn off interrupts!
              mov       ax, 0
              mov       es, ax
              mov       ax, es:[9*4]
              mov       word ptr OldInt9, ax
              mov       ax, es:[9*4 + 2]
              mov       word ptr OldInt9+2, ax
              mov       es:[9*4], offset MyInt9
              mov       es:[9*4+2], seg ResidentSeg

              mov       ax, es:[13h*4]
              mov       word ptr OldInt13, ax
              mov       ax, es:[13h*4 + 2]
              mov       word ptr OldInt13+2, ax
              mov       es:[13h*4], offset MyInt13
              mov       es:[13h*4+2], seg ResidentSeg

              mov       ax, es:[16h*4]
              mov       word ptr OldInt16, ax
              mov       ax, es:[16h*4 + 2]
              mov       word ptr OldInt16+2, ax
              mov       es:[16h*4], offset MyInt16
              mov       es:[16h*4+2], seg ResidentSeg

              mov       ax, es:[1Ch*4]
              mov       word ptr OldInt1C, ax
              mov       ax, es:[1Ch*4 + 2]
              mov       word ptr OldInt1C+2, ax
              mov       es:[1Ch*4], offset MyInt1C
              mov       es:[1Ch*4+2], seg ResidentSeg

              mov       ax, es:[28h*4]
              mov       word ptr OldInt28, ax
              mov       ax, es:[28h*4 + 2]
```

```
                mov       word ptr OldInt28+2, ax
                mov       es:[28h*4], offset MyInt28
                mov       es:[28h*4+2], seg ResidentSeg

                mov       ax, es:[2Fh*4]
                mov       word ptr OldInt2F, ax
                mov       ax, es:[2Fh*4 + 2]
                mov       word ptr OldInt2F+2, ax
                mov       es:[2Fh*4], offset MyInt2F
                mov       es:[2Fh*4+2], seg ResidentSeg
                sti                         ;Okay, ints back on.

; We’re hooked up, the only thing that remains is to terminate and
; stay resident.

                print
                byte      “Installed.”,cr,lf,0


                mov       dx, EndResident   ;Compute size of program.
                sub       dx, PSP
                mov       ax, 3100h         ;DOS TSR command.
                int       21h
Main            endp
cseg            ends

sseg            segment   para stack ‘stack’
stk             db        1024 dup (“stack “)
sseg            ends

zzzzzzseg       segment   para public ‘zzzzzz’
LastBytes       db        16 dup (?)
zzzzzzseg       ends
                end       Main
```

The following is a short little application that reads the data file produced by the above program and produces a simple report of the date, time, and keystrokes:

```
; This program reads the file created by the KEYEVAL.EXE TSR program.
; It displays the log containing dates, times, and number of keystrokes.

                .xlist
                .286
                include   stdlib.a
                includelib stdlib.lib
                .list

dseg            segment   para public ‘data’

FileHandle      word      ?

month           byte      0
day             byte      0
year            word      0
hour            byte      0
minute          byte      0
second          byte      0
KeyStrokes      word      0
RecSize         =         $-month

dseg            ends



cseg            segment   para public ‘code’
                assume    cs:cseg, ds:dseg
```

```
; SeeIfPresent-          Checks to see if our TSR is present in memory.
;                        Sets the zero flag if it is, clears the zero flag if
;                        it is not.

SeeIfPresent  proc       near
              push       es
              push       ds
              pusha
              mov        cx, 0ffh           ;Start with ID 0FFh.
IDLoop:       mov        ah, cl
              push       cx
              mov        al, 0              ;Verify presence call.
              int        2Fh
              pop        cx
              cmp        al, 0              ;Present in memory?
              je         TryNext
              strcmpl
              byte       “Keypress Logger TSR”,0
              je         Success

TryNext:      dec        cl                 ;Test USER IDs of 80h..FFh
              js         IDLoop
              cmp        cx, 0              ;Clear zero flag.
Success:      popa
              pop        ds
              pop        es
              ret
SeeIfPresent  endp



Main          proc
              meminit

              mov        ax, dseg
              mov        ds, ax



              argc
              cmp        cx, 1              ;Must have exactly 1 parm.
              je         GoodParmCnt
              print
              byte       “Usage:”,cr,lf
              byte       “ KEYRPT filename”,cr,lf,0
              ExitPgm



GoodParmCnt:  mov        ax, 1
              argv

              print
              byte       “Keypress logger report program”,cr,lf
              byte       “Processing file:”,0
              puts
              putcr

              mov        ah, 3Dh            ;Open file command.
              mov        al, 0              ;Open for reading.
              push       ds
              push       es                 ;Point ds:dx at name
              pop        ds
              mov        dx, di
              int        21h                ;Open the file
              jnc        GoodOpen
              print
              byte       “DOS error #”,0
              puti
              print
              byte       “ opening file.”,cr,lf,0
              ExitPgm
```

```
GoodOpen:       pop       ds
                mov       FileHandle, ax    ;Save file handle.


; Okay, read the data and display it:

ReadLoop:       mov       ah, 3Fh           ;Read file command
                mov       bx, FileHandle
                mov       cx, RecSize       ;Number of bytes.
                mov       dx, offset month  ;Place to put data.
                int       21h
                jc        ReadError
                test      ax, ax            ;EOF?
                je        Quit

                mov       cx, year
                mov       dl, day
                mov       dh, month
                dtoam
                puts
                free
                print
                byte      “, “,0

                mov       ch, hour
                mov       cl, minute
                mov       dh, second
                mov       dl, 0
                ttoam
                puts
                free
                printf
                byte      “, keystrokes = %d\n”,0
                dword     KeyStrokes
                jmp       ReadLoop

ReadError:      print
                byte      “Error reading file”,cr,lf,0

Quit:           mov       bx, FileHandle
                mov       ah, 3Eh           ;Close file
                int       21h
                ExitPgm

Main            endp
cseg            ends

sseg            segment   para stack ‘stack’
stk             db        1024 dup (“stack “)
sseg            ends

zzzzzzseg       segment   para public ‘zzzzzz’
LastBytes       db        16 dup (?)
zzzzzzseg       ends
                end       Main
```

18.9 Semiresident Programs

A *semiresident* program is one that temporarily loads itself into memory, executes another program (a child process), and then removes itself from memory after the child process terminates. Semiresident programs behave like resident programs while the child executes, but they do not stay in memory once the child terminates.

The main use for semiresident programs is to extend an existing application or *patch* an application[6] (the child process). The nice thing about a semiresident program patch is that it does not have to modify

6. *Patching* a program means to replace certain opcode bytes in the object file. Programmers apply patches to correct bugs or extend a product whose sources are not available.

the application's ".EXE" file directly on the disk. If for some reason the patch fails, you haven't destroyed the '.EXE" file, you've only wiped out the object code in memory.

A semiresident application, like a TSR, has a transient and a resident part. The resident part remains in memory while the child process executes. The transient part initializes the program and then transfers control to the resident part that loads the child application over the resident portion. The transient code patches the interrupt vectors and does all the things a TSR does *except it doesn't issue the TSR command.* Instead, the resident program loads the application into memory and transfers control to that program. When the application returns control to the resident program, it exits to DOS using the standard ExitPgm call (ah=4Ch).

While the application is running, the resident code behaves like any other TSR. Unless the child process is aware of the semiresident program, or the semiresident program patches interrupt vectors the application normally uses, the semiresident program will probably be an active resident program, patching into one or more of the hardware interrupts. Of course, all the rules that apply to active TSRs also apply to active semiresident programs.

The following is a very generic example of s semiresident program. This program, "RUN.ASM", runs the application whose name and command line parameters appear as command line parameters to run. In other words:

```
c:> run pgm.exe parm1 parm2 etc.
```

is equivalent to

```
pgm parm1 parm2 etc.
```

Note that you must supply the ".EXE" or ".COM" extension to the program's filename. This code begins by extracting the program's filename and command line parameters from run's command line. Run builds an exec structure (see "MS-DOS, PC-BIOS, and File I/O" on page 699) and then calls DOS to execute the program. On return, run fixes up the stack and returns to DOS.

```
; RUN.ASM - The barebones semiresident program.
;
;       Usage:
;             RUN <program.exe> <program's command line>
;        or   RUN <program.com> <program's command line>
;
; RUN executes the specified program with the supplied command line parameters.
; At first, this may seem like a stupid program. After all, why not just run
; the program directly from DOS and skip the RUN altogether? Actually, there
; is a good reason for RUN-- It lets you (by modifying the RUN source file)
; set up some environment prior to running the program and clean up that
; environment after the program terminates ("environment" in this sense does
; not necessarily refer to the MS-DOS ENVIRONMENT area).
;
; For example, I have used this program to switch the mode of a TSR prior to
; executing an EXE file and then I restored the operating mode of that TSR
; after the program terminated.
;
; In general, you should create a new version of RUN.EXE (and, presumbably,
; give it a unique name) for each application you want to use this program
; with.
;
;
;----------------------------------------------------------------------------
;
;
; Put these segment definitions 1st because we want the Standard Library
; routines to load last in memory, so they wind up in the transient portion.

CSEG            segment    para public 'CODE'
CSEG            ends
SSEG            segment    para stack 'stack'
SSEG            ends
ZZZZZZSEG       segment    para public 'zzzzzzseg'
ZZZZZZSEG       ends
```

```
; Includes for UCR Standard Library macros.

              include    consts.a
              include stdin.a
              include stdout.a
              include misc.a
              include memory.a
              include    strings.a

              includelib stdlib.lib


CSEG          segment    para public 'CODE'
              assume     cs:cseg, ds:cseg


; Variables used by this program.


; MS-DOS EXEC structure.

ExecStruct    dw         0                  ;Use parent's Environment blk.
              dd         CmdLine            ;For the cmd ln parms.
              dd         DfltFCB
              dd         DfltFCB

DfltFCB       db         3," ",0,0,0,0,0
CmdLine       db         0, 0dh, 126 dup (" ") ;Cmd line for program.
PgmName       dd         ?                  ;Points at pgm name.




Main          proc
              mov        ax, cseg           ;Get ptr to vars segment
              mov        ds, ax

              MemInit                       ;Start the memory mgr.



; If you want to do something before the execution of the command-line
; specified program, here is a good place to do it:



;        -------------------------------------



; Now let's fetch the program name, etc., from the command line and execute
; it.

              argc                          ;See how many cmd ln parms
              or         cx, cx             ; we have.
              jz         Quit               ;Just quit if no parameters.

              mov        ax, 1              ;Get the first parm (pgm name)
              argv
              mov        word ptr PgmName, di;Save ptr to name
              mov        word ptr PgmName+2, es


; Okay, for each word on the command line after the filename, copy
; that word to CmdLine buffer and separate each word with a space,
; just like COMMAND.COM does with command line parameters it processes.

              lea        si, CmdLine+1  ;Index into cmdline.
ParmLoop:     dec        cx
              jz         ExecutePgm

              inc        ax                 ;Point at next parm.
              argv                          ;Get the next parm.
              push      ax
              mov       byte ptr [si], ' ' ;1st item and separator on ln.
              inc       CmdLine
              inc       si
CpyLp:        mov       al, es:[di]
              cmp       al, 0
              je        StrDone
              inc       CmdLine          ;Increment byte cnt
              mov       ds:[si], al
              inc       si
              inc       di
              jmp       CpyLp

StrDone:      mov       byte ptr ds:[si], cr ;In case this is the end.
              pop       ax               ;Get current parm #
              jmp       ParmLoop


; Okay, we've built the MS-DOS execute structure and the necessary
; command line, now let's see about running the program.
; The first step is to free up all the memory that this program
; isn't using. That would be everything from zzzzzzseg on.

ExecutePgm:   mov       ah, 62h          ;Get our PSP value
              int       21h
              mov       es, bx
              mov       ax, zzzzzzseg    ;Compute size of
              sub       ax, bx           ; resident run code.
              mov       bx, ax
              mov       ah, 4ah          ;Release unused memory.
              int       21h

; Warning! No Standard Library calls after this point. We've just
; released the memory that they're sitting in. So the program load
; we're about to do will wipe out the Standard Library code.

              mov       bx, seg ExecStruct
              mov       es, bx
              mov       bx, offset ExecStruct ;Ptr to program record.
              lds       dx, PgmName
              mov       ax, 4b00h        ;Exec pgm
              int       21h

; When we get back, we can't count on *anything* being correct. First, fix
; the stack pointer and then we can finish up anything else that needs to
; be done.

              mov       ax, sseg
              mov       ss, ax
              mov       sp, offset EndStk
              mov       ax, seg cseg
              mov       ds, ax

; Okay, if you have any great deeds to do after the program, this is a
; good place to put such stuff.

;       ------------------------------------

; Return control to MS-DOS

Quit:         ExitPgm
Main          endp
cseg          ends

sseg          segment   para stack 'stack'
              dw        128 dup (0)
endstk        dw        ?
sseg          ends

; Set aside some room for the heap.

zzzzzzseg     segment   para public 'zzzzzzseg'
Heap          db        200h dup (?)
```

```
zzzzzzseg       ends

                end         Main
```

Since RUN.ASM is rather simple perhaps a more complex example is in order. The following is a fully functional patch for the Lucasart's game XWING™. The motivation for this patch can about because of the annoyance of having to look up a password everytime you play the game. This little patch searches for the code that calls the password routine and stores NOPs over that code in memory.

The operation of this code is a little different than that of RUN.ASM. The RUN program sends an execute command to DOS that runs the desired program. All system changes RUN needs to make must be made before or after the application executes. XWPATCH operates a little differently. It loads the XWING.EXE program into memory and searches for some specific code (the call to the password routine). Once it finds this code, it stores NOP instructions over the top of the call.

Unfortunately, life isn't quite that simple. When XWING.EXE loads, the password code isn't yet present in memory. XWING loads that code as an overlay later on. So the XWPATCH program finds something that XWING.EXE does load into memory right away – the joystick code. XWPATCH patches the joystick code so that any call to the joystick routine (when detecting or calibrating the joystick) produces a call to XWPATCH's code that searches for the password code. Once XWPATCH locates and NOPs out the call to the password routine, it restores the code in the joystick routine. From that point forward, XWPATCH is simply taking up memory space; XWING will never call it again until XWING terminates.

```
; XWPATCH.ASM
;
;       Usage:
;               XWPATCH    - must be in same directory as XWING.EXE
;
; This program executes the XWING.EXE program and patches it to avoid
; having to enter the password every time you run it.
;
; This program is intended for educational purposes only.
; It is a demonstration of how to write a semiresident program.
; It is not intended as a device to allow the piracy of commercial software.
; Such use is illegal and is punishable by law.
;
; This software is offered without warranty or any expectation of
; correctness. Due to the dynamic nature of software design, programs
; that patch other programs may not work with slight changes in the
; patched program (XWING.EXE). USE THIS CODE AT YOUR OWN RISK.
;
;----------------------------------------------------------------------------


byp             textequ    <byte ptr>
wp              textequ    <word ptr>

; Put these segment definitions here so the UCR Standard Library will
; load after zzzzzzseg (in the transient section).

cseg            segment para public 'CODE'
cseg            ends

sseg            segment    para stack 'STACK'
sseg            ends

zzzzzzseg       segment    para public 'zzzzzzseg'
zzzzzzseg       ends

                .286
                include        stdlib.a
                includelib stdlib.lib


CSEG            segment    para public 'CODE'
```

```
              assume     cs:cseg, ds:nothing


; CountJSCalls-Number of times xwing calls the Joystick code before
; we patch out the password call.

CountJSCalls  dw         250


; PSP-   Program Segment Prefix. Needed to free up memory before running
;        the real application program.

PSP           dw         0



; Program Loading data structures (for DOS).

ExecStruct    dw         0                 ;Use parent’s Environment blk.
              dd         CmdLine           ;For the cmd ln parms.
              dd         DfltFCB
              dd         DfltFCB
LoadSSSP      dd         ?
LoadCSIP      dd         ?
PgmName       dd         Pgm

DfltFCB       db         3,” “,0,0,0,0,0
CmdLine       db         2, “ “, 0dh, 16 dup (“ “);Cmd line for program
Pgm           db         “XWING.EXE”,0


;****************************************************************************
; XWPATCH begins here. This is the memory resident part. Only put code
; which which has to be present at run-time or needs to be resident after
; freeing up memory.
;****************************************************************************

Main          proc
              mov        cs:PSP, ds
              mov        ax, cseg          ;Get ptr to vars segment
              mov        ds, ax

              mov        ax, zzzzzzseg
              mov        es, ax
              mov        cx, 1024/16
              meminit2


; Now, free up memory from ZZZZZZSEG on to make room for XWING.
; Note: Absolutely no calls to UCR Standard Library routines from
; this point forward! (ExitPgm is okay, it’s just a macro which calls DOS.)
; Note that after the execution of this code, none of the code & data
; from zzzzzzseg on is valid.

              mov        bx, zzzzzzseg
              sub        bx, PSP
              inc        bx
              mov        es, PSP
              mov        ah, 4ah
              int        21h
              jnc        GoodRealloc

; Okay, I lied. Here’s a StdLib call, but it’s okay because we failed
; to load the application over the top of the standard library code.
; But from this point on, absolutely no more calls!

              print
              byte       “Memory allocation error.”
              byte       cr,lf,0
              jmp        Quit

GoodRealloc:

; Now load the XWING program into memory:
```

```
              mov       bx, seg ExecStruct
              mov       es, bx
              mov       bx, offset ExecStruct ;Ptr to program record.
              lds       dx, PgmName
              mov       ax, 4b01h         ;Load, do not exec, pgm
              int       21h
              jc        Quit              ;If error loading file.

; Unfortunately, the password code gets loaded dynamically later on.
; So it's not anywhere in memory where we can search for it. But we
; do know that the joystick code is in memory, so we'll search for
; that code. Once we find it, we'll patch it so it calls our SearchPW
; routine. Note that you must use a joystick (and have one installed)
; for this patch to work properly.

              mov       si, zzzzzzseg
              mov       ds, si
              xor       si, si

              mov       di, cs
              mov       es, di
              mov       di, offset JoyStickCode
              mov       cx, JoyLength
              call      FindCode
              jc        Quit              ;If didn't find joystick code.


; Patch the XWING joystick code here

              mov       byp ds:[si], 09ah;Far call
              mov       wp ds:[si+1], offset SearchPW
              mov       wp ds:[si+3], cs

; Okay, start the XWING.EXE program running

              mov       ah, 62h           ;Get PSP
              int       21h
              mov       ds, bx
              mov       es, bx
              mov       wp ds:[10], offset Quit
              mov       wp ds:[12], cs
              mov       ss, wp cseg:LoadSSSP+2
              mov       sp, wp cseg:LoadSSSP
              jmp       dword ptr cseg:LoadCSIP


Quit:         ExitPgm
Main          endp


; SearchPW gets call from XWING when it attempts to calibrate the joystick.
; We'll let XWING call the joystick several hundred times before we
; actually search for the password code. The reason we do this is because
; XWING calls the joystick code early on to test for the presence of a
; joystick. Once we get into the calibration code, however, it calls
; the joystick code repetitively, so a few hundred calls doesn't take
; very long to expire. Once we're in the calibration code, the password
; code has been loaded into memory, so we can search for it then.

SearchPW      proc      far
              cmp       cs:CountJSCalls, 0
              je        DoSearch
              dec       cs:CountJSCalls
              sti                         ;Code we stole from xwing for
              neg       bx                ; the patch.
              neg       di
              ret

; Okay, search for the password code.

DoSearch:     push      bp
              mov       bp, sp
              push      ds
```

```
                push        es
                pusha

; Search for the password code in memory:

                mov         si, zzzzzzseg
                mov         ds, si
                xor         si, si

                mov         di, cs
                mov         es, di
                mov         di, offset PasswordCode
                mov         cx, PWLength
                call        FindCode
                jc          NotThere          ;If didn't find pw code.


; Patch the XWING password code here. Just store NOPs over the five
; bytes of the far call to the password routine.

                mov         byp ds:[si+11], 090h            ;NOP out a far call
                mov         byp ds:[si+12], 090h
                mov         byp ds:[si+13], 090h
                mov         byp ds:[si+14], 090h
                mov         byp ds:[si+15], 090h

; Adjust the return address and restore the patched joystick code so
; that it doesn't bother jumping to us anymore.

NotThere:       sub         word ptr [bp+2], 5 ;Back up return address.
                les         bx, [bp+2]        ;Fetch return address.

; Store the original joystick code over the call we patched to this
; routine.

                mov         ax, word ptr JoyStickCode
                mov         es:[bx], ax
                mov         ax, word ptr JoyStickCode+2
                mov         es:[bx+2], ax
                mov         al, byte ptr JoyStickCode+4
                mov         es:[bx+4], al

                popa
                pop         es
                pop         ds
                pop         bp
                ret
SearchPW        endp

;****************************************************************************
;
; FindCode: On entry, ES:DI points at some code in *this* program which
;         appears in the XWING game. DS:SI points at a block of memory
;         in the XWING game. FindCode searches through memory to find the
;         suspect piece of code and returns DS:SI pointing at the start of
;         that code. This code assumes that it *will* find the code!
;         It returns the carry clear if it finds it, set if it doesn't.

FindCode        proc        near
                push        ax
                push        bx
                push        dx

DoCmp:          mov         dx, 1000h         ;Search in 4K blocks.
CmpLoop:        push        di                ;Save ptr to compare code.
                push        si                ;Save ptr to start of string.
                push        cx                ;Save count.
        repe    cmpsb
                pop         cx
                pop         si
                pop         di
                je          FoundCode
                inc         si
                dec         dx
```

```
              jne       CmpLoop
              sub       si, 1000h
              mov       ax, ds
              inc       ah
              mov       ds, ax
              cmp       ax, 9000h          ;Stop at address 9000:0
              jb        DoCmp              ; and fail if not found.

              pop       dx
              pop       bx
              pop       ax
              stc
              ret

FoundCode:    pop       dx
              pop       bx
              pop       ax
              clc
              ret
FindCode      endp


;****************************************************************************
;
; Call to password code that appears in the XWING game. This is actually
; data that we're going to search for in the XWING object code.

PasswordCode  proc      near
              call      $+47h
              mov       [bp-4], ax
              mov       [bp-2], dx
              push      dx
              push      ax
              byte      9ah, 04h, 00
PasswordCode  endp
EndPW:

PWLength      =         EndPW-PasswordCode


; The following is the joystick code we're going to search for.

JoyStickCode  proc      near
              sti
              neg       bx
              neg       di
              pop       bp
              pop       dx
              pop       cx
              ret
              mov       bp, bx
              in        al, dx
              mov       bl, al
              not       al
              and       al, ah
              jnz       $+11h
              in        al, dx
JoyStickCode  endp
EndJSC:

JoyLength     =         EndJSC-JoyStickCode
cseg          ends

sseg          segment   para stack 'STACK'
              dw        256 dup (0)
endstk        dw        ?
sseg          ends

zzzzzzseg     segment   para public 'zzzzzzseg'
Heap          db        1024 dup (0)
zzzzzzseg     ends
              end       Main
```

18.10 Summary

Resident programs provide a small amount of multitasking to DOS' single tasking world. DOS provides support for resident programs through a rudimentary memory management system. When an application issues the terminate and stay resident call, DOS adjusts its memory pointers so the memory space reserved by the TSR code is protected from future program loading operations. For more information on how this process works, see

- "DOS Memory Usage and TSRs" on page 1025

TSRs come in two basic forms: active and passive. Passive TSRs are not self-activating. A foreground application must call a routine in a passive TSR to activate it. Generally, an application interfaces to a passive TSR using the 80x86 trap mechanism (software interrupts). Active TSRs, on the other hand, do not rely on the foreground application for activation. Instead, they attach themselves to a hardware interrupt that activates them independently of the foreground process. For more information, see

- "Active vs. Passive TSRs" on page 1029

The nature of an active TSR introduces many compatibility problems. The primary problem is that an active TSR might want to call a DOS or BIOS routine after having just interrupted either of these systems. This creates problems because DOS and BIOS are not *reentrant*. Fortunately, MS-DOS provides some hooks that give active TSRs the ability to schedule DOS calls with DOS is inactive. Although the BIOS routines do not provide this same facility, it is easy to add a *wrapper* around a BIOS call to let you schedule calls appropriately. One additional problem with DOS is that an active TSR might disturb some global variable in use by the foreground process. Fortunately, DOS lets the TSR save and restore these values, preventing some nasty compatibility problems. For details, see

- "Reentrancy" on page 1032
- "Reentrancy Problems with DOS" on page 1032
- "Reentrancy Problems with BIOS" on page 1033
- "Reentrancy Problems with Other Code" on page 1034
- "Other DOS Related Issues" on page 1039

MS-DOS provides a special interrupt to coordinate communication between TSRs and other applications. The *multiplex* interrupt lets you easily check for the presence of a TSR in memory, remove a TSR from memory, or pass various information between the TSR and an active application. For more information, see

- "The Multiplex Interrupt (INT 2Fh)" on page 1034

Well written TSRs follow stringent rules. In particular, a good TSR follows certain conventions during installation and always provide the user with a safe removal mechanism that frees all memory in use by the TSR. In those rare cases where a TSR cannot remove itself, it always reports an appropriate error and instructs the user how to solve the problem. For more information on load and removing TSRs, see

- "Installing a TSR" on page 1035
- "Removing a TSR" on page 1037
- "A Keyboard Monitor TSR" on page 1041

A semiresident routine is one that is resident during the execution of some specific program. It automatically unloads itself when that application terminates. Semiresident applications find application as program patchers and "time-release TSRs." For more information on semiresident programs, see

- "Semiresident Programs" on page 1055