The PC Keyboard Chapter 20

The PC's keyboard is the primary human input device on the system. Although it seems rather mundane, the keyboard is the primary input device for most software, so learning how to program the keyboard properly is very important to application developers.

IBM and countless keyboard manufacturers have produced numerous keyboards for PCs and compatibles. Most modern keyboards provide at least 101 different keys and are reasonably compatible with the IBM PC/AT 101 Key Enhanced Keyboard. Those that do provide extra keys generally program those keys to emit a sequence of other keystrokes or allow the user to program a sequence of keystrokes on the extra keys. Since the 101 key keyboard is ubiquitous, we will assume its use in this chapter.

When IBM first developed the PC, they used a very simple interface between the keyboard and the computer. When IBM introduced the PC/AT, they completely redesigned the keyboard interface. Since the introduction of the PC/AT, almost every keyboard has conformed to the PC/AT standard. Even when IBM introduced the PS/2 systems, the changes to the keyboard interface were minor and upwards compatible with the PC/AT design. Therefore, this chapter will also limit its attention to PC/AT compatible devices since so few PC/XT keyboards and systems are still in use.

There are five main components to the keyboard we will consider in this chapter – basic keyboard information, the DOS interface, the BIOS interface, the int 9 keyboard interrupt service routine, and the hardware interface to the keyboard. The last section of this chapter will discuss how to fake keyboard input into an application.

20.1 Keyboard Basics

The PC's keyboard is a computer system in its own right. Buried inside the keyboards case is an 8042 microcontroller chip that constantly scans the switches on the keyboard to see if any keys are down. This processing goes on in parallel with the normal activities of the PC, hence the keyboard never misses a keystroke because the 80x86 in the PC is busy.

A typical keystroke starts with the user pressing a key on the keyboard. This closes an electrical contact in the switch so the microcontroller and sense that you've pressed the switch. Alas, switches (being the mechanical things that they are) do not always close (make contact) so cleanly. Often, the contacts bounce off one another several times before coming to rest making a solid contact. If the microcontroller chip reads the switch constantly, these bouncing contacts will look like a very quick series of key presses and releases. This could generate *multiple* keystrokes to the main computers, a phenomenon known as *keybounce*, common to many cheap and old keyboards. But even on the most expensive and newest keyboards, keybounce is a problem if you look at the switch a million times a second; mechanical switches simply cannot settle down that quickly. Most keyboard scanning algorithms, therefore, control how often they scan the keyboard. A typical inexpensive key will settle down within five milliseconds, so if the keyboard scanning software only looks at the key every ten milliseconds, or so, the controller will effectively miss the keybounce[1].

Simply noting that a key is pressed is not sufficient reason to generate a key code. A user may hold a key down for many tens of milliseconds before releasing it. The keyboard controller must not generate a new key sequence every time it scans the keyboard and finds a key held down. Instead, it should generate a single key code value when the key goes from an up position to the down position (a *down key* operation). Upon detecting a down key stroke, the microcontroller sends a keyboard *scan code* to the PC. The scan code is *not* related to the ASCII code for that key, it is an arbitrary value IBM chose when they first developed the PC's keyboard.

1. A typical user cannot type 100 characters/sec nor reliably press a key for less than 1/50th of a second, so scanning the keyboard at 10 msec intervals will not lose any keystrokes.

The PC keyboard actually generates *two* scan codes for every key you press. It generates a *down code* when you press a key and an *up code* when you release the key. The 8042 microcontroller chip transmits these scan codes to the PC where they are processed by the keyboard's interrupt service routine. Having separate up and down codes is important because certain keys (like shift, control, and alt) are only meaningful when held down. By generating up codes for all the keys, the keyboard ensures that the keyboard interrupt service routine knows which keys are pressed while the user is holding down one of these *modifier* keys. The following table lists the scan codes that the keyboard microcontroller transmits to the PC:

Table 72: PC Keyboard Scan Codes (in hex)

Key	Down	Up	Key	Down	Up	Key	Down	Up	Key	Down	Up
Esc	1	81	[{	1A	9A	, <	33	B3	***center***	4C	CC
1 !	2	82	] }	1B	9B	. >	34	B4	***right***	4D	CD
2 @	3	83	Enter	1C	9C	/ ?	35	B5	**+**	4E	CE
3 #	4	84	Ctrl	1D	9D	R shift	36	B6	***end***	4F	CF
4 $	5	85	A	1E	9E	* PrtSc	37	B7	***down***	50	D0
5 %	6	86	S	1F	9F	alt	38	B8	***pgdn***	51	D1
6 ^	7	87	D	20	A0	space	39	B9	***ins***	52	D2
7 &	8	88	F	21	A1	CAPS	3A	BA	***del***	53	D3
8 *	9	89	G	22	A2	F1	3B	BB	/	E0 35	B5
9 (	0A	8A	H	23	A3	F2	3C	BC	***enter***	E0 1C	9C
0)	0B	8B	J	24	A4	F3	3D	BD	F11	57	D7
- _	0C	8C	K	25	A5	F4	3E	BE	F12	58	D8
= +	0D	8D	L	26	A6	F5	3F	BF	ins	E0 52	D2
Bksp	0E	8E	; :	27	A7	F6	40	C0	del	E0 53	D3
Tab	0F	8F	' "	28	A8	F7	41	C1	home	E0 47	C7
Q	10	90	` ~	29	A9	F8	42	C2	end	E0 4F	CF
W	11	91	L shift	2A	AA	F9	43	C3	pgup	E0 49	C9
E	12	92	\ |	2B	AB	F10	44	C4	pgdn	E0 51	D1
R	13	93	Z	2C	AC	NUM	45	C5	left	E0 4B	CB
T	14	94	X	2D	AD	SCRL	46	C6	right	E0 4D	CD
Y	15	95	C	2E	AE	***home***	47	C7	up	E0 48	C8
U	16	96	V	2F	AF	***up***	48	C8	down	E0 50	D0
I	17	97	B	30	B0	***pgup***	49	C9	R alt	E0 38	B8
O	18	98	N	31	B1	**-**	4A	CA	R ctrl	E0 1D	9D
P	19	99	M	32	B2	***left***	4B	CB	Pause	E1 1D 45 E1 9D C5	-

The keys in italics are found on the numeric keypad. Note that certain keys transmit two or more scan codes to the system. The keys that transmit more than one scan code were new keys added to the keyboard when IBM designed the 101 key enhanced keyboard.

When the scan code arrives at the PC, a second microcontroller chip receives the scan code, does a conversion on the scan code[2], makes the scan code available at I/O port 60h, and then interrupts the processor and leaves it up to the keyboard ISR to fetch the scan code from the I/O port.

The keyboard (int 9) interrupt service routine reads the scan code from the keyboard input port and processes the scan code as appropriate. Note that the scan code the system receives from the keyboard microcontroller is a single value, even though some keys on the keyboard represent up to four different values. For example, the "A" key on the keyboard can produce A, a, ctrl-A, or alt-A. The actual code the system yields depends upon the current state of the modifier keys (shift, ctrl, alt, capslock, and numlock). For example, if an A key scan code comes along (1Eh) and the shift key is down, the system produces the ASCII code for an uppercase A. If the user is pressing *multiple* modifier keys the system prioritizes them from low to high as follows:

- No modifier key down
- Numlock/Capslock (same precedence, lowest priority)
- shift
- ctrl
- alt (highest priority)

Numlock and capslock affect different sets of keys[3], so there is no ambiguity resulting from their equal precedence in the above chart. If the user is pressing two modifier keys at the same time, the system only recognizes the modifier key with the highest priority above. For example, if the user is pressing the ctrl and alt keys at the same time, the system only recognizes the alt key. The numlock, capslock, and shift keys are a special case. If numlock or capslock is active, pressing the shift key makes it inactive. Likewise, if numlock or capslock is inactive, pressing the shift key effectively "activates" these modifiers.

Not all modifiers are legal for every key. For example, ctrl-8 is not a legal combination. The keyboard interrupt service routine ignores all keypresses combined with illegal modifier keys. For some unknown reason, IBM decided to make certain key combinations legal and others illegal. For example, ctrl-left and ctrl-right are legal, but ctrl-up and ctrl-down are not. You'll see how to fix this problem a little later.

The shift, ctrl, and alt keys are *active* modifiers. That is, modification to a keypress occurs only while the user holds down one of these modifier keys. The keyboard ISR keeps track of whether these keys are down or up by setting an associated bit upon receiving the down code and clearing that bit upon receiving the up code for shift, ctrl, or alt. In contrast, the numlock, scroll lock, and capslock keys are *toggle* modifiers[4]. The keyboard ISR inverts an associated bit every time it sees a down code followed by an up code for these keys.

Most of the keys on the PC's keyboard correspond to ASCII characters. When the keyboard ISR encounters such a character, it translates it to a 16 bit value whose L.O. byte is the ASCII code and the H.O. byte is the key's scan code. For example, pressing the "A" key with no modifier, with shift, and with control produces 1E61h, 1E41h, and 1E01h, respectively ("a", "A", and ctrl-A). Many key sequences do not have corresponding ASCII codes. For example, the function keys, the cursor control keys, and the alt key sequences do not have corresponding ASCII codes. For these special *extended* code, the keyboard ISR stores a zero in the L.O. byte (where the ASCII code typically goes) and the extended code goes in the H.O. byte. The extended code is usually, though certainly not always, the scan code for that key.

The only problem with this extended code approach is that the value zero is a legal ASCII character (the NUL character). Therefore, you cannot directly enter NUL characters into an application. If an application must input NUL characters, IBM has set aside the extended code 0300h (ctrl-3) for this purpose. You application must explicitly convert this extended code to the NUL character (actually, it need only recog-

2. The keyboard doesn't actually transmit the scan codes appearing in the previous table. Instead, it transmits its own scan code that the PC's microcontroller translates to the scan codes in the table. Since the programmer never sees the native scan codes so we will ignore them.
3. Numlock only affects the keys on the numeric keypad, capslock only affects the alphabetic keys.
4. It turns out the INS key is also a toggle modifier, since it toggles a bit in the BIOS variable area. However, INS also returns a scan code, the other modifiers do not.

nize the H.O. value 03, since the L.O. byte already is the NUL character). Fortunately, very few programs need to allow the input of the NUL character from the keyboard, so this problem is rarely an issue.

The following table lists the scan and extended key codes the keyboard ISR generates for applications in response to a keypress with various modifiers. Extended codes are in italics. All other values (except the scan code column) represent the L.O. eight bits of the 16 bit code. The H.O. byte comes from the scan code column.

Table 73: Keyboard Codes (in hex)

Key	Scan Code	ASCII	Shift[a]	Ctrl	Alt	Num	Caps	Shift Caps	Shift Num
Esc	01	1B	1B	1B		1B	1B	1B	1B
1 !	02	31	21		***7800***	31	31	31	31
2 @	03	32	40	***0300***	***7900***	32	32	32	32
3 #	04	33	23		***7A00***	33	33	33	33
4 $	05	34	24		***7B00***	34	34	34	34
5 %	06	35	25		***7C00***	35	35	35	35
6 ^	07	36	5E	1E	***7D00***	36	36	36	36
7 &	08	37	26		***7E00***	37	37	37	37
8 *	09	38	2A		***7F00***	38	38	38	38
9 (	0A	39	28		***8000***	39	39	39	39
0)	0B	30	29		***8100***	30	30	30	30
- _	0C	2D	5F	1F	***8200***	2D	2D	5F	5F
= +	0D	3D	2B		***8300***	3D	3D	2B	2B
Bksp	0E	08	08	7F		08	08	08	08
Tab	0F	09	***0F00***			09	09	***0F00***	***0F00***
Q	10	71	51	11	***1000***	71	51	71	51
W	11	77	57	17	***1100***	77	57	77	57
E	12	65	45	05	***1200***	65	45	65	45
R	13	72	52	12	***1300***	72	52	72	52
T	14	74	54	14	***1400***	74	54	74	54
Y	15	79	59	19	***1500***	79	59	79	59
U	16	75	55	15	***1600***	75	55	75	55
I	17	69	49	09	***1700***	69	49	69	49
O	18	6F	4F	0F	***1800***	6F	4F	6F	4F
P	19	70	50	10	***1900***	70	50	70	50
[{	1A	5B	7B	1B		5B	5B	7B	7B
] }	1B	5D	7D	1D		5D	5D	7D	7D
enter	1C	0D	0D	0A		0D	0D	0A	0A
ctrl	1D								
A	1E	61	41	01	***1E00***	61	41	61	41
S	1F	73	53	13	***1F00***	73	53	73	53
D	20	64	44	04	***2000***	64	44	64	44
F	21	66	46	06	***2100***	66	46	66	46
G	22	67	47	07	***2200***	67	47	67	47
H	23	68	48	08	***2300***	68	48	68	48
J	24	6A	4A	0A	***2400***	6A	4A	6A	4A
K	25	6B	4B	0B	***2500***	6B	4B	6B	4B
L	26	6C	4C	0C	***2600***	6C	4C	6C	4C
; :	27	3B	3A			3B	3B	3A	3A
‘ “	28	27	22			27	27	22	22
Key	Scan Code	ASCII	Shift	Ctrl	Alt	Num	Caps	Shift Caps	Shift Num

Table 73: Keyboard Codes (in hex)

Key	Scan Code	ASCII	Shift[a]	Ctrl	Alt	Num	Caps	Shift Caps	Shift Num
` ~	29	60	7E			60	60	7E	7E
Lshift	2A								
\ |	2B	5C	7C	1C		5C	5C	7C	7C
Z	2C	7A	5A	1A	***2C00***	7A	5A	7A	5A
X	2D	78	58	18	***2D00***	78	58	78	58
C	2E	63	43	03	***2E00***	63	43	63	43
V	2F	76	56	16	***2F00***	76	56	76	56
B	30	62	42	02	***3000***	62	42	62	42
N	31	6E	4E	0E	***3100***	6E	4E	6E	4E
M	32	6D	4D	0D	***3200***	6D	4D	6D	4D
, <	33	2C	3C			2C	2C	3C	3C
. >	34	2E	3E			2E	2E	3E	3E
/ ?	35	2F	3F			2F	2F	3F	3F
Rshift	36								
* PrtSc	37	2A	INT 5[b]	10[c]		2A	2A	INT 5	INT 5
alt	38								
space	39	20	20	20		20	20	20	20
caps	3A								
F1	3B	***3B00***	***5400***	***5E00***	***6800***	***3B00***	***3B00***	***5400***	***5400***
F2	3C	***3C00***	***5500***	***5F00***	***6900***	***3C00***	***3C00***	***5500***	***5500***
F3	3D	***3D00***	***5600***	***6000***	***6A00***	***3D00***	***3D00***	***5600***	***5600***
F4	3E	***3E00***	***5700***	***6100***	***6B00***	***3E00***	***3E00***	***5700***	***5700***
F5	3F	***3F00***	***5800***	***6200***	***6C00***	***3F00***	***3F00***	***5800***	***5800***
F6	40	***4000***	***5900***	***6300***	***6D00***	***4000***	***4000***	***5900***	***5900***
F7	41	***4100***	***5A00***	***6400***	***6E00***	***4100***	***4100***	***5A00***	***5A00***
F8	42	***4200***	***5B00***	***6500***	***6F00***	***4200***	***4200***	***5B00***	***5B00***
F9	43	***4300***	***5C00***	***6600***	***7000***	***4300***	***4300***	***5C00***	***5C00***
F10	44	***4400***	***5D00***	***6700***	***7100***	***4400***	***4400***	***5D00***	***5D00***
num	45								
scrl	46								
home	47	***4700***	37	***7700***		37	4700	37	4700
up	48	***4800***	38			38	4800	38	4800
pgup	49	***4900***	39	***8400***		39	4900	39	4900
-[d]	4A	2D	2D			2D	2D	2D	2D
left	4B	***4B00***	34	***7300***		34	4B00	34	4B00
center	4C	***4C00***	35			35	4C00	35	4C00
right	4D	***4D00***	36	***7400***		36	4D00	36	4D00
+[e]	4E	2B	2B			2B	2B	2B	2B
end	4F	***4F00***	31	***7500***		31	4F00	31	4F00
down	50	***5000***	32			32	5000	32	5000
pgdn	51	***5100***	33	***7600***		33	5100	33	5100
ins	52	***5200***	30			30	5200	30	5200
del	53	***5300***	2E			2E	5300	2E	5300
Key	Scan Code	ASCII	Shift	Ctrl	Alt	Num	Caps	Shift Caps	Shift Num

a. For the alphabetic characters, if capslock is active then see the shift-capslock column.
b. Pressing the PrtSc key does not produce a scan code. Instead, BIOS executes an int 5 instruction which should print the screen.
c. This is the control-P character that will activate the printer under MS-DOS.
d. This is the minus key on the keypad.
e. This is the plus key on the keypad.

The 101-key keyboards generally provide an enter key and a "/" key on the numeric keypad. Unless you write your own int 9 keyboard ISR, you will not be able to differentiate these keys from the ones on the main keyboard. The separate cursor control pad also generates the same extended codes as the numeric keypad, except it never generates numeric ASCII codes. Otherwise, you cannot differentiate these keys from the equivalent keys on the numeric keypad (assuming numlock is off, of course).

The keyboard ISR provides a special facility that lets you enter the ASCII code for a keystroke directly from the keyboard. To do this, hold down the alt key and typing out the *decimal* ASCII code (0..255) for a character on the numeric keypad. The keyboard ISR will convert these keystrokes to an eight-bit value, attach at H.O. byte of zero to the character, and use that as the character code.

The keyboard ISR inserts the 16 bit value into the PC's *type ahead buffer*. The system type ahead buffer is a circular queue that uses the following variables

```
40:1A -  HeadPtr word ?
40:1C -  TailPtr word ?
40:1E -  Buffer  word 16 dup (?)
```

The keyboard ISR inserts data at the location pointed at by `TailPtr`. The BIOS keyboard function removes characters from the location pointed at by the `HeadPtr` variable. These two pointers almost always contain an offset into the `Buffer` array[5]. If these two pointers are equal, the type ahead buffer is empty. If the value in `HeadPtr` is two greater than the value in `TailPtr` (or `HeadPtr` is 1Eh and `TailPtr` is 3Ch), then the buffer is full and the keyboard ISR will reject any additional keystrokes.

Note that the `TailPtr` variable always points at the next available location in the type ahead buffer. Since there is no "count" variable providing the number of entries in the buffer, we must always leave one entry free in the buffer area; this means the type ahead buffer can only hold 15 keystrokes, not 16.

In addition to the type ahead buffer, the BIOS maintains several other keyboard-related variables in segment 40h. The following table lists these variables and their contents:

Table 74: Keyboard Related BIOS Variables

Name	Address[a]	Size	Description
KbdFlags1 (modifier flags)	40:17	Byte	This byte maintains the current status of the modifier keys on the keyboard. The bits have the following meanings: bit 7: Insert mode toggle bit 6: Capslock toggle (1=capslock on) bit 5: Numlock toggle (1=numlock on) bit 4: Scroll lock toggle (1=scroll lock on) bit 3: Alt key (1=alt is down) bit 2: Ctrl key (1=ctrl is down) bit 1: Left shift key (1=left shift is down) bit 0: Right shift key (1=right shift is down)

5. It is possible to change these pointers so they point elsewhere in the 40H segment, but this is not a good idea because many applications assume that these two pointers contain a value in the range 1Eh..3Ch.

Table 74: Keyboard Related BIOS Variables

Name	Address[a]	Size	Description
KbdFlags2 (Toggle keys down)	40:18	Byte	Specifies if a toggle key is currently down. bit 7: Insert key (currently down if 1) bit 6: Capslock key (currently down if 1) bit 5: Numlock key (currently down if 1) bit 4: Scroll lock key (currently down if 1) bit 3: Pause state locked (ctrl-Numlock) if one bit 2: SysReq key (currently down if 1) bit 1: Left alt key (currently down if 1) bit 0: Left ctrl key (currently down if 1)
AltKpd	40:19	Byte	BIOS uses this to compute the ASCII code for an alt--Keypad sequence.
BufStart	40:80	Word	Offset of start of keyboard buffer (1Eh). Note: this variable is not supported on many systems, be careful if you use it.
BufEnd	40:82	Word	Offset of end of keyboard buffer (3Eh). See the note above.
KbdFlags3	40:96	Byte	Miscellaneous keyboard flags. bit 7: Read of keyboard ID in progress bit 6: Last char is first kbd ID character bit 5: Force numlock on reset bit 4: 1 if 101-key kbd, 0 if 83/84 key kbd. bit 3: Right alt key pressed if 1 bit 2: Right ctrl key pressed if 1 bit 1: Last scan code was E0h bit 0: Last scan code was E1h
KbdFlags4	40:97	Byte	More miscellaneous keyboard flags. bit 7: Keyboard transmit error bit 6: Mode indicator update bit 5: Resend receive flag bit 4: Acknowledge received bit 3: Must always be zero bit 2: Capslock LED (1=on) bit 1: Numlock LED (1=on) bit 0: Scroll lock LED (1=on)

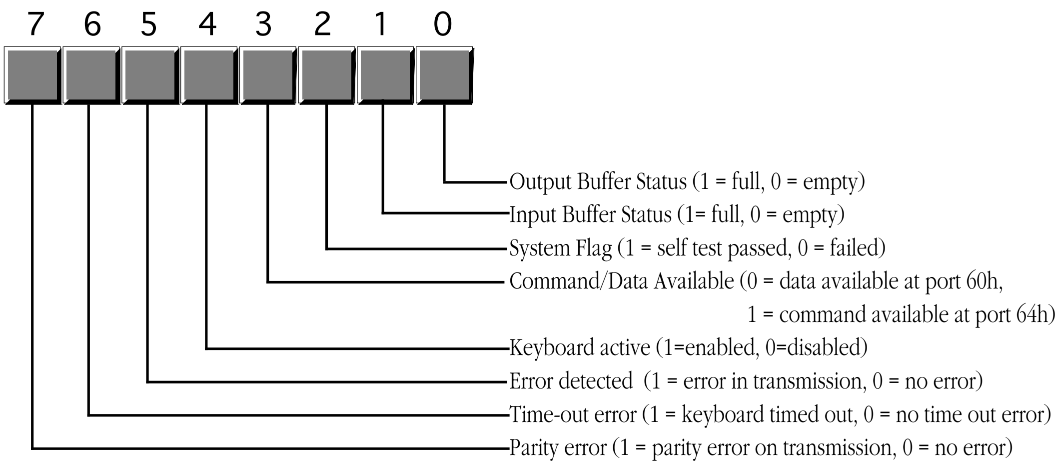
a. Addresses are all given in hexadecimal

One comment is in order about `KbdFlags1` and `KbdFlags4`. Bits zero through two of the `KbdFlags4` variable is BIOS' current settings for the LEDs on the keyboard. periodically, BIOS compares the values for capslock, numlock, and scroll lock in `KbdFlags1` against these three bits in `KbdFlags4`. If they do not agree, BIOS will send an appropriate command to the keyboard to update the LEDs and it will change the values in the `KbdFlags4` variable so the system is consistent. Therefore, if you mask in new values for numlock, scroll lock, or caps lock, the BIOS will automatically adjust `KbdFlags4` and set the LEDs accordingly.

20.2 The Keyboard Hardware Interface

IBM used a very simple hardware design for the keyboard port on the original PC and PC/XT machines. When they introduced the PC/AT, IBM completely resigned the interface between the PC and the keyboard. Since then, almost every PC model and PC clone has followed this keyboard interface standard[6]. Although IBM extended the capabilities of the keyboard controller when they introduced their PS/2 systems, the PS/2 models are still upwards compatible from the PC/AT design. Since there are so few original PCs in use today (and fewer people write original software for them), we will ignore the original PC keyboard interface and concentrate on the AT and later designs.

There are two keyboard microcontrollers that the system communicates with – one on the PC's motherboard (the *on-board* microcontroller) and one inside the keyboard case (the *keyboard* microcontroller). Communication with the on-board microcontroller is through I/O port 64h. Reading this byte provides the status of the keyboard controller. Writing to this byte sends the on-board microcontroller a command. The organization of the status byte is



On-Board 8042 Keyboard Microcontroller Status Byte (Read Port 64h)

Communication to the microcontroller in the keyboard unit is via the bytes at I/O addresses 60h and 64h. Bits zero and one in the status byte at port 64h provide the necessary *handshaking* control for these ports. Before writing any data to these ports, bit zero of port 64h must be zero; data is available for reading from port 60h when bit one of port 64h contains a one. The keyboard enable and disable bits in the command byte (port 64h) determine whether the keyboard is active and whether the keyboard will interrupt the system when the user presses (or releases) a key, etc.

Bytes written to port 60h are sent to the keyboard microcontroller and bytes written to port 64h are sent to the on-board microcontroller. Bytes read from port 60h generally come from the keyboard, although you can program the on-board microcontroller to return certain values at this port, as well. The following tables lists the commands sent to the keyboard microcontroller and the values you can expect back. The following table lists the allowable commands you can write to port 64h:

Table 75: On-Board Keyboard Controller Commands (Port 64h)

Value (hex)	Description
20	Transmit keyboard controller's command byte to system as a scan code at port 60h.
60	The next byte written to port 60h will be stored in the keyboard controller's command byte.

6. We will ignore the PCjr machine in this discussion.

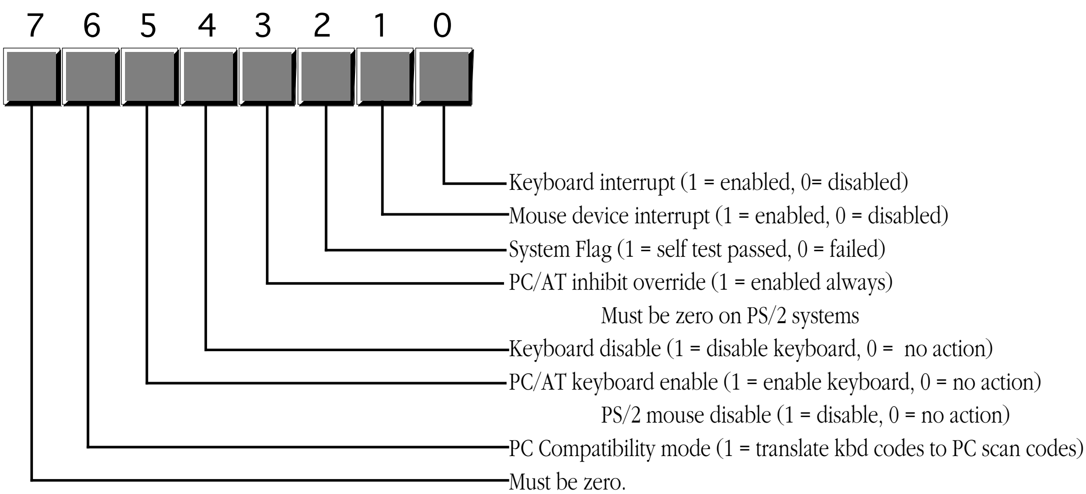
Table 75: On-Board Keyboard Controller Commands (Port 64h)

Value (hex)	Description
A4	Test if a password is installed (PS/2 only). Result comes back in port 60h. 0FAh means a password is installed, 0F1h means no password.
A5	Transmit password (PS/2 only). Starts receipt of password. The next sequence of scan codes written to port 60h, ending with a zero byte, are the new password.
A6	Password match. Characters from the keyboard are compared to password until a match occurs.
A7	Disable mouse device (PS/2 only). Identical to setting bit five of the command byte.
A8	Enable mouse device (PS/2 only). Identical to clearing bit five of the command byte.
A9	Test mouse device. Returns 0 if okay, 1 or 2 if there is a stuck clock, 3 or 4 if there is a stuck data line. Results come back in port 60h.
AA	Initiates self-test. Returns 55h in port 60h if successful.
AB	Keyboard interface test. Tests the keyboard interface. Returns 0 if okay, 1 or 2 if there is a stuck clock, 3 or 4 if there is a stuck data line. Results come back in port 60h.
AC	Diagnostic. Returns 16 bytes from the keyboard's microcontroller chip. Not available on PS/2 systems.
AD	Disable keyboard. Same operation as setting bit four of the command register.
AE	Enable keyboard. Same operation as clearing bit four of the command register.
C0	Read keyboard input port to port 60h. This input port contains the following values: bit 7: Keyboard inhibit keyswitch (0 = inhibit, 1 = enabled). bit 6: Display switch (0=color, 1=mono). bit 5: Manufacturing jumper. bit 4: System board RAM (always 1). bits 0-3: undefined.
C1	Copy input port (above) bits 0-3 to status bits 4-7. (PS/2 only)
C2	Copy input pot (above) bits 4-7 to status port bits 4-7. (PS/2 only).
D0	Copy microcontroller output port value to port 60h (see definition below).
D1	Write the next data byte written to port 60h to the microcontroller output port. This port has the following definition: bit 7: Keyboard data. bit 6: Keyboard clock. bit 5: Input buffer empty flag. bit 4: Output buffer full flag. bit 3: Undefined. bit 2: Undefined. bit 1: Gate A20 line. bit 0: System reset (if zero). Note: writing a zero to bit zero will reset the machine. Writing a one to bit one combines address lines 19 and 20 on the PC's address bus.
D2	Write keyboard buffer. The keyboard controller returns the next value sent to port 60h as though a keypress produced that value. (PS/2 only).
D3	Write mouse buffer. The keyboard controller returns the next value sent to port 60h as though a mouse operation produced that value. (PS/2 only).
D4	Writes the next data byte (60h) to the mouse (auxiliary) device. (PS/2 only).

Table 75: On-Board Keyboard Controller Commands (Port 64h)

Value (hex)	Description
E0	Read test inputs. Returns in port 60h the status of the keyboard serial lines. Bit zero contains the keyboard clock input, bit one contains the keyboard data input.
F*x*	Pulse output port (see definition for D1). Bits 0-3 of the keyboard controller command byte are pulsed onto the output port. Resets the system if bit zero is a zero.

Commands 20h and 60h let you read and write the *keyboard controller command byte*. This byte is internal to the on-board microcontroller and has the following layout:



On-Board 8042 Keyboard Microcontroller Command byte (see commands 20h and 60h)

The system transmits bytes written to I/O port 60h directly to the keyboard's microcontroller. Bit zero of the status register must contain a zero before writing any data to this port. The commands the keyboard recognizes are

Table 76: Keyboard Microcontroller Commands (Port 60h)

Value (hex)	Description
ED	Send LED bits. The next byte written to port 60h updates the LEDs on the keyboard. The parameter (next) byte contains: bits 3-7: Must be zero. bit 2: Capslock LED (1 = on, 0 = off). bit 1: Numlock LED (1 = on, 0 = off). bit 0: Scroll lock LED (1 = on, 0 = off).
EE	Echo commands. Returns 0EEh in port 60h as a diagnostic aid.

Table 76: Keyboard Microcontroller Commands (Port 60h)

Value (hex)	Description
F0	Select alternate scan code set (PS/2 only). The next byte written to port 60h selects one of the following options: 00: Report current scan code set in use (next value read from port 60h). 01: Select scan code set #1 (standard PC/AT scan code set). 02: Select scan code set #2. 03: Select scan code set #3.
F2	Send two-byte keyboard ID code as the next two bytes read from port 60h (PS/2 only).
F3	Set Autorepeat delay and repeat rate. Next byte written to port 60h determines rate: bit 7: must be zero bits 5,6: Delay. 00- $^1/_4$ sec, 01- $^1/_2$ sec, 10- $^3/_4$ sec, 11- 1 sec. bits 0-4: Repeat rate. 0- approx 30 chars/sec to 1Fh- approx 2 chars/sec.
F4	Enable keyboard.
F5	Reset to power on condition and wait for enable command.
F6	Reset to power on condition and begin scanning keyboard.
F7	Make all keys autorepeat (PS/2 only).
F8	Set all keys to generate an up code and a down code (PS/2 only).
F9	Set all keys to generate an up code only (PS/2 only).
FA	Set all keys to autorepeat and generate up and down codes (PS/2 only).
FB	Set an individual key to autorepeat. Next byte contains the scan code of the desired key. (PS/2 only).
FC	Set an individual key to generate up and down codes. Next byte contains the scan code of the desired key. (PS/2 only).
FD	Set an individual key to generate only down codes. Next byte contains the scan code of the desired key. (PS/2 only).
FE	Resend last result. Use this command if there is an error receiving data.
FF	Reset keyboard to power on state and start the self-test.

The following short program demonstrates how to send commands to the keyboard's controller. This little TSR utility programs a "light show" on the keyboard's LEDs.

```
; LEDSHOW.ASM
;
; This short TSR creates a light show on the keyboard's LEDs. For space
; reasons, this code does not implement a multiplex handler nor can you
; remove this TSR once installed. See the chapter on resident programs
; for details on how to do this.
;
; cseg and EndResident must occur before the standard library segments!

cseg            segment    para public 'code'
cseg            ends

; Marker segment, to find the end of the resident section.

EndResident     segment    para public 'Resident'
EndResident     ends

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

```
byp             equ        <byte ptr>

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



; SetCmd-       Sends the command byte in the AL register to the 8042
;               keyboard microcontroller chip (command register at
;               port 64h).

SetCmd          proc       near
                push       cx
                push       ax                  ;Save command value.
                cli                            ;Critical region, no ints now.

; Wait until the 8042 is done processing the current command.

                xor        cx, cx              ;Allow 65,536 times thru loop.
Wait4Empty:     in         al, 64h             ;Read keyboard status register.
                test       al, 10b             ;Input buffer full?
                loopnz     Wait4Empty          ;If so, wait until empty.

; Okay, send the command to the 8042:

                pop        ax                  ;Retrieve command.
                out        64h, al
                sti                            ;Okay, ints can happen again.
                pop        cx
                ret
SetCmd          endp




; SendCmd-      The following routine sends a command or data byte to the
;               keyboard data port (port 60h).

SendCmd         proc       near
                push       ds
                push       bx
                push       cx
                mov        cx, 40h
                mov        ds, cx
                mov        bx, ax              ;Save data byte

                mov        al, 0ADh            ;Disable kbd for now.
                call       SetCmd

                cli                            ;Disable ints while accessing HW.

; Wait until the 8042 is done processing the current command.

                xor        cx, cx              ;Allow 65,536 times thru loop.
Wait4Empty:     in         al, 64h             ;Read keyboard status register.
                test       al, 10b             ;Input buffer full?
                loopnz     Wait4Empty          ;If so, wait until empty.

; Okay, send the data to port 60h

                mov        al, bl
                out        60h, al

                mov        al, 0AEh            ;Reenable keyboard.
                call       SetCmd
                sti                            ;Allow interrupts now.

                pop        cx
                pop        bx
                pop        ds
                ret
SendCmd         endp
```

```
; SetLEDs-      Writes the value in AL to the LEDs on the keyboard.
;               Bits 0..2 correspond to scroll, num, and caps lock,
;               respectively.

SetLEDs         proc        near
                push        ax
                push        cx

                mov         ah, al              ;Save LED bits.

                mov         al, 0EDh            ;8042 set LEDs cmd.
                call        SendCmd             ;Send the command to 8042.
                mov         al, ah              ;Get parameter byte
                call        SendCmd             ;Send parameter to the 8042.

                pop         cx
                pop         ax
                ret
SetLEDs         endp



; MyInt1C-      Every 1/4 seconds (every 4th call) this routine
;               rotates the LEDs to produce an interesting light show.

CallsPerIter    equu        4
CallCnt         byte        CallsPerIter
LEDIndex        word        LEDTable
LEDTable        byte        111b, 110b, 101b, 011b,111b, 110b, 101b, 011b
                byte        111b, 110b, 101b, 011b,111b, 110b, 101b, 011b
                byte        111b, 110b, 101b, 011b,111b, 110b, 101b, 011b
                byte        111b, 110b, 101b, 011b,111b, 110b, 101b, 011b

                byte        000b, 100b, 010b, 001b, 000b, 100b, 010b, 001b
                byte        000b, 100b, 010b, 001b, 000b, 100b, 010b, 001b
                byte        000b, 100b, 010b, 001b, 000b, 100b, 010b, 001b
                byte        000b, 100b, 010b, 001b, 000b, 100b, 010b, 001b

                byte        000b, 001b, 010b, 100b, 000b, 001b, 010b, 100b
                byte        000b, 001b, 010b, 100b, 000b, 001b, 010b, 100b
                byte        000b, 001b, 010b, 100b, 000b, 001b, 010b, 100b
                byte        000b, 001b, 010b, 100b, 000b, 001b, 010b, 100b

                byte        010b, 001b, 010b, 100b, 010b, 001b, 010b, 100b
                byte        010b, 001b, 010b, 100b, 010b, 001b, 010b, 100b
                byte        010b, 001b, 010b, 100b, 010b, 001b, 010b, 100b
                byte        010b, 001b, 010b, 100b, 010b, 001b, 010b, 100b

                byte        000b, 111b, 000b, 111b, 000b, 111b, 000b, 111b
                byte        000b, 111b, 000b, 111b, 000b, 111b, 000b, 111b
                byte        000b, 111b, 000b, 111b, 000b, 111b, 000b, 111b
                byte        000b, 111b, 000b, 111b, 000b, 111b, 000b, 111b
TableEnd        equ         this byte

OldInt1C        dword       ?

MyInt1C         proc        far
                assume      ds:cseg

                push        ds
                push        ax
                push        bx

                mov         ax, cs
                mov         ds, ax

                dec         CallCnt
                jne         NotYet
                mov         CallCnt, CallsPerIter           ;Reset call count.
                mov         bx, LEDIndex
                mov         al, [bx]
                call        SetLEDs
```

```
                inc         bx
                cmp         bx, offset TableEnd
                jne         SetTbl
                lea         bx, LEDTable
SetTbl:         mov         LEDIndex, bx
NotYet:         pop         bx
                pop         ax
                pop         ds
                jmp         cs:OldInt1C
MyInt1C         endp


Main            proc

                mov         ax, cseg
                mov         ds, ax

                print
                byte        "LED Light Show",cr,lf
                byte        "Installing....",cr,lf,0

; Patch into the INT 1Ch interrupt vector. Note that the
; statements above have made cseg the current data segment,
; so we can store the old INT 1Ch values directly into
; the OldInt1C variable.

                cli                           ;Turn off interrupts!
                mov         ax, 0
                mov         es, ax
                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], cs
                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
```

The keyboard microcontroller also sends data to the on-board microcontroller for processing and release to the system through port 60h. Most of these values are key press scan codes (up or down codes), but the keyboard transmits several other values as well. A well designed keyboard interrupt service routine should be able to handle (or at least ignore) the non-scan code values. Any particular, any program that sends commands to the keyboard needs to be able to handle the resend and acknowledge commands that the keyboard microcontroller returns in port 60h. The keyboard microcontroller sends the following values to the system:

Table 77: Keyboard to System Transmissions

Value (hex)	Description
00	Data overrun. System sends a zero byte as the last value when the keyboard controller's internal buffer overflows.
1..58 81..D8	Scan codes for key presses. The positive values are down codes, the negative values (H.O. bit set) are up codes.
83AB	Keyboard ID code returned in response to the F2 command (PS/2 only).
AA	Returned during basic assurance test after reset. Also the up code for the left shift key.
EE	Returned by the ECHO command.
F0	Prefix to certain up codes (N/A on PS/2).
FA	Keyboard acknowledge to keyboard commands other than resend or ECHO.
FC	Basic assurance test failed (PS/2 only).
FD	Diagnostic failure (not available on PS/2).
FE	Resend. Keyboard requests the system to resend the last command.
FF	Key error (PS/2 only).

Assuming you have not disabled keyboard interrupts (see the keyboard controller command byte), any value the keyboard microcontroller sends to the system through port 60h will generate an interrupt on IRQ line one (int 9). Therefore, the keyboard interrupt service routine normally handles all the above codes. If you are patching into int 9, don't forget to send and end of interrupt (EOI) signal to the 8259A PIC at the end of your ISR code. Also, don't forget you can enable or disable the keyboard interrupt at the 8259A.

In general, your application software should *not* access the keyboard hardware directly. Doing so will probably make your software incompatible with utility software such as keyboard enhancers (keyboard macro programs), pop-up software, and other resident programs that read the keyboard or insert data into the system's type ahead buffer. Fortunately, DOS and BIOS provide an excellent set of functions to read and write keyboard data. Your programs will be much more robust if you stick to using those functions. Accessing the keyboard hardware directly should be left to keyboard ISRs and those keyboard enhancers and pop-up programs that absolutely have to talk directly to the hardware.

20.3 The Keyboard DOS Interface

MS-DOS provides several calls to read characters from the keyboard (see "MS-DOS, PC-BIOS, and File I/O" on page 699). The primary thing to note about the DOS calls is that they only return a single byte. This means that you lose the scan code information the keyboard interrupt service routine saves in the type ahead buffer.

If you press a key that has an extended code rather than an ASCII code, MS-DOS returns two keycodes. On the first call MS-DOS returns a zero value. This tells you that you must call the get character routine again. The code MS-DOS returns on the second call is the extended key code.

Note that the Standard Library routines call MS-DOS to read characters from the keyboard. Therefore, the Standard Library `getc` routine also returns extended keycodes in this manner. The `gets` and `getsm` routines throw away any non-ASCII keystrokes since it would not be a good thing to insert zero bytes into the middle of a zero terminated string.

20.4 The Keyboard BIOS Interface

Although MS-DOS provides a reasonable set of routines to read ASCII and extended character codes from the keyboard, the PC's BIOS provides much better keyboard input facilities. Furthermore, there are lots of interesting keyboard related variables in the BIOS data area you can poke around at. In general, if you do not need the I/O redirection facilities provided by MS-DOS, reading your keyboard input using BIOS functions provides much more flexibility.

To call the MS-DOS BIOS keyboard services you use the int 16h instruction. The BIOS provides the following keyboard functions:

Table 78: BIOS Keyboard Support Functions

Function # (AH)	Input Parameters	Output Parameters	Description
0		al- ASCII character ah- scan code	Read character. Reads next available character from the system's type ahead buffer. Wait for a keystroke if the buffer is empty.
1		ZF- Set if no key. ZF- Clear if key available. al- ASCII code ah- scan code	Checks to see if a character is available in the type ahead buffer. Sets the zero flag if not key is available, clears the zero flag if a key is available. If there is an available key, this function returns the ASCII and scan code value in ax. The value in ax is undefined if no key is available.
2		al- shift flags	Returns the current status of the shift flags in al. The shift flags are defined as follows: bit 7: Insert toggle bit 6: Capslock toggle bit 5: Numlock toggle bit 4: Scroll lock toggle bit 3: Alt key is down bit 2: Ctrl key is down bit 1: Left shift key is down bit 0: Right shift key is down
3	al = 5 bh = 0, 1, 2, 3 for 1/4, 1/2, 3/4, or 1 second delay bl= 0..1Fh for 30/sec to 2/sec.		Set auto repeat rate. The bh register contains the amount of time to wait before starting the autorepeat operation, the bl register contains the autorepeat rate.
5	ch = scan code cl = ASCII code		Store keycode in buffer. This function stores the value in the cx register at the end of the type ahead buffer. Note that the scan code in ch doesn't have to correspond to the ASCII code appearing in cl. This routine will simply insert the data you provide into the system type ahead buffer.

Table 78: BIOS Keyboard Support Functions

Function # (AH)	Input Parameters	Output Parameters	Description
10h		al- ASCII character ah- scan code	Read extended character. Like ah=0 call, except this one passes all key codes, the ah=0 call throws away codes that are not PC/XT compatible.
11h		ZF- Set if no key. ZF- Clear if key available. al- ASCII code ah- scan code	Like the ah=01h call except this one does not throw away keycodes that are not PC/XT compatible (i.e., the extra keys found on the 101 key keyboard).
12h		al- shift flags ah- extended shift flags	Returns the current status of the shift flags in ax. The shift flags are defined as follows: bit 15: SysReq key pressed bit 14: Capslock key currently down bit 13: Numlock key currently down bit 12: Scroll lock key currently down bit 11: Right alt key is down bit 10:Right ctrl key is down bit 9: Left alt key is down bit 8: Left ctrl key is down bit 7: Insert toggle bit 6: Capslock toggle bit 5: Numlock toggle bit 4: Scroll lock toggle bit 3: Either alt key is down (some machines, left only) bit 2: Either ctrl key is down bit 1: Left shift key is down bit 0: Right shift key is down

Note that many of these functions are not supported in every BIOS that was ever written. In fact, only the first three functions were available in the original PC. However, since the AT came along, most BIOSes have supported *at least* the functions above. Many BIOS provide extra functions, and there are many TSR applications you can buy that extend this list even farther. The following assembly code demonstrates how to write an int 16h TSR that provides all the functions above. You can easily extend this if you desire.

```
; INT16.ASM
;
; A short passive TSR that replaces the BIOS' int 16h handler.
; This routine demonstrates the function of each of the int 16h
; functions that a standard BIOS would provide.
;
; Note that this code does not patch into int 2Fh (multiplex interrupt)
; nor can you remove this code from memory except by rebooting.
; If you want to be able to do these two things (as well as check for
; a previous installation), see the chapter on resident programs. Such
; code was omitted from this program because of length constraints.
;
;
; cseg and EndResident must occur before the standard library segments!

cseg            segment    para public 'code'
cseg            ends

; Marker segment, to find the end of the resident section.
```

```
EndResident    segment    para public 'Resident'
EndResident    ends

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


byp            equ        <byte ptr>

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

OldInt16       dword      ?


; BIOS variables:

KbdFlags1      equu       <ds:[17h]>
KbdFlags2      equ        <ds:[18h]>
AltKpd         equ        <ds:[19h]>
HeadPtr        equ        <ds:[1ah]>
TailPtr        equ        <ds:[1ch]>
Buffer         equ        1eh
EndBuf         equ        3eh

KbdFlags3      equ        <ds:[96h]>
KbdFlags4      equ        <ds:[97h]>

incptr         macro      which
               local      NoWrap
               add        bx, 2
               cmp        bx, EndBuf
               jb         NoWrap
               mov        bx, Buffer
NoWrap:        mov        which, bx
               endm


; MyInt16-     This routine processes the int 16h function requests.
;
;              AH         Description
;              --         ------------------------------------------------
;              00h        Get a key from the keyboard, return code in AX.
;              01h        Test for available key, ZF=1 if none, ZF=0 and
;                         AX contains next key code if key available.
;              02h        Get shift status. Returns shift key status in AL.
;              03h        Set Autorepeat rate. BH=0,1,2,3 (delay time in
;                         quarter seconds), BL=0..1Fh for 30 char/sec to
;                         2 char/sec repeat rate.
;              05h        Store scan code (in CX) in the type ahead buffer.
;              10h        Get a key (same as 00h in this implementation).
;              11h        Test for key (same as 01h).
;              12h        Get extended key status. Returns status in AX.


MyInt16        proc       far
               test       ah, 0EFh          ;Check for 0h and 10h
               je         GetKey
               cmp        ah, 2             ;Check for 01h and 02h
               jb         TestKey
               je         GetStatus
               cmp        ah, 3             ;Check for AutoRpt function.
               je         SetAutoRpt
               cmp        ah, 5             ;Check for StoreKey function.
               je         StoreKey
               cmp        ah, 11h           ;Extended test key opcode.
               je         TestKey
               cmp        ah, 12h           ;Extended status call
               je         ExtStatus

; Well, it's a function we don't know about, so just return to the caller.
```

```
                iret

; If the user specified ah=0 or ah=10h, come down here (we will not
; differentiate between extended and original PC getc calls).

GetKey:         mov         ah, 11h
                int         16h                 ;See if key is available.
                je          GetKey              ;Wait for keystroke.

                push        ds
                push        bx
                mov         ax, 40h
                mov         ds, ax
                cli                             ;Critical region! Ints off.
                mov         bx, HeadPtr         ;Ptr to next character.
                mov         ax, [bx]            ;Get the character.
                incptr      HeadPtr             ;Bump up HeadPtr
                pop         bx
                pop         ds
                iret                            ;Restores interrupt flag.

; TestKey-      Checks to see if a key is available in the keyboard buffer.
;               We need to turn interrupts on here (so the kbd ISR can
;               place a character in the buffer if one is pending).
;               Generally, you would want to save the interrupt flag here.
;               But BIOS always forces interrupts on, so there may be some
;               programs out there that depend on this, so we won't "fix"
;               this problem.
;
;               Returns key status in ZF and AX. If ZF=1 then no key is
;               available and the value in AX is indeterminate. If ZF=0
;               then a key is available and AX contains the scan/ASCII
;               code of the next available key. This call does not remove
;               the next character from the input buffer.

TestKey:        sti                             ;Turn on the interrupts.
                push        ds
                push        bx
                mov         ax, 40h
                mov         ds, ax
                cli                             ;Critical region, ints off!
                mov         bx, HeadPtr
                mov         ax, [bx]            ;BIOS returns avail keycode.
                cmp         bx, TailPtr         ;ZF=1, if empty buffer
                pop         bx
                pop         ds
                sti                             ;Inst back on.
                retf        2                   ;Pop flags (ZF is important!)


; The GetStatus call simply returns the KbdFlags1 variable in AL.

GetStatus:      push        ds
                mov         ax, 40h
                mov         ds, ax
                mov         al, KbdFlags1       ;Just return Std Status.
                pop         ds
                iret


; StoreKey-     Inserts the value in CX into the type ahead buffer.

StoreKey:       push        ds
                push        bx
                mov         ax, 40h
                mov         ds, ax
                cli                             ;Ints off, critical region.
                mov         bx, TailPtr         ;Address where we can put
                push        bx                  ; next key code.
                mov         [bx], cx            ;Store the key code away.
                incptr      TailPtr             ;Move on to next entry in buf.
                cmp         bx, HeadPtr         ;Data overrun?
                jne         StoreOkay           ;If not, jump, if so
                pop         TailPtr             ; ignore key entry.
```

```
                sub         sp, 2               ;So stack matches alt path.
StoreOkay:      add         sp, 2               ;Remove junk data from stk.
                pop         bx
                pop         ds
                iret                            ;Restores interrupts.


; ExtStatus-    Retrieve the extended keyboard status and return it in
;               AH, also returns the standard keyboard status in AL.

ExtStatus:      push        ds
                mov         ax, 40h
                mov         ds, ax

                mov         ah, KbdFlags2
                and         ah, 7Fh             ;Clear final sysreq field.
                test        ah, 100b            ;Test cur sysreq bit.
                je          NoSysReq            ;Skip if it’s zero.
                or          ah, 80h             ;Set final sysreq bit.
NoSysReq:
                and         ah, 0F0h            ;Clear alt/ctrl bits.
                mov         al, KbdFlags3
                and         al, 1100b           ;Grab rt alt/ctrl bits.
                or          ah, al              ;Merge into AH.
                mov         al, KbdFlags2
                and         al, 11b             ;Grab left alt/ctrl bits.
                or          ah, al              ;Merge into AH.

                mov         al, KbdFlags1       ;AL contains normal flags.
                pop         ds
                iret

; SetAutoRpt-   Sets the autorepeat rate. On entry, bh=0, 1, 2, or 3 (delay
;               in 1/4 sec before autorepeat starts) and bl=0..1Fh (repeat
;               rate, about 2:1 to 30:1 (chars:sec).

SetAutoRpt:     push        cx
                push        bx

                mov         al, 0ADh            ;Disable kbd for now.
                call        SetCmd

                and         bh, 11b             ;Force into proper range.
                mov         cl, 5
                shl         bh, cl              ;Move to final position.
                and         bl, 1Fh             ;Force into proper range.
                or          bh, bl              ;8042 command data byte.
                mov         al, 0F3h            ;8042 set repeat rate cmd.
                call        SendCmd             ;Send the command to 8042.
                mov         al, bh              ;Get parameter byte
                call        SendCmd             ;Send parameter to the 8042.

                mov         al, 0AEh            ;Reenable keyboard.
                call        SetCmd
                mov         al, 0F4h            ;Restart kbd scanning.
                call        SendCmd

                pop         bx
                pop         cx
                iret

MyInt16         endp



; SetCmd-       Sends the command byte in the AL register to the 8042
;               keyboard microcontroller chip (command register at
;               port 64h).

SetCmd          proc        near
                push        cx
                push        ax                  ;Save command value.
                cli                             ;Critical region, no ints now.
```

```
; Wait until the 8042 is done processing the current command.

                xor         cx, cx              ;Allow 65,536 times thru loop.
Wait4Empty:     in          al, 64h             ;Read keyboard status register.
                test        al, 10b             ;Input buffer full?
                loopnz      Wait4Empty          ;If so, wait until empty.

; Okay, send the command to the 8042:

                pop         ax                  ;Retrieve command.
                out         64h, al
                sti                             ;Okay, ints can happen again.
                pop         cx
                ret
SetCmd          endp



; SendCmd-      The following routine sends a command or data byte to the
;               keyboard data port (port 60h).

SendCmd         proc        near
                push        ds
                push        bx
                push        cx
                mov         cx, 40h
                mov         ds, cx
                mov         bx, ax              ;Save data byte

                mov         bh, 3               ;Retry cnt.
RetryLp:        cli                             ;Disable ints while accessing HW.

; Clear the Error, Acknowledge received, and resend received flags
; in KbdFlags4

                and         byte ptr KbdFlags4, 4fh

; Wait until the 8042 is done processing the current command.

                xor         cx, cx              ;Allow 65,536 times thru loop.
Wait4Empty:     in          al, 64h             ;Read keyboard status register.
                test        al, 10b             ;Input buffer full?
                loopnz      Wait4Empty          ;If so, wait until empty.

; Okay, send the data to port 60h

                mov         al, bl
                out         60h, al
                sti                             ;Allow interrupts now.

; Wait for the arrival of an acknowledgement from the keyboard ISR:

                xor         cx, cx              ;Wait a long time, if need be.
Wait4Ack:       test        byp KbdFlags4, 10 ;Acknowledge received bit.
                jnz         GotAck
                loop        Wait4Ack
                dec         bh                  ;Do a retry on this guy.
                jne RetryLp

; If the operation failed after 3 retries, set the error bit and quit.

                or          byp KbdFlags4, 80h ;Set error bit.

GotAck:         pop         cx
                pop         bx
                pop         ds
                ret
SendCmd         endp


Main            proc
```

```
                mov         ax, cseg
                mov         ds, ax

                print
                byte        "INT 16h Replacement",cr,lf
                byte        "Installing....",cr,lf,0

; Patch into the INT 9 and INT 16 interrupt vectors. Note that the
; statements above have made cseg 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, 0
                mov         es, ax
                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], cs
                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
```

20.5 The Keyboard Interrupt Service Routine

The int 16h ISR is the interface between application programs and the keyboard. In a similar vein, the int 9 ISR is the interface between the keyboard hardware and the int 16h ISR. It is the job of the int 9 ISR to process keyboard hardware interrupts, convert incoming scan codes to scan/ASCII code combinations and place them in the typeahead buffer, and process other messages the keyboard generates.

To convert keyboard scan codes to scan/ASCII codes, the int 9 ISR must keep track of the current state of the modifier keys. When a scan code comes along, the int 9 ISR can use the `xlat` instruction to translate the scan code to an ASCII code using a table int 9 selects on the basis of the modifier flags. Another important issue is that the int 9 handler must handle special key sequences like ctrl-alt-del (reset) and PrtSc. The following assembly code provides a simple int 9 handler for the keyboard. It does not support alt-Keypad ASCII code entry or a few other minor features, but it does support almost everything you need for a keyboard interrupt service routine. Certainly it demonstrates all the techniques you need to know when programming the keyboard.

```
; INT9.ASM
;
; A short TSR to provide a driver for the keyboard hardware interrupt.
;
; Note that this code does not patch into int 2Fh (multiplex interrupt)
; nor can you remove this code from memory except by rebooting.
; If you want to be able to do these two things (as well as check for
; a previous installation), see the chapter on resident programs. Such
; code was omitted from this program because of length constraints.
;
;
; cseg and EndResident must occur before the standard library segments!

cseg            segment     para public 'code'
OldInt9         dword       ?
cseg            ends

; Marker segment, to find the end of the resident section.

EndResident     segment     para public 'Resident'
EndResident     ends

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


NumLockScan     equ         45h
ScrlLockScan    equ         46h
CapsLockScan    equ         3ah
CtrlScan        equ         1dh
AltScan         equ         38h
RShiftScan      equ         36h
LShiftScan      equ         2ah
InsScanCode     equ         52h
DelScanCode     equ         53h

; Bits for the various modifier keys

RShfBit         equ         1
LShfBit         equ         2
CtrlBit         equ         4
AltBit          equ         8
SLBit           equ         10h
NLBit           equ         20h
CLBit           equ         40h
InsBit          equ         80h


KbdFlags        equ         <byte ptr ds:[17h]>
KbdFlags2       equ         <byte ptr ds:[18h]>
KbdFlags3       equ         <byte ptr ds:[96h]>
KbdFlags4       equ         <byte ptr ds:[97h]>

byp             equ         <byte ptr>


cseg            segment     para public 'code'
                assume      ds:nothing

; Scan code translation table.
; The incoming scan code from the keyboard selects a row.
; The modifier status selects the column.
; The word at the intersection of the two is the scan/ASCII code to
; put into the PC's type ahead buffer.
; If the value fetched from the table is zero, then we do not put the
; character into the type ahead buffer.
;
;               norm   shft   ctrl   alt    num   caps   shcap  shnum

ScanXlat word  0000h, 0000h, 0000h, 0000h, 0000h, 0000h, 0000h, 0000h
         word  011bh, 011bh, 011bh, 011bh, 011bh, 011bh, 011bh, 011bh    ;ESC
         word  0231h, 0231h, 0000h, 7800h, 0231h, 0231h, 0231h, 0321h    ;1 !
```

```
                word  0332h, 0340h, 0300h, 7900h, 0332h, 0332h, 0332h, 0332h   ;2 @
                word  0433h, 0423h, 0000h, 7a00h, 0433h, 0433h, 0423h, 0423h   ;3 #
                word  0534h, 0524h, 0000h, 7b00h, 0534h, 0534h, 0524h, 0524h   ;4 $
                word  0635h, 0625h, 0000h, 7c00h, 0635h, 0635h, 0625h, 0625h   ;5 %
                word  0736h, 075eh, 071eh, 7d00h, 0736h, 0736h, 075eh, 075eh   ;6 ^

                word  0837h, 0826h, 0000h, 7e00h, 0837h, 0837h, 0826h, 0826h   ;7 &
                word  0938h, 092ah, 0000h, 7f00h, 0938h, 0938h, 092ah, 092ah   ;8 *
                word  0a39h, 0a28h, 0000h, 8000h, 0a39h, 0a39h, 0a28h, 0a28h   ;9 (
                word  0b30h, 0b29h, 0000h, 8100h, 0b30h, 0b30h, 0b29h, 0b29h   ;0 )
                word  0c2dh, 0c5fh, 0000h, 8200h, 0c2dh, 0c2dh, 0c5fh, 0c5fh   ;- _
                word  0d3dh, 0d2bh, 0000h, 8300h, 0d3dh, 0d3dh, 0d2bh, 0d2bh   ;= +
                word  0e08h, 0e08h, 0e7fh, 0000h, 0e08h, 0e08h, 0e08h, 0e08h   ;bksp
                word  0f09h, 0f00h, 0000h, 0000h, 0f09h, 0f09h, 0f00h, 0f00h   ;Tab

;                     norm   shft   ctrl   alt    num   caps   shcap  shnum
                word  1071h, 1051h, 1011h, 1000h, 1071h, 1051h, 1051h, 1071h   ;Q
                word  1177h, 1057h, 1017h, 1100h, 1077h, 1057h, 1057h, 1077h   ;W
                word  1265h, 1245h, 1205h, 1200h, 1265h, 1245h, 1245h, 1265h   ;E
                word  1372h, 1352h, 1312h, 1300h, 1272h, 1252h, 1252h, 1272h   ;R
                word  1474h, 1454h, 1414h, 1400h, 1474h, 1454h, 1454h, 1474h   ;T
                word  1579h, 1559h, 1519h, 1500h, 1579h, 1559h, 1579h, 1559h   ;Y
                word  1675h, 1655h, 1615h, 1600h, 1675h, 1655h, 1675h, 1655h   ;U
                word  1769h, 1749h, 1709h, 1700h, 1769h, 1749h, 1769h, 1749h   ;I

                word  186fh, 184fh, 180fh, 1800h, 186fh, 184fh, 186fh, 184fh   ;O
                word  1970h, 1950h, 1910h, 1900h, 1970h, 1950h, 1970h, 1950h   ;P
                word  1a5bh, 1a7bh, 1a1bh, 0000h, 1a5bh, 1a5bh, 1a7bh, 1a7bh   ;[ {
                word  1b5dh, 1b7dh, 1b1dh, 0000h, 1b5dh, 1b5dh, 1b7dh, 1b7dh   ;] }
                word  1c0dh, 1c0dh, 1c0ah, 0000h, 1c0dh, 1c0dh, 1c0ah, 1c0ah   ;enter
                word  1d00h, 1d00h, 1d00h, 1d00h, 1d00h, 1d00h, 1d00h, 1d00h   ;ctrl
                word  1e61h, 1e41h, 1e01h, 1e00h, 1e61h, 1e41h, 1e61h, 1e41h   ;A
                word  1f73h, 1f5eh, 1f13h, 1f00h, 1f73h, 1f53h, 1f73h, 1f53h   ;S

;                     norm   shft   ctrl   alt    num   caps   shcap  shnum
                word  2064h, 2044h, 2004h, 2000h, 2064h, 2044h, 2064h, 2044h   ;D
                word  2166h, 2146h, 2106h, 2100h, 2166h, 2146h, 2166h, 2146h   ;F
                word  2267h, 2247h, 2207h, 2200h, 2267h, 2247h, 2267h, 2247h   ;G
                word  2368h, 2348h, 2308h, 2300h, 2368h, 2348h, 2368h, 2348h   ;H
                word  246ah, 244ah, 240ah, 2400h, 246ah, 244ah, 246ah, 244ah   ;J
                word  256bh, 254bh, 250bh, 2500h, 256bh, 254bh, 256bh, 254bh   ;K
                word  266ch, 264ch, 260ch, 2600h, 266ch, 264ch, 266ch, 264ch   ;L
                word  273bh, 273ah, 0000h, 0000h, 273bh, 273bh, 273ah, 273ah   ;; :

                word  2827h, 2822h, 0000h, 0000h, 2827h, 2827h, 2822h, 2822h   ;' "
                word  2960h, 297eh, 0000h, 0000h, 2960h, 2960h, 297eh, 297eh   ;` ~
                word  2a00h, 2a00h, 2a00h, 2a00h, 2a00h, 2a00h, 2a00h, 2a00h   ;LShf
                word  2b5ch, 2b7ch, 2b1ch, 0000h, 2b5ch, 2b5ch, 2b7ch, 2b7ch   ;\ |
                word  2c7ah, 2c5ah, 2c1ah, 2c00h, 2c7ah, 2c5ah, 2c7ah, 2c5ah   ;Z
                word  2d78h, 2d58h, 2d18h, 2d00h, 2d78h, 2d58h, 2d78h, 2d58h   ;X
                word  2e63h, 2e43h, 2e03h, 2e00h, 2e63h, 2e43h, 2e63h, 2e43h   ;C
                word  2f76h, 2f56h, 2f16h, 2f00h, 2f76h, 2f56h, 2f76h, 2f56h   ;V

;                     norm   shft   ctrl   alt    num   caps   shcap  shnum
                word  3062h, 3042h, 3002h, 3000h, 3062h, 3042h, 3062h, 3042h   ;B
                word  316eh, 314eh, 310eh, 3100h, 316eh, 314eh, 316eh, 314eh   ;N
                word  326dh, 324dh, 320dh, 3200h, 326dh, 324dh, 326dh, 324dh   ;M
                word  332ch, 333ch, 0000h, 0000h, 332ch, 332ch, 333ch, 333ch   ;, <
                word  342eh, 343eh, 0000h, 0000h, 342eh, 342eh, 343eh, 343eh   ;. >
                word  352fh, 353fh, 0000h, 0000h, 352fh, 352fh, 353fh, 353fh   ;/ ?
                word  3600h, 3600h, 3600h, 3600h, 3600h, 3600h, 3600h, 3600h   ;rshf
                word  372ah, 0000h, 3710h, 0000h, 372ah, 372ah, 0000h, 0000h   ;* PS

                word  3800h, 3800h, 3800h, 3800h, 3800h, 3800h, 3800h, 3800h   ;alt
                word  3920h, 3920h, 3920h, 0000h, 3920h, 3920h, 3920h, 3920h   ;spc
                word  3a00h, 3a00h, 3a00h, 3a00h, 3a00h, 3a00h, 3a00h, 3a00h   ;caps
                word  3b00h, 5400h, 5e00h, 6800h, 3b00h, 3b00h, 5400h, 5400h   ;F1
                word  3c00h, 5500h, 5f00h, 6900h, 3c00h, 3c00h, 5500h, 5500h   ;F2
                word  3d00h, 5600h, 6000h, 6a00h, 3d00h, 3d00h, 5600h, 5600h   ;F3
                word  3e00h, 5700h, 6100h, 6b00h, 3e00h, 3e00h, 5700h, 5700h   ;F4
                word  3f00h, 5800h, 6200h, 6c00h, 3f00h, 3f00h, 5800h, 5800h   ;F5

;                     norm   shft   ctrl   alt    num   caps   shcap  shnum
                word  4000h, 5900h, 6300h, 6d00h, 4000h, 4000h, 5900h, 5900h   ;F6
```

```
        word  4100h, 5a00h, 6400h, 6e00h, 4100h, 4100h, 5a00h, 5a00h   ;F7
        word  4200h, 5b00h, 6500h, 6f00h, 4200h, 4200h, 5b00h, 5b00h   ;F8
        word  4300h, 5c00h, 6600h, 7000h, 4300h, 4300h, 5c00h, 5c00h   ;F9
        word  4400h, 5d00h, 6700h, 7100h, 4400h, 4400h, 5d00h, 5d00h   ;F10
        word  4500h, 4500h, 4500h, 4500h, 4500h, 4500h, 4500h, 4500h   ;num
        word  4600h, 4600h, 4600h, 4600h, 4600h, 4600h, 4600h, 4600h   ;scrl
        word  4700h, 4737h, 7700h, 0000h, 4737h, 4700h, 4737h, 4700h   ;home

        word  4800h, 4838h, 0000h, 0000h, 4838h, 4800h, 4838h, 4800h   ;up
        word  4900h, 4939h, 8400h, 0000h, 4939h, 4900h, 4939h, 4900h   ;pgup
        word  4a2dh, 4a2dh, 0000h, 0000h, 4a2dh, 4a2dh, 4a2dh, 4a2dh   ;-
        word  4b00h, 4b34h, 7300h, 0000h, 4b34h, 4b00h, 4b34h, 4b00h   ;left
        word  4c00h, 4c35h, 0000h, 0000h, 4c35h, 4c00h, 4c35h, 4c00h   ;Center
        word  4d00h, 4d36h, 7400h, 0000h, 4d36h, 4d00h, 4d36h, 4d00h   ;right
        word  4e2bh, 4e2bh, 0000h, 0000h, 4e2bh, 4e2bh, 4e2bh, 4e2bh   ;+
        word  4f00h, 4f31h, 7500h, 0000h, 4f31h, 4f00h, 4f31h, 4f00h   ;end

;             norm   shft   ctrl   alt    num   caps   shcap  shnum
        word  5000h, 5032h, 0000h, 0000h, 5032h, 5000h, 5032h, 5000h   ;down
        word  5100h, 5133h, 7600h, 0000h, 5133h, 5100h, 5133h, 5100h   ;pgdn
        word  5200h, 5230h, 0000h, 0000h, 5230h, 5200h, 5230h, 5200h   ;ins
        word  5300h, 532eh, 0000h, 0000h, 532eh, 5300h, 532eh, 5300h   ;del
        word  0,0,0,0,0,0,0,0                                          ; --
        word  0,0,0,0,0,0,0,0                                          ; --
        word  0,0,0,0,0,0,0,0                                          ; --
        word  5700h, 0000h, 0000h, 0000h, 5700h, 5700h, 0000h, 0000h   ;F11

        word  5800h, 0000h, 0000h, 0000h, 5800h, 5800h, 0000h, 0000h   ;F12


;****************************************************************************
;
; AL contains keyboard scan code.

PutInBuffer     proc near
                push ds
                push bx

                mov bx, 40h                     ;Point ES at the BIOS
                mov ds, bx                      ; variables.

; If the current scan code is E0 or E1, we need to take note of this fact
; so that we can properly process cursor keys.

                cmp       al, 0e0h
                jne       TryE1
                or        KbdFlags3, 10b        ;Set E0 flag
                and       KbdFlags3, 0FEh       ;Clear E1 flag
                jmp       Done

TryE1:          cmp       al, 0e1h
                jne       DoScan
                or        KbdFlags3, 1          ;Set E1 flag
                and       KbdFlags3, 0FDh       ;Clear E0 Flag
                jmp       Done


; Before doing anything else, see if this is Ctrl-Alt-Del:

DoScan:         cmp       al, DelScanCode
                jnz       TryIns
                mov       bl, KbdFlags
                and       bl, AltBit or CtrlBit ;Alt = bit 3, ctrl = bit 2
                cmp       bl, AltBit or CtrlBit
                jne       DoPIB
                mov       word ptr ds:[72h], 1234h ;Warm boot flag.
                jmp       dword ptr cs:RebootAdrs  ;REBOOT Computer

RebootAdrs      dword     0ffff0000h            ;Reset address.


; Check for the INS key here. This one needs to toggle the ins bit
; in the keyboard flags variables.
```

```
TryIns:         cmp     al, InsScanCode
                jne     TryInsUp
                or      KbdFlags2, InsBit               ;Note INS is down.
                jmp     doPIB                           ;Pass on INS key.

TryInsUp:       cmp     al, InsScanCode+80h             ;INS up scan code.
                jne     TryLShiftDn
                and     KbdFlags2, not InsBit           ;Note INS is up.
                xor     KbdFlags, InsBit                ;Toggle INS bit.
                jmp     QuitPIB

; Handle the left and right shift keys down here.

TryLShiftDn:    cmp     al, LShiftScan
                jne     TryLShiftUp
                or      KbdFlags, LShfBit               ;Note that the left
                jmp     QuitPIB                         ; shift key is down.

TryLShiftUp:    cmp     al, LShiftScan+80h
                jne     TryRShiftDn
                and     KbdFlags, not LShfBit           ;Note that the left
                jmp     QuitPIB                         ; shift key is up.


TryRShiftDn:    cmp     al, RShiftScan
                jne     TryRShiftUp
                or      KbdFlags, RShfBit               ;Right shf is down.
                jmp     QuitPIB

TryRShiftUp:    cmp     al, RShiftScan+80h
                jne     TryAltDn
                and     KbdFlags, not RShfBit           ;Right shf is up.
                jmp     QuitPIB

; Handle the ALT key down here.

TryAltDn:       cmp     al, AltScan
                jne     TryAltUp
                or      KbdFlags, AltBit                ;Alt key is down.
GotoQPIB:       jmp     QuitPIB

TryAltUp:       cmp     al, AltScan+80h
                jne     TryCtrlDn
                and     KbdFlags, not AltBit            ;Alt key is up.
                jmp     DoPIB


; Deal with the control key down here.

TryCtrlDn:      cmp     al, CtrlScan
                jne     TryCtrlUp
                or      KbdFlags, CtrlBit               ;Ctrl key is down.
                jmp     QuitPIB

TryCtrlUp:      cmp     al, CtrlScan+80h
                jne     TryCapsDn
                and     KbdFlags, not CtrlBit           ;Ctrl key is up.
                jmp     QuitPIB

; Deal with the CapsLock key down here.

TryCapsDn:      cmp     al, CapsLockScan
                jne     TryCapsUp
                or      KbdFlags2, CLBit                ;Capslock is down.
                xor     KbdFlags, CLBit                 ;Toggle capslock.
                jmp     QuitPIB

TryCapsUp:      cmp     al, CapsLockScan+80h
                jne     TrySLDn
                and     KbdFlags2, not CLBit            ;Capslock is up.
                call    SetLEDs
                jmp     QuitPIB
```

```
; Deal with the Scroll Lock key down here.

TrySLDn:        cmp       al, ScrlLockScan
                jne       TrySLUp
                or        KbdFlags2, SLBit                ;Scrl lock is down.
                xor       KbdFlags, SLBit                 ;Toggle scrl lock.
                jmp       QuitPIB

TrySLUp:        cmp       al, ScrlLockScan+80h
                jne       TryNLDn
                and       KbdFlags2, not SLBit            ;Scrl lock is up.
                call      SetLEDs
                jmp       QuitPIB

; Handle the NumLock key down here.


TryNLDn:        cmp       al, NumLockScan
                jne       TryNLUp
                or        KbdFlags2, NLBit                ;Numlock is down.
                xor       KbdFlags, NLBit                 ;Toggle numlock.
                jmp       QuitPIB

TryNLUp:        cmp       al, NumLockScan+80h
                jne       DoPIB
                and       KbdFlags2, not NLBit            ;Numlock is up.
                call      SetLEDs
                jmp       QuitPIB



; Handle all the other keys here:

DoPIB:          test      al, 80h                        ;Ignore other up keys.
                jnz       QuitPIB

; If the H.O. bit is set at this point, we'd best only have a zero in AL.
; Otherwise, this is an up code which we can safely ignore.

                call      Convert
                test      ax, ax                          ;Chk for bad code.
                je        QuitPIB

PutCharInBuf:   push      cx
                mov       cx, ax
                mov       ah, 5                           ;Store scan code into
                int       16h                             ; type ahead buffer.
                pop       cx

QuitPIB:        and       KbdFlags3, 0FCh                 ;E0, E1 not last code.

Done:           pop bx
                pop ds
                ret
PutInBuffer     endp



;****************************************************************************
;
; Convert-      AL contains a PC Scan code. Convert it to an ASCII char/Scan
;               code pair and return the result in AX. This code assumes
;               that DS points at the BIOS variable space (40h).

Convert         proc      near
                push      bx

                test      al, 80h             ;See if up code
                jz        DownScanCode
                mov       ah, al
                mov       al, 0
                jmp       CSDone
```

```
; Okay, we've got a down key. But before going on, let's see if we've
; got an ALT-Keypad sequence.

DownScanCode: mov       bh, 0
              mov       bl, al
              shl       bx, 1             ;Multiply by eight to compute
              shl       bx, 1             ; row index index the scan
              shl       bx, 1             ; code xlat table

; Compute modifier index as follows:
;
;        if alt then modifier = 3

              test      KbdFlags, AltBit
              je        NotAlt
              add       bl, 3
              jmp       DoConvert

;        if ctrl, then modifier = 2

NotAlt:       test      KbdFlags, CtrlBit
              je        NotCtrl
              add       bl, 2
              jmp       DoConvert

; Regardless of the shift setting, we've got to deal with numlock
; and capslock. Numlock is only a concern if the scan code is greater
; than or equal to 47h. Capslock is only a concern if the scan code
; is less than this.

NotCtrl:      cmp       al, 47h
              jb        DoCapsLk
              test      KbdFlags, NLBit                  ;Test Numlock bit
              je        NoNumLck
              test      KbdFlags, LShfBit or RShfBit     ;Check l/r shift.
              je        NumOnly
              add       bl, 7                            ;Numlock and shift.
              jmp       DoConvert

NumOnly:      add       bl, 4                            ;Numlock only.
              jmp       DoConvert

; If numlock is not active, see if a shift key is:

NoNumLck:     test      KbdFlags, LShfBit or RShfBit     ;Check l/r shift.
              je        DoConvert                        ;normal if no shift.
              add       bl, 1
              jmp       DoConvert

; If the scan code's value is below 47h, we need to check for capslock.

DoCapsLk:     test      KbdFlags, CLBit                  ;Chk capslock bit
              je        DoShift
              test      KbdFlags, LShfBit or RShfBit     ;Chk for l/r shift
              je        CapsOnly
              add       bl, 6                            ;Shift and capslock.
              jmp       DoConvert

CapsOnly:     add       bl, 5                            ;Capslock
              jmp       DoConvert

; Well, nothing else is active, check for just a shift key.

DoShift:      test      KbdFlags, LShfBit or RShfBit     ;l/r shift.
              je        DoConvert
              add       bl, 1                            ;Shift

DoConvert:    shl       bx, 1                            ;Word array
              mov       ax, ScanXlat[bx]
CSDone:       pop       bx
              ret
Convert       endp
```

```
; SetCmd-       Sends the command byte in the AL register to the 8042
;               keyboard microcontroller chip (command register at
;               port 64h).

SetCmd          proc      near
                push      cx
                push      ax              ;Save command value.
                cli                       ;Critical region, no ints now.

; Wait until the 8042 is done processing the current command.

                xor       cx, cx          ;Allow 65,536 times thru loop.
Wait4Empty:     in        al, 64h         ;Read keyboard status register.
                test      al, 10b         ;Input buffer full?
                loopnz    Wait4Empty      ;If so, wait until empty.

; Okay, send the command to the 8042:

                pop       ax              ;Retrieve command.
                out       64h, al
                sti                       ;Okay, ints can happen again.
                pop       cx
                ret
SetCmd          endp



; SendCmd-      The following routine sends a command or data byte to the
;               keyboard data port (port 60h).

SendCmd         proc      near
                push      ds
                push      bx
                push      cx
                mov       cx, 40h
                mov       ds, cx
                mov       bx, ax          ;Save data byte

                mov       bh, 3           ;Retry cnt.
RetryLp:        cli                       ;Disable ints while accessing HW.

; Clear the Error, Acknowledge received, and resend received flags
; in KbdFlags4

                and       byte ptr KbdFlags4, 4fh

; Wait until the 8042 is done processing the current command.

                xor       cx, cx             ;Allow 65,536 times thru loop.
Wait4Empty:     in        al, 64h            ;Read keyboard status register.
                test      al, 10b            ;Input buffer full?
                loopnz    Wait4Empty         ;If so, wait until empty.

; Okay, send the data to port 60h

                mov       al, bl
                out       60h, al
                sti                          ;Allow interrupts now.

; Wait for the arrival of an acknowledgement from the keyboard ISR:

                xor       cx, cx             ;Wait a long time, if need be.
Wait4Ack:       test      byp KbdFlags4,10h ;Acknowledge received bit.
                jnz       GotAck
                loop      Wait4Ack
                dec       bh                 ;Do a retry on this guy.
                jne RetryLp

; If the operation failed after 3 retries, set the error bit and quit.

                or        byp KbdFlags4,80h ;Set error bit.
```

```
GotAck:         pop         cx
                pop         bx
                pop         ds
                ret
SendCmd         endp



; SetLEDs-      Updates the KbdFlags4 LED bits from the KbdFlags
;               variable and then transmits new flag settings to
;               the keyboard.

SetLEDs         proc        near
                push        ax
                push        cx
                mov         al, KbdFlags
                mov         cl, 4
                shr         al, cl
                and         al, 111b
                and         KbdFlags4, 0F8h   ;Clear LED bits.
                or          KbdFlags4, al     ;Mask in new bits.
                mov         ah, al            ;Save LED bits.

                mov         al, 0ADh          ;Disable kbd for now.
                call        SetCmd

                mov         al, 0EDh          ;8042 set LEDs cmd.
                call        SendCmd           ;Send the command to 8042.
                mov         al, ah            ;Get parameter byte
                call        SendCmd           ;Send parameter to the 8042.

                mov         al, 0AEh          ;Reenable keyboard.
                call        SetCmd
                mov         al, 0F4h          ;Restart kbd scanning.
                call        SendCmd
                pop         cx
                pop         ax
                ret
SetLEDs         endp


; MyInt9-       Interrupt service routine for the keyboard hardware
;               interrupt.

MyInt9          proc        far
                push        ds
                push        ax
                push        cx

                mov         ax, 40h
                mov         ds, ax

                mov         al, 0ADh          ;Disable keyboard
                call        SetCmd
                cli                           ;Disable interrupts.
                xor         cx, cx
Wait4Data:      in          al, 64h           ;Read kbd status port.
                test        al, 10b           ;Data in buffer?
                loopz       Wait4Data         ;Wait until data available.
                in          al, 60h           ;Get keyboard data.
                cmp         al, 0EEh          ;Echo response?
                je          QuitInt9
                cmp         al, 0FAh          ;Acknowledge?
                jne         NotAck
                or          KbdFlags4, 10h    ;Set ack bit.
                jmp         QuitInt9

NotAck:         cmp         al, 0FEh          ;Resend command?
                jne         NotResend
                or          KbdFlags4, 20h    ;Set resend bit.
                jmp         QuitInt9

; Note: other keyboard controller commands all have their H.O. bit set
```

```
; and the PutInBuffer routine will ignore them.

NotResend:      call        PutInBuffer         ;Put in type ahead buffer.

QuitInt9:       mov         al, 0AEh            ;Reenable the keyboard
                call        SetCmd

                mov         al, 20h             ;Send EOI (end of interrupt)
                out         20h, al             ; to the 8259A PIC.
                pop         cx
                pop         ax
                pop         ds
                iret
MyInt9          endp



Main            proc
                assume      ds:cseg

                mov         ax, cseg
                mov         ds, ax

                print
                byte        "INT 9 Replacement",cr,lf
                byte        "Installing....",cr,lf,0

; Patch into the INT 9 interrupt vector. Note that the
; statements above have made cseg the current data segment,
; so we can store the old INT 9 value directly into
; the OldInt9 variable.

                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], cs
                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             byte        1024 dup ("stack ")
sseg            ends

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

20.6 Patching into the INT 9 Interrupt Service Routine

For many programs, such as pop-up programs or keyboard enhancers, you may need to intercept certain "hot keys" and pass all remaining scan codes through to the default keyboard interrupt service routine. You can insert an int 9 interrupt service routine into an interrupt nine chain just like any other interrupt. When the keyboard interrupts the system to send a scan code, your interrupt service routine can read the scan code from port 60h and decide whether to process the scan code itself or pass control on to some other int 9 handler. The following program demonstrates this principle; it deactivates the ctrl-alt-del reset function on the keyboard by intercepting and throwing away delete scan codes when the ctrl and alt bits are set in the keyboard flags byte.

```
; NORESET.ASM
;
; A short TSR that patches the int 9 interrupt and intercepts the
; ctrl-alt-del keystroke sequence.
;
; Note that this code does not patch into int 2Fh (multiplex interrupt)
; nor can you remove this code from memory except by rebooting.
; If you want to be able to do these two things (as well as check for
; a previous installation), see the chapter on resident programs. Such
; code was omitted from this program because of length constraints.
;
;
; cseg and EndResident must occur before the standard library segments!

cseg            segment    para public 'code'
OldInt9         dword      ?
cseg            ends

; Marker segment, to find the end of the resident section.

EndResident     segment    para public 'Resident'
EndResident     ends

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


DelScanCode     equ        53h

; Bits for the various modifier keys

CtrlBit         equ        4
AltBit          equ        8


KbdFlags        equ        <byte ptr ds:[17h]>



cseg            segment    para public 'code'
                assume     ds:nothing


; SetCmd-       Sends the command byte in the AL register to the 8042
;               keyboard microcontroller chip (command register at
;               port 64h).

SetCmd          proc       near
                push       cx
                push       ax                  ;Save command value.
                cli                            ;Critical region, no ints now.

; Wait until the 8042 is done processing the current command.

                xor        cx, cx              ;Allow 65,536 times thru loop.
Wait4Empty:     in         al, 64h             ;Read keyboard status register.
```

```
                test        al, 10b             ;Input buffer full?
                loopnz      Wait4Empty          ;If so, wait until empty.

; Okay, send the command to the 8042:

                pop         ax                  ;Retrieve command.
                out         64h, al
                sti                             ;Okay, ints can happen again.
                pop         cx
                ret
SetCmd          endp


; MyInt9-       Interrupt service routine for the keyboard hardware
;               interrupt. Tests to see if the user has pressed a
;               DEL key. If not, it passes control on to the original
;               int 9 handler. If so, it first checks to see if the
;               alt and ctrl keys are currently down; if not, it passes
;               control to the original handler. Otherwise it eats the
;               scan code and doesn't pass the DEL through.

MyInt9          proc        far
                push        ds
                push        ax
                push        cx

                mov         ax, 40h
                mov         ds, ax

                mov         al, 0ADh            ;Disable keyboard
                call        SetCmd
                cli                             ;Disable interrupts.
                xor         cx, cx
Wait4Data:      in          al, 64h             ;Read kbd status port.
                test        al, 10b             ;Data in buffer?
                loopz       Wait4Data           ;Wait until data available.

                in          al, 60h             ;Get keyboard data.
                cmp         al, DelScanCode     ;Is it the delete key?
                jne         OrigInt9
                mov         al, KbdFlags        ;Okay, we've got DEL, is
                and         al, AltBit or CtrlBit ; ctrl+alt down too?
                cmp         al, AltBit or CtrlBit
                jne         OrigInt9

; If ctrl+alt+DEL is down, just eat the DEL code and don't pass it through.

                mov         al, 0AEh            ;Reenable the keyboard
                call        SetCmd

                mov         al, 20h             ;Send EOI (end of interrupt)
                out         20h, al             ; to the 8259A PIC.
                pop         cx
                pop         ax
                pop         ds
                iret

; If ctrl and alt aren't both down, pass DEL on to the original INT 9
; handler routine.

OrigInt9:       mov         al, 0AEh        ;Reenable the keyboard
                call        SetCmd

                pop         cx
                pop         ax
                pop         ds
                jmp         cs:OldInt9
MyInt9          endp



Main            proc
                assume      ds:cseg
```

```
                mov         ax, cseg
                mov         ds, ax

                print
                byte        "Ctrl-Alt-Del Filter",cr,lf
                byte        "Installing....",cr,lf,0

; Patch into the INT 9 interrupt vector. Note that the
; statements above have made cseg the current data segment,
; so we can store the old INT 9 value directly into
; the OldInt9 variable.

                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], cs
                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
```

20.7 Simulating Keystrokes

At one point or another you may want to write a program that passes keystrokes on to another application. For example, you might want to write a keyboard macro TSR that lets you capture certain keys on the keyboard and send a sequence of keys through to some underlying application. Perhaps you'll want to program an entire string of characters on a normally unused keyboard sequence (e.g., ctrl-up or ctrl--down). In any case, your program will use some technique to pass characters to a foreground application. There are three well-known techniques for doing this: store the scan/ASCII code directly in the keyboard buffer, use the 80x86 *trace* flag to simulate `in al, 60h` instructions, or program the on-board 8042 microcontroller to transmit the scan code for you. The next three sections describe these techniques in detail.

20.7.1 Stuffing Characters in the Type Ahead Buffer

Perhaps the easiest way to insert keystrokes into an application is to insert them directly into the system's type ahead buffer. Most modern BIOSes provide an int 16h function to do this (see "The Keyboard

BIOS Interface” on page 1168). Even if your system does not provide this function, it is easy to write your own code to insert data in the system type ahead buffer; or you can copy the code from the int 16h handler provided earlier in this chapter.

The nice thing about this approach is that you can deal directly with ASCII characters (at least, for those key sequences that are ASCII). You do not have to worry about sending shift up and down codes around the scan code for tn “A” so you can get an upper case “A”, you need only insert 1E41h into the buffer. In fact, most programs ignore the scan code, so you can simply insert 0041h into the buffer and almost any application will accept the funny scan code of zero.

The major drawback to the buffer insertion technique is that many (popular) applications bypass DOS and BIOS when reading the keyboard. Such programs go directly to the keyboard’s port (60h) to read their data. As such, shoving scan/ASCII codes into the type ahead buffer will have no effect. Ideally, you would like to stuff a scan code directly into the keyboard controller chip and have it return that scan code as though someone actually pressed that key. Unfortunately, there is no universally compatible way to do this. However, there are some close approximations, keep reading...

20.7.2 Using the 80x86 Trace Flag to Simulate IN AL, 60H Instructions

One way to deal with applications that access the keyboard hardware directly is to *simulate* the 80x86 instruction set. For example, suppose we were able to take control of the int 9 interrupt service routine and execute each instruction under our control. We could choose to let all instructions *except* the `in` instruction execute normally. Upon encountering an `in` instruction (that the keyboard ISR uses to read the keyboard data), we check to see if it is accessing port 60h. If so, we simply load the `al` register with the desired scan code rather than actually execute the `in` instruction. It is also important to check for the `out` instruction, since the keyboard ISR will want to send and EOI signal to the 8259A PIC after reading the keyboard data, we can simply ignore `out` instructions that write to port 20h.

The only difficult part is telling the 80x86 to pass control to our routine when encountering certain instructions (like `in` and `out`) and to execute other instructions normally. While this is not directly possible in real mode[7], there is a close approximation we can make. The 80x86 CPUs provide a *trace* flag that generates an exception after the execution of each instruction. Normally, debuggers use the trace flag to single step through a program. However, by writing our own exception handler for the trace exception, we can gain control of the machine between the execution of every instruction. Then, we can look at the opcode of the next instruction to execute. If it is not an `in` or `out` instruction, we can simply return and execute the instruction normally. If it is an `in` or `out` instruction, we can determine the I/O address and decide whether to simulate or execute the instruction.

In addition to the `in` and `out` instructions, we will need to simulate any `int` instructions we find as well. The reason is because the `int` instruction pushes the flags on the stack and then clears the trace bit in the flags register. This means that the interrupt service routine associated with that `int` instruction would execute normally and we would miss any `in` or `out` instructions appearing therein. However, it is easy to simulate the `int` instruction, leaving the trace flag enabled, so we will add `int` to our list of instructions to interpret.

The only problem with this approach is that it is slow. Although the trace trap routine will only execute a few instructions on each call, it does so for every instruction in the int 9 interrupt service routine. As a result, during simulation, the interrupt service routine will run 10 to 20 times slower than the real code would. This generally isn’t a problem because most keyboard interrupt service routines are very short. However, you might encounter an application that has a large internal int 9 ISR and this method would noticeably slow the program. However, for most applications this technique works just fine and no one will notice any performance loss while they are typing away (slowly) at the keyboard.

7. It is possible to trap I/O instructions when running in protected mode.

The following assembly code provides a short example of a trace exception handler that simulates keystrokes in this fashion:

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

cseg          segment    para public 'code'
              assume     ds:nothing

; ScanCode must be in the Code segment.

ScanCode      byte       0


;****************************************************************************
;
; KbdSim- Passes the scan code in AL through the keyboard controller
; using the trace flag. The way this works is to turn on the
; trace bit in the flags register. Each instruction then causes a trace
; trap. The (installed) trace handler then looks at each instruction to
; handle IN, OUT, INT, and other special instructions. Upon encountering
; an IN AL, 60 (or equivalent) this code simulates the instruction and
; returns the specified scan code rather than actually executing the IN
; instruction. Other instructions need special treatment as well. See
; the code for details. This code is pretty good at simulating the hardware,
; but it runs fairly slow and has a few compatibility problems.


KbdSim        proc       near

              pushf
              push       es
              push       ax
              push       bx


              xor        bx, bx             ;Point es at int vector tbl
              mov        es, bx             ; (to simulate INT 9).
              cli                           ;No interrupts for now.
              mov        cs:ScanCode, al    ;Save output scan code.

              push       es:[1*4]           ;Save current INT 1 vector
              push       es:2[1*4]          ; so we can restore it later.


; Point the INT 1 vector at our INT 1 handler:

              mov        word ptr es:[1*4], offset MyInt1
              mov        word ptr es:[1*4 + 2], cs



; Turn on the trace trap (bit 8 of flags register):

              pushf
              pop        ax
              or         ah, 1
              push       ax
              popf


; Simulate an INT 9 instruction. Note: cannot actually execute INT 9 here
; since INT instructions turn off the trace operation.


              pushf
              call       dword ptr es:[9*4]
```

```
; Turn off the trace operation:


                pushf
                pop         ax
                and         ah, 0feh            ;Clear trace bit.
                push        ax
                popf


; Disable trace operation.


                pop         es:[1*4 + 2]        ;Restore previous INT 1
                pop         es:[1*4]            ; handler.


; Okay, we're done. Restore registers and return.

VMDone:         pop         bx
                pop         ax
                pop         es
                popf
                ret
KbdSim          endp



;----------------------------------------------------------------------------
;
; MyInt1- Handles the trace trap (INT 1). This code looks at the next
; opcode to determine if it is one of the special opcodes we have to
; handle ourselves.


MyInt1          proc        far
                push        bp
                mov         bp, sp              ;Gain access to return adrs via BP.
                push        bx
                push        ds

; If we get down here, it's because this trace trap is directly due to
; our having punched the trace bit. Let's process the trace trap to
; simulate the 80x86 instruction set.
;
; Get the return address into DS:BX

NextInstr:      lds         bx, 2[bp]

; The following is a special case to quickly eliminate most opcodes and
; speed up this code by a tiny amount.

                cmp         byte ptr [bx], 0cdh ;Most opcodes are less than
                jnb         NotSimple           ; 0cdh, hence we quickly
                pop         ds                  ; return back to the real
                pop         bx                  ; program.
                pop         bp
                iret

NotSimple:      je          IsIntInstr          ;If it's an INT instruction.

                mov         bx, [bx]            ;Get current instruction's opcode.
                cmp         bl, 0e8h            ;CALL opcode
                je          ExecInstr
                jb          TryInOut0

                cmp         bl, 0ech            ;IN al, dx instr.
                je          MayBeIn60
                cmp         bl, 0eeh            ;OUT dx, al instr.
                je          MayBeOut20
                pop         ds                  ;A normal instruction if we get
                pop         bx                  ; down here.
                pop         bp
                iret
```

```
TryInOut0:     cmp        bx, 60e4h     ;IN al, 60h instr.
               je         IsINAL60
               cmp        bx, 20e6h     ;out 20, al instr.
               je         IsOut20

; If it wasn't one of our magic instructions, execute it and continue.

ExecInstr:     pop        ds
               pop        bx
               pop        bp
               iret

; If this instruction is IN AL, DX we have to look at the value in DX to
; determine if it's really an IN AL, 60h instruction.

MayBeIn60:     cmp        dx, 60h
               jne        ExecInstr
               inc        word ptr 2[bp]    ;Skip over this 1 byte instr.
               mov        al, cs:ScanCode
               jmp        NextInstr

; If this is an IN AL, 60h instruction, simulate it by loading the current
; scan code into AL.

IsInAL60:      mov        al, cs:ScanCode
               add        word ptr 2[bp], 2 ;Skip over this 2-byte instr.
               jmp        NextInstr


; If this instruction is OUT DX, AL we have to look at DX to see if we're
; outputting to location 20h (8259).

MayBeOut20:    cmp        dx, 20h
               jne        ExecInstr
               inc        word ptr 2[bp]    ;Skip this 1 byte instruction.
               jmp        NextInstr

; If this is an OUT 20h, al instruction, simply skip over it.

IsOut20:       add        word ptr 2[bp], 2 ;Skip instruction.
               jmp        NextInstr


; IsIntInstr- Execute this code if it's an INT instruction.
;
; The problem with the INT instructions is that they reset the trace bit
; upon execution. For certain guys (see above) we can't have that.
;
; Note: at this point the stack looks like the following:
;
;       flags
;
;       rtn cs -+
;               |
;       rtn ip  +-- Points at next instr the CPU will execute.
;       bp
;       bx
;       ds
;
; We need to simulate the appropriate INT instruction by:
;
;       (1)   adding two to the return address on the stack (so it returns
;             beyond the INT instruction.
;       (2)   pushing the flags onto the stack.
;       (3)   pushing a phony return address onto the stack which simulates
;             the INT 1 interrupt return address but which "returns" us to
;             the specified interrupt vector handler.
;
; All this results in a stack which looks like the following:
;
;       flags
;
;       rtn cs -+
```

```
;               |
;       rtn ip  +-- Points at next instr beyond the INT instruction.
;
;       flags   --- Bogus flags to simulate those pushed by INT instr.
;
;       rtn cs -+
;               |
;       rtn ip  +-- "Return address" which points at the ISR for this INT.
;       bp
;       bx
;       ds


IsINTInstr:     add         word ptr 2[bp], 2 ;Bump rtn adrs beyond INT instr.
                mov         bl, 1[bx]
                mov         bh, 0
                shl         bx, 1             ;Multiply by 4 to get vector
                shl         bx, 1             ; address.

                push        [bp-0]            ;Get and save BP
                push        [bp-2]            ;Get and save BX.
                push        [bp-4]            ;Get and save DS.

                push        cx
                xor         cx, cx            ;Point DS at interrupt
                mov         ds, cx            ; vector table.

                mov         cx, [bp+6]        ;Get original flags.
                mov         [bp-0], cx        ;Save as pushed flags.

                mov         cx, ds:2[bx]      ;Get vector and use it as
                mov         [bp-2], cx        ; the return address.
                mov         cx, ds:[bx]
                mov         [bp-4], cx

                pop         cx
                pop         ds
                pop         bx
                pop         bp
                iret
;
MyInt1          endp



; Main program - Simulates some keystrokes to demo the above code.

Main            proc

                mov         ax, cseg
                mov         ds, ax

                print
                byte        "Simulating keystrokes via Trace Flag",cr,lf
                byte        "This program places 'DIR' in the keyboard buffer"
                byte        cr,lf,0

                mov         al, 20h           ;"D" down scan code
                call        KbdSim
                mov         al, 0a0h          ;"D" up scan code
                call        KbdSim

                mov         al, 17h           ;"I" down scan code
                call        KbdSim
                mov         al, 97h           ;"I" up scan code
                call        KbdSim

                mov         al, 13h           ;"R" down scan code
                call        KbdSim
                mov         al, 93h           ;"R" up scan code
                call        KbdSim

                mov         al, 1Ch           ;Enter down scan code
```

```
                call      KbdSim
                mov       al, 9Ch             ;Enter up scan code
                call      KbdSim



                ExitPgm
Main            endp


cseg            ends

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

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

20.7.3 Using the 8042 Microcontroller to Simulate Keystrokes

Although the trace flag based "keyboard stuffer" routine works with most software that talks to the hardware directly, it still has a few problems. Specifically, it doesn't work at all with programs that operate in protected mode via a "DOS Extender" library (programming libraries that let programmers access more than one megabyte of memory while running under DOS). The last technique we will look at is to program the on-board 8042 keyboard microcontroller to transmit a keystroke for us. There are two ways to do this: the PS/2 way and the hard way.

The PS/2's microcontroller includes a command specifically designed to return user programmable scan codes to the system. By writing a 0D2h byte to the controller command port (64h) and a scan code byte to port 60h, you can force the controller to return that scan code as though the user pressed a key on the keyboard. See "The Keyboard Hardware Interface" on page 1159 for more details.

Using this technique provides the most compatible (with existing software) way to return scan codes to an application. Unfortunately, this trick only works on machines that have keyboard controllers that are compatible with the PS/2's; this is not the majority of machines out there. However, if you are writing code for PS/2s or compatibles, this is the best way to go.

The keyboard controller on the PC/AT and most other PC compatible machines does not support the 0D2h command. Nevertheless, there is a sneaky way to force the keyboard controller to transmit a scan code, if you're willing to break a few rules. This trick may not work on all machines (indeed, there are many machines on which this trick is known to fail), but it does provide a workaround on a large number of PC compatible machines.

The trick is simple. Although the PC's keyboard controller doesn't have a command to return a byte you send it, it does provide a command to return the keyboard controller command byte (KCCB). It also provides another command to write a value to the KCCB. So by writing a value to the KCCB and then issuing the read KCCB command, we can trick the system into returning a user programmable code. Unfortunately, the KCCB contains some undefined reserved bits that have different meanings on different brands of keyboard microcontroller chips. That is the main reason this technique doesn't work with all machines. The following assembly code demonstrates how to use the PS/2 and PC keyboard controller stuffing methods:

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

cseg            segment    para public 'code'
```

```
                assume      ds:nothing

;*****************************************************************************
;
; PutInATBuffer-
;
; The following code sticks the scan code into the AT-class keyboard
; microcontroller chip and asks it to send the scan code back to us
; (through the hardware port).
;
; The AT keyboard controller:
;
; Data port is at I/O address 60h
; Status port is at I/O address 64h (read only)
; Command port is at I/O address 64h (write only)
;
; The controller responds to the following values sent to the command port:
;
; 20h - Read Keyboard Controller's Command Byte (KCCB) and send the data to
; the data port (I/O address 60h).
;
; 60h - Write KCCB. The next byte written to I/O address 60h is placed in
; the KCCB. The bits of the KCCB are defined as follows:
;
;       bit 7- Reserved, should be a zero
;       bit 6- IBM industrial computer mode.
;       bit 5- IBM industrial computer mode.
;       bit 4- Disable keyboard.
;       bit 3- Inhibit override.
;       bit 2- System flag
;       bit 1- Reserved, should be a zero.
;       bit 0- Enable output buffer full interrupt.
;
;       AAh - Self test
;       ABh - Interface test
;       ACh - Diagnostic dump
;       ADh - Disable keyboard
;       AEh - Enable keyboard
;       C0h - Read Keyboard Controller input port (equip installed)
;       D0h - Read Keyboard Controller output port
;       D1h - Write Keyboard Controller output port
;       E0h - Read test inputs
;       F0h - FFh - Pulse Output port.
;
; The keyboard controller output port is defined as follows:
;
;       bit 7 - Keyboard data (output)
;       bit 6 - Keyboard clock (output)
;       bit 5 - Input buffer empty
;       bit 4 - Output buffer full
;       bit 3 - undefined
;       bit 2 - undefined
;       bit 1 - Gate A20
;       bit 0 - System reset (0=reset)
;
; The keyboard controller input port is defined as follows:
;
;       bit 7 - Keyboard inhibit switch (0=inhibited)
;       bit 6 - Display switch (0=color, 1= mono)
;       bit 5 - Manufacturing jumper
;       bit 4 - System board RAM (0=disable 2nd 256K RAM on system board).
;       bits 0-3 - undefined.
;
; The keyboard controller status port (64h) is defined as follows:
;
;       bit 1 - Set if input data (60h) not available.
;       bit 0 - Set if output port (60h) cannot accept data.


PutInATBuffer   proc        near
                assume      ds:nothing
                pushf
                push        ax
```

```
                push        bx
                push        cx
                push        dx


                mov         dl, al              ;Save char to output.

; Wait until the keyboard controller does not contain data before
; proceeding with shoving stuff down its throat.

                xor         cx, cx
WaitWhlFull:    in          al, 64h
                test        al, 1
                loopnz      WaitWhlFull


; First things first, let's mask the interrupt controller chip (8259) to
; tell it to ignore interrupts coming from the keyboard. However, turn the
; interrupts on so we properly process interrupts from other sources (this
; is especially important because we're going to wind up sending a false
; EOI to the interrupt controller inside the INT 9 BIOS routine).

                cli
                in          al, 21h             ;Get current mask
                push        ax                  ;Save intr mask
                or          al, 2               ;Mask keyboard interrupt
                out         21h, al

; Transmit the desired scan code to the keyboard controller. Call this
; byte the new keyboard controller command (we've turned off the keyboard,
; so this won't affect anything).
;
; The following code tells the keyboard controller to take the next byte
; sent to it and use this byte as the KCCB:


                call        WaitToXmit
                mov         al, 60h             ;Write new KCCB command.
                out         64h, al

; Send the scan code as the new KCCB:

                call        WaitToXmit
                mov         al, dl
                out         60h, al

; The following code instructs the system to transmit the KCCB (i.e., the
; scan code) to the system:

                call        WaitToXmit
                mov         al, 20h             ;"Send KCCB" command.
                out         64h, al

                xor         cx, cx
Wait4OutFull:   in          al, 64h
                test        al, 1
                loopz       Wait4OutFull

; Okay, Send a 45h back as the new KCCB to allow the normal keyboard to work
; properly.

                call        WaitToXmit
                mov         al, 60h
                out         64h, al

                call        WaitToXmit
                mov         al, 45h
                out         60h, al

; Okay, execute an INT 9 routine so the BIOS (or whoever) can read the key
; we just stuffed into the keyboard controller. Since we've masked INT 9
; at the interrupt controller, there will be no interrupt coming along from
; the key we shoved in the buffer.
```

```
DoInt9:         in          al, 60h             ;Prevents ints from some codes.
                int         9                   ;Simulate hardware kbd int.


; Just to be safe, reenable the keyboard:

                call        WaitToXmit
                mov         al, 0aeh
                out         64h, al

; Okay, restore the interrupt mask for the keyboard in the 8259a.

                pop         ax
                out         21h, al

                pop         dx
                pop         cx
                pop         bx
                pop         ax
                popf
                ret
PutInATBuffer   endp



; WaitToXmit-   Wait until it's okay to send a command byte to the keyboard
;               controller port.

WaitToXmit      proc        near
                push        cx
                push        ax
                xor         cx, cx
TstCmdPortLp:   in          al, 64h
                test        al, 2           ;Check cntrlr input buffer full flag.
                loopnz      TstCmdPortLp
                pop         ax
                pop         cx
                ret
WaitToXmit      endp



;****************************************************************************
;
; PutInPS2Buffer- Like PutInATBuffer, it uses the keyboard controller chip
;                to return the keycode. However, PS/2 compatible controllers
;                have an actual command to return keycodes.

PutInPS2Buffer proc         near
                pushf
                push        ax
                push        bx
                push        cx
                push        dx

                mov         dl, al              ;Save char to output.

; Wait until the keyboard controller does not contain data before
; proceeding with shoving stuff down its throat.

                xor         cx, cx
WaitWhlFull:    in          al, 64h
                test        al, 1
                loopnz      WaitWhlFull


; The following code tells the keyboard controller to take the next byte
; sent to it and return it as a scan code.


                call        WaitToXmit
                mov         al, 0d2h            ;Return scan code command.
                out         64h, al
```

```
; Send the scan code:

                call        WaitToXmit
                mov         al, dl
                out         60h, al

                pop         dx
                pop         cx
                pop         bx
                pop         ax
                popf
                ret
PutInPS2Buffer endp


; Main program - Simulates some keystrokes to demo the above code.

Main            proc

                mov         ax, cseg
                mov         ds, ax

                print
                byte        "Simulating keystrokes via Trace Flag",cr,lf
                byte        "This program places 'DIR' in the keyboard buffer"
                byte        cr,lf,0

                mov         al, 20h             ;"D" down scan code
                call        PutInATBuffer
                mov         al, 0a0h            ;"D" up scan code
                call        PutInATBuffer

                mov         al, 17h             ;"I" down scan code
                call        PutInATBuffer
                mov         al, 97h             ;"I" up scan code
                call        PutInATBuffer

                mov         al, 13h             ;"R" down scan code
                call        PutInATBuffer
                mov         al, 93h             ;"R" up scan code
                call        PutInATBuffer

                mov         al, 1Ch             ;Enter down scan code
                call        PutInATBuffer
                mov         al, 9Ch             ;Enter up scan code
                call        PutInATBuffer

                ExitPgm
Main            endp


cseg            ends

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

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

20.8 Summary

This chapter might seem excessively long for such a mundane topic as keyboard I/O. After all, the Standard Library provides only one primitive routine for keyboard input, getc. However, the keyboard on the PC is a complex beast, having no less than two specialized microprocessors controlling it. These microprocessors accept commands from the PC and send commands and data to the PC. If you want to write some tricky keyboard handling code, you need to have a firm understanding of the keyboard's underlying hardware.

This chapter began by describing the actions the system takes when a user presses a key. As it turns out, the system transmits two *scan codes* every time you press a key – one scan code when you press the key and one scan code when you release the key. These are called down codes and up codes, accordingly. The scan codes the keyboard transmits to the system have little relationship to the standard ASCII character set. Instead, the keyboard uses its own character set and relies upon the keyboard interrupt service routine to translate these scan codes to their appropriate ASCII codes. Some keys do not have ASCII codes, for these keys the system passes along an *extended key code* to the application requesting keyboard input. While translating scan codes to ASCII codes, the keyboard interrupt service routine makes use of certain BIOS flags that track the position of the *modifier* keys. These keys include the shift, ctrl, alt, capslock, and numlock keys. These keys are known as modifiers because the modify the normal code produced by keys on the keyboard. The keyboard interrupt service routine stuffs incoming characters in the system *type ahead buffer* and updates other BIOS variables in segment 40h. An application program or other system service can access this data prepared by the keyboard interrupt service routine. For more information, see

• "Keyboard Basics" on page 1153

The PC interfaces to the keyboard using two separate microcontroller chips. These chips provide user programming registers and a very flexible command set. If you want to program the keyboard beyond simply reading the keystrokes produced by the keyboard (i.e., manipulate the LEDs on the keyboard), you will need to become familiar with the registers and command sets of these microcontrollers. The discussion of these topics appears in

• "The Keyboard Hardware Interface" on page 1159

Both DOS and BIOS provide facilities to read a key from the system's type ahead buffer. As usual, BIOS' functions provide the most flexibility in terms of getting at the hardware. Furthermore, the BIOS int 16h routine lets you check shift key status, stuff scan/ASCII codes into the type ahead buffer, adjust the autorepeat rate, and more. Given this flexibility, it is difficult to understand why someone would want to talk directly to the keyboard hardware, especially considering the compatibility problems that seem to plague such projects. To learn the proper way to read characters from the keyboard, and more, see

• "The Keyboard DOS Interface" on page 1167
• "The Keyboard BIOS Interface" on page 1168

Although accessing the keyboard hardware directly is a bad idea for most applications, there is a small class of programs, like keyboard enhancers and pop-up programs, that really do need to access the keyboard hardware directly. These programs must supply an interrupt service routine for the int 9 (keyboard) interrupt. For all the details, see:

• "The Keyboard Interrupt Service Routine" on page 1174
• "Patching into the INT 9 Interrupt Service Routine" on page 1184

A keyboard macro program (keyboard enhancer) is a perfect example of a program that might need to talk directly to the keyboard hardware. One problem with such programs is that they need to pass characters along to some underlying application. Given the nature of applications present in the world, this can be a difficult task if you want to be compatible with a large number of PC applications. The problems, and some solutions, appear in

• "Simulating Keystrokes" on page 1186
• "Stuffing Characters in the Type Ahead Buffer" on page 1186
• "Using the 80x86 Trace Flag to Simulate IN AL, 60H Instructions" on page 1187
• "Using the 8042 Microcontroller to Simulate Keystrokes" on page 1192