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Contents

Introduction and Welcome

These are the Proceedings of the IBM Personal Computer Seminar, designed for independent developers of products for IBM Personal Computers. The purpose of these Proceedings is to aid you in your development efforts by providing relevant information about new product announcements and enhancements to existing products. This issue is prepared in conjunction with this seminar. The Proceedings of future seminars for IBM Personal Computers also will be published and will cover topics presented at those seminars.

This issue of the Proceedings is devoted to the IBM PC Convertible and related offerings. These offerings include the IBM Personal Computer Disk Operating System (DOS) Version 3.2 and the IBM Personal Computer 3.5" External Diskette Drive.

Throughout these Proceedings, the term IBM Personal Computer and the term family of IBM Personal Computers address the IBM Personal Computer, the IBM Personal Computer XT, the IBM PC*jr*, the IBM *Portable* Personal Computer, the IBM Personal Computer AT and the IBM PC Convertible (referred to as PC Convertible).

Purpose

What is our purpose in issuing a publication such as this? It is quite simple.

The IBM Personal Computer family is a resounding success. We've had a lot of help in achieving this success, and much of it came from the independent developers.

As you proceed with your development, do you at times wish for some bit of information or direction which would make the job easier? Information which IBM can provide? This is the type of information we want to make available to you.

Since we want to be assured of giving you the information you need, we ask you to complete the questionnaire which appears at the end of these Proceedings. Your response to this questionnaire will be taken into account in preparing the content of future issues, as well as the content of seminars we will present at microcomputer industry trade shows.

Topics

The following list gives a general indication of the topics we plan to cover in future seminars and include in the IBM Personal Computer Seminar Proceedings:

- Information exchange forum — letters to the editor format
- Development tools — languages, database offerings
- Compatibility issues
- New devices — capacities and speeds
- System capacities — disk and memory
- Enhancements in maintenance releases
- Tips and techniques
- New system software
- Hardware design parameters
- Tips on organizing and writing documents for clear and easy reading
- Changes to terms and conditions

IBM PC Convertible Architecture

System Unit

The IBM PC Convertible is a battery-operated, portable member of the IBM Personal Computer family. The system unit is the center of the PC Convertible and contains the processor, two 3.5" diskette drives, keyboard, removable liquid crystal display (LCD), internal memory, power supply and battery pack. An AC adapter is included for powering the system unit and recharging the battery. A *Guide to Operations* Manual is included which optionally contains the IBM Application Selector.

Optional features can be added to the IBM PC Convertible which are either installed internally or attached to the back of the system unit. These features include additional internal memory, an internal modem, a portable printer, a Serial/Parallel Adapter and a CRT Display Adapter. Also available are a Monochrome and a Color Display which were specifically designed for the PC Convertible.

The major components of the IBM PC Convertible system unit are:

- Processor
- System clock
- System timer
- Interrupt controller
- Direct-memory-access (DMA) controller
- Read-only memory (ROM)
- Random-access (read-write) memory (RAM)
- Input/output (I/O) channel
- Liquid crystal display (LCD)
- LCD controller
- Keyboard
- Keyboard controller
- Audio controller and speaker
- Diskette drive
- Diskette controller
- Portable printer interface
- Real-time clock
- Power supply.

Figure 1 on page 3 shows an overview of the functional units.

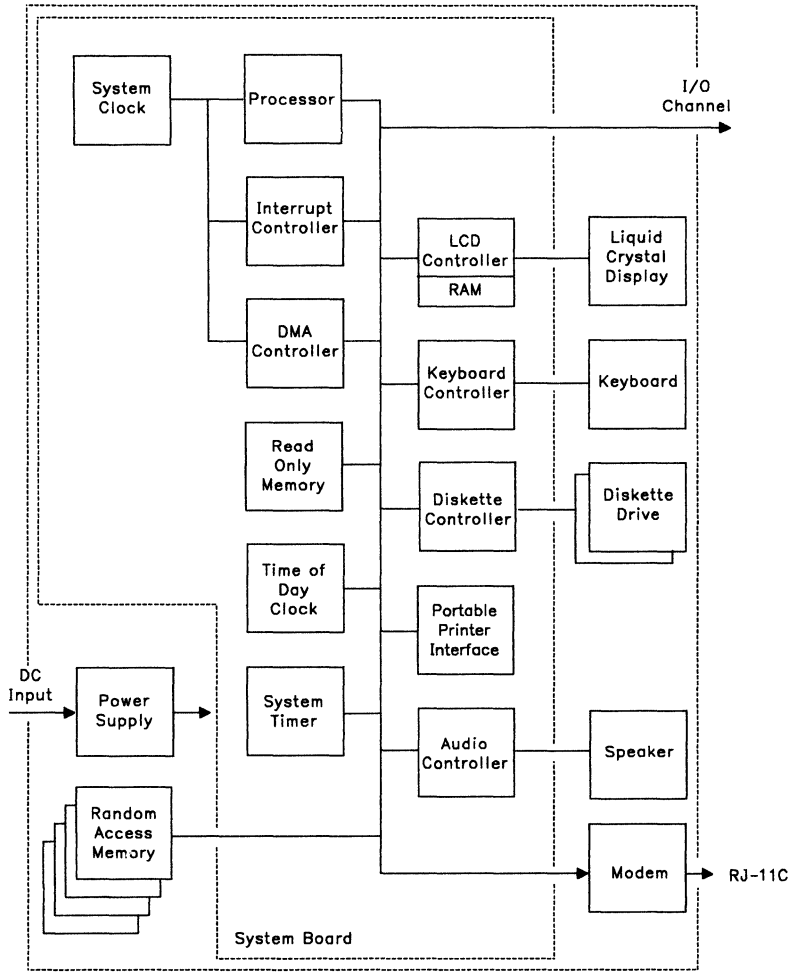

Figure 1. IBM PC Convertible System Unit Functional Units

Many of the components are installed on the system board. Figure 2 shows the major components on the system board:

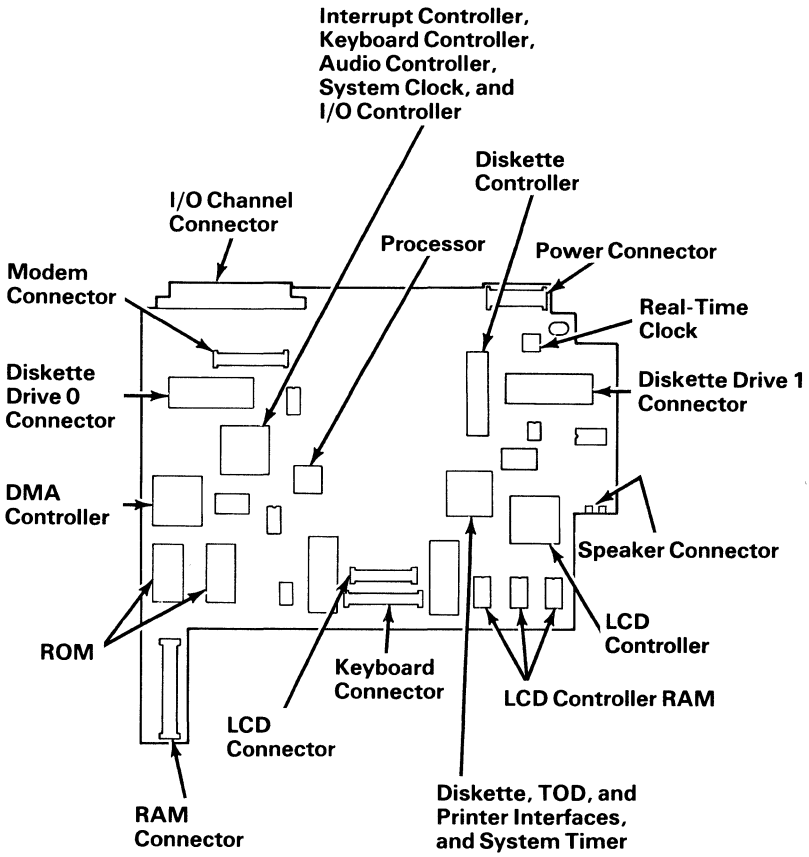

Figure 2. System Board Components

Processor

The processor used in the IBM PC Convertible is directly compatible with the Intel®[1] 8088 Microprocessor, and it is compatible with the instruction set used for the Intel 8086 Microprocessor family. The processor in the IBM PC Convertible uses a 16-bit internal architecture with an 8-bit data bus interface. This processor has a 20-bit address bus that supports a 1-megabyte address space.

1 Registered trademark of Intel Corporation.

The internal circuitry of the processor is static, and the internal registers, counters and latches do not require continuous clocking for refresh. The processor operates at a 4.77 MHz clock rate.

System Resources

System Clock

The system clock consists of a continuously running clock and a software-controlled clock. The continuously running clock provides continuous timing pulses at the maximum clock frequency. The software-controlled clock (the sleep clock) is used to operate the processor and other system components that do not require constant operation. The sleep clock can be stopped using a BIOS function call that causes the processor to enter standby mode to conserve battery power.

The 4.77 MHz processor clock rate is derived by dividing a 14.3181 MHz oscillator frequency by 3. The clock period is 210 nanoseconds. The clock has a 33 percent duty cycle.

The system clock supports a sleep mode that stops the system clock when the system is waiting for some nonprocessor event to occur. The wait for an external event BIOS function call (interrupt hex 15) is used to access the sleep function. BIOS automatically invokes the sleep function for the keyboard and diskette functions. When the system is in sleep mode, interrupts are processed as normal. After each interrupt is serviced, control is returned to the sleep function to determine if the requested event has occurred. If the event has occurred, control is returned to the application; otherwise, sleep mode is reentered.

System Timer

The system timer provides functions and modes similar to those provided by an Intel 8253 Programmable Interval Timer. The timer provides two programmable timer channels. Timer 0 is used as a general purpose and software-interrupt timer. Timer 0 does not support modes 1 and 5. Timer 2 is used to support the tone generation for the audio speaker.

The timer channel clock rate is derived by dividing a 4.77 MHz clock frequency by 4. Each channel has a minimum timing resolution of 840 nanoseconds.

Interrupt Controller

The interrupt controller is fully programmable and uses an interface and command set that is compatible with the Intel 8259 Programmable Interrupt Controller.

The interrupt controller does not support rotating priority. Additionally, when programmed in the special mask mode, the current level must be masked as soon as it is entered.

The power-on routines set the controller to edge-triggered mode with the interrupt vectors assigned to processor vectors 8 through 16. Each interrupt requires an end-of-interrupt command to reset the interrupt service.

The interrupt controller supports nine levels of interrupts; there is one nonmaskable interrupt (NMI) level and eight maskable interrupt levels. Interrupt levels 2-7 are available at the system I/O channel. Interrupt levels 0, 1, 6 and 7 are used on the system board.

Direct Memory Access (DMA) Controller

The direct memory access controller provides functions similar to those provided by the Intel 8237 Programmable Direct Memory Access Controller. The IBM PC Convertible DMA controller supports three DMA channels on the I/O channel. Memory refresh using the DMA controller is not supported because the system RAM does not require refresh.

The DMA method allows certain I/O devices to transfer information to or from memory without using the processor. The DMA channels are accessed by the I/O devices through commands sent over the I/O channel.

The DMA controller supports single, block and demand transfer modes. All DMA data transfers require five clock cycles or 1.05 microseconds per byte.

The DMA controller does not support automatic initialization, rotating priority, cascading or memory-to-memory transfers.

Read-Only Memory (ROM)

The system ROM is made up of two 32K by 8-bit modules. The two modules are arranged in a 64K by 8-bit configuration. The ROM is assigned addresses hex F0000 through hex FFFFF. Figure 3 shows the mapping of ROM.

ROM does not use parity.

Address (hex)	Length (K Bytes)	Usage
F0000	24	POST, BIOS
F6000	32	Resident BASIC
FE000	8	POST, BIOS

Figure 3. ROM Map

Random Access Memory (RAM)

The RAM is used to store application programs and user data. All RAM is static and does not require refresh. RAM does not use parity. The RAM is contained on cards; each card has 128K bytes of storage. A maximum of four cards can be installed in the system.

I/O Channel

The I/O channel is an extension of the internal bus used by the processor and other functional units in the IBM PC Convertible. The channel contains multiplexed, low-order, address/data lines (bidirectional), high-order address lines, six interrupt control lines, memory and I/O read or write control lines, clock and timing lines, three DMA control lines, a channel-check line, and power and ground lines for the optional features. A serial printer interface for the IBM PC Convertible Printer is also provided on the I/O channel connector.

Memory (RAM or ROM) can be addressed on the I/O channel only above address hex A0000 (640K). Memory reads or writes below that address are directed to the RAM connector.

The lines of the I/O channel are provided at the rear of the system unit on a 72-pin connector. Figures 4 and 5 show the pin locations and the signal definitions in the I/O connector on the back of the system unit. The plus (+) or minus (-) preceding the signal name indicates the active state of the signals. The input/output column indicates whether the signal direction is to or from the system unit. The I/O signals have sufficient drive to power up to two CMOS loads, plus one low-power Schottky (LS) TTL load.

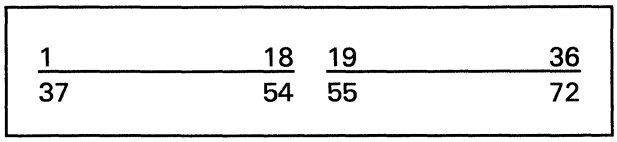

Diagram of the I/O Connector

I/O Pin	Signal Name	Input/Output
01	Shell ground	Ground
02	+Address Latch Enable	Output
03	+5 V DC	Power
04	+Address Enable	Output
05	+I/O Channel Ready	Input
06	Ground	Ground
07	Spare	
08	Ground	Ground
09	-I/O Channel Check	Input
10	+Sleep Clock	Output
11	+Terminal Count	Output
12	+12 V DC	Power
13	-I/O Write	Output
14	-Memory Read	Output
15	-Memory Write	Output
16	+Adapter Power	Power
17	+Address Bit 10	Output
18	+Address Bit 11	Output
19	+Address Bit 12	Output
20	+Address Bit 13	Output
21	+Address Bit 14	Output
22	+Address Bit 15	Output
23	+Address Bit 16	Output
24	+Address Bit 17	Output
25	-13 V DC	Power
26	Ground	Ground
27	+Address Bit 18	Output
28	+Address Bit 19	Output
29	+Power Adapter Active	Output
30	+Printer Power	Power

Figure 4. (Part 1 of 2) System I/O Connector

I/O Pin	Signal Name	Input/Output
31	Ground	Ground
32	-Transmit Data	Output
33	-Printer Error	Input
34	+Printer Enable	Output
35	-Printer Busy	Input
36	Shell Ground	Ground
37	+Address/Data Bit 0	Input/Output
38	+Address/Data Bit 1	Input/Output
39	+Address/Data Bit 2	Input/Output
40	+Address/Data Bit 3	Input/Output
41	+Address/Data Bit 4	Input/Output
42	+Address/Data Bit 5	Input/Output
43	+Address/Data Bit 6	Input/Output
44	+Address/Data Bit 7	Input/Output
45	+Address Bit 8	Output
46	Ground	Ground
47	+Address Bit 9	Output
48	+Interrupt Request 4	Input
49	-I/O Read	Output
50	+Reset	Output
51	-Data Enable	Output
52	Reserved	
53	Ground	Ground
54	+DMA Request 1	Input
55	-DMA Acknowledge 1	Output
56	Ground	Ground
57	+DMA Request 2	Input
58	-DMA Acknowledge 2	Output
59	+DMA Request 3	Input
60	Ground	Ground
61	-DMA Acknowledge 3	Output
62	+Interrupt Request 2	Input
63	+Interrupt Request 3	Input
64	Ground	Ground
65	+Interrupt Request 6	Input
66	Spare	
67	+Interrupt Request 5	Input
68	Spare	
69	Reserved	
70	+Power Enable	Output
71	Ground	Ground
72	+Interrupt Request 7	Input

Figure 5. **(Part 2 of 2) System I/O Connector**

The following paragraphs describe the interface lines:

Address/Data Bit 0 through 7: These multiplexed lines are used to form either the low-order bits of an address or a byte of data. At the falling edge of the 'address latch enable' signal, the attachments access these eight lines along with lines 'address bit 8' through 'address bit 19' to form a 20-bit address. At the low level of signal 'memory read', 'memory write', 'I/O read' or 'I/O write', the attachments access these eight lines to form a data byte. The least significant bit is 'address/data bit 0.'

Address Bit 8 Through 15: These lines are used to address memory and I/O devices within the system.

Address Bit 16 Through 19: These multiplexed lines contain either address or status bits. At the falling edge of the 'address latch enable' signal, the attachments access these lines to complete a 20-bit address. These lines are inactive during I/O operations.

Sleep Clock: This line provides the sleep clock pulses. It has a 210 nanoseconds (4.77 MHz) cycle.

During sleep mode (waiting for I/O activity), this clock may be stopped. It resumes at normal speed when an interrupt or DMA request is received. When the clock is stopped, this line is set to the low level.

Reset: This line is used to reset or initialize the system logic during the power-on sequence.

Address Latch Enable: This line is used to indicate that the address bus (address and data bit 0 through 19) contains a valid address. Because the address bus is multiplexed, the I/O attachments must use the falling edge of the 'address latch enable' signal to latch processor addresses 0 through 7 and 16 through 19.

I/O Channel Check: This line indicates an I/O device error.

I/O Channel Ready: This line is used by I/O devices or memory devices to lengthen the I/O or memory cycle. This is done by forcing the line to low level (not ready); the cycle is then extended by any number of complete 'clock' cycles (210 nanoseconds). Devices using this line should force it to low level immediately after detecting a valid address and either a read or write command.

Interrupt Request 2 Through 7: These lines are used to signal the processor that an I/O device requires attention. The lines are in order of priority with 'interrupt request 2' having the highest priority and 'interrupt request 7' having the lowest priority. An interrupt request is generated by raising a line to the high level and maintaining that level until the interrupt service routine acknowledges the request.

I/O Read: This command line is used by either the processor or DMA controller to instruct an I/O device to place data on the data bus.

I/O Write: This command line is used by either the processor or DMA controller to instruct an I/O device to read the data on the data bus.

Memory Read: This command line is used by either the processor or DMA controller to instruct the addressed memory device to place data on the data bus.

Memory Write: This command line is used by either the processor or DMA controller to instruct the addressed memory device to store the data that is present on the data bus.

DMA Request 1, 2 and 3: These lines are used by the I/O devices to request DMA data transfers. The lines are in order of priority with 'DMA request 1' having the highest priority and 'DMA request 3' the lowest. A request is generated when a 'DMA request' line is activated. The line must be held active until the corresponding 'DMA acknowledge' line is activated.

DMA Acknowledge 1, 2 and 3: These lines are used by the DMA controller to acknowledge DMA data transfer requests.

Terminal Count: This line is used to indicate that the byte count has reached a count of zero and is active at the completion of a DMA operation.

Address Enable: This line indicates that the DMA controller has control of the I/O channel during DMA transfer operations.

Data Enable: This line indicates when data should be gated onto the multiplexed address/data bus.

Adapter Power: This line provides an unregulated DC output (+9.2 to +16.0 volts) when either the automobile or the AC adapter is powering the system, regardless of whether or not the power enable signals are active. The output is routed to the I/O connector to power external attachments.

Power Adapter Active: This line is used by the attached devices to detect when the IBM PC Convertible is operating on the battery, so that the devices can reduce their power consumption or turn

themselves off. The line is provided by the power supply. An "up" level indicates that the system power is being supplied by the AC adapter or automobile power adapter.

Power Enable: This line is used to indicate when power is applied to the system.

Transmit Data: This line contains the serial data for the printer. A low level indicates a "mark" condition and a high level indicates a "space" condition. The line operates at 1200 bits per second and the data consists of 8 data bits and 2 stop bits. Parity bits are not used.

Printer Busy: This line is used by the printer to indicate when it is no longer able to accept data (offline, printing, buffer full, page eject or error condition). When this line is at the low level, the printer cannot accept data.

Printer Error: This line is used by the printer to indicate when the printer has an error condition that needs attention from the operator. A low level indicates a printer error (offline, paper out, or end of ribbon).

Printer Power: This line provides an unregulated DC output (+8.0 to +16.0 volts) when a charged battery pack, AC adapter or automobile power adapter is powering the system. The output is used to power the printer.

Printer Enable: This line is used to reset the IBM PC Convertible Printer and control the standby/active status of the printer. An "up" level on this line causes the printer to become ready.

Real-Time Clock

The real-time clock provides the time of day with alarm, 100-year calendar and programmable interrupt functions. The clock operates in either 12- or 24-hour mode and compensates for daylight savings time, end of month and leap years. The real-time clock uses a Motorola MC146818A Real-Time Clock (or equivalent).

The IBM PC Convertible uses three types of real-time clock interrupts:

Periodic Interrupt: This interrupt is used by the post/wait-on-time (interrupt hex 15) function calls. This interrupt can occur once every 976.56 microseconds.

Alarm Interrupt: This interrupt is used by the time-of-day (interrupt hex 1A) interrupt to activate the system at a specified time and to notify an application that a specified time of day has been reached. This interrupt causes an alarm (interrupt hex 4A) function call and can occur once every 24 hours, unless the interrupt is set to a new time or reset within a 24-hour period.

Update Ended Interrupt: This interrupt is activated by BIOS when the LCD blank, low-battery warning or auto-power-off options are enabled in the system profile. The interrupt is used as a time base to determine if keyboard or diskette activity does not occur within a given period of time. The interrupt can occur once each second.

The real-time clock function and registers should be accessed through BIOS function interrupts (interrupt hex 1A).

Power Supply

The power supply is contained inside the system unit and provides the power for the system unit and attachments. The supply provides five voltage levels and is rated at 12 watts.

The supply accepts input from four DC sources: a battery pack, an AC adapter, an automobile adapter or a battery charger (used only to charge the batteries).

Onboard I/O Subsystems

Liquid Crystal Display (LCD) and Controller

The display for the IBM PC Convertible is a liquid-crystal, dot matrix display capable of displaying 25 lines of 80 characters or 640 by 200 picture elements (pels).

The LCD can be disconnected from the system when a monitor is connected to the system.

The LCD controller provides the interface to the liquid crystal display.

The LCD controller is compatible with programs that use the IBM Monochrome Display Adapter or the IBM Color/Graphics Display Adapter. To accomplish this, the LCD controller uses two address ranges for control registers, one for monochrome operations and one for color/graphics operations. The operation and register interface of the LCD controller are similar to operation and interface of the Motorola 6845 CRT Controller.

The LCD controller can address 16K bytes of display storage (used for video refresh) and supports up to 512 different character codes in two font storage areas. One of the font storage areas contains the main font, while the other contains the alternate font. The power-on routines initialize the

font areas to the IBM PC character set that is stored in read-only memory. Both areas are initialized to the same character set at system power-on time.

The LCD controller supports two basic modes of operation, alphanumeric and graphics (all points addressable). In alphanumeric mode, the LCD controller maps the character and attribute information in the refresh buffer to the display panel, using the data in the font storage area. In graphics mode, the LCD controller directly maps the refresh buffer to the display panel on a bit-per-pel (picture element) basis.

For monochrome operations, the IBM PC Convertible LCD controller operates similarly to the IBM Personal Computer Monochrome Display Adapter. Characters are displayed within an 8-by-8 dot matrix, using the character set stored in the font storage area. Monochrome operations use a 16K-byte refresh buffer that starts at address hex B0000.

For color/graphics operations, the IBM PC Convertible LCD controller operates similarly to the IBM Personal Computer Color/Graphics Display Adapter. Characters are displayed within an 8-by-8 dot matrix. The characters are stored in the font storage area in RAM. The LCD can display 640 by 200 pels of information in color/graphics mode. Color/graphics operations use a 16K byte refresh buffer that starts at address hex B8000.

Programming Considerations: Depending on the application, the display control registers and refresh buffer can occupy one of two possible ranges. Monochrome applications use display control registers in the hex 3B0 through hex 3BF range and refresh buffer in the hex B0000 through hex B3FFF range. Color/graphics applications use display control registers in the hex 3D0 through hex 3DF range and refresh buffer in the hex B8000 through hex BBFFF range.

Monochrome or color/graphics operation can be selected through the system profile. An application can change the operating mode by using the video I/O function call provided by BIOS. This is accomplished by modifying the video bit mask in the equipment word and using the mode set function of the interrupt hex 10 BIOS function call. If the IBM PC Convertible CRT Display Adapter is installed, the LCD is set up to emulate the IBM Personal Computer Monochrome Display Adapter and this mode cannot be changed.

Applications that directly access the refresh buffer do not need to synchronize the access with vertical and horizontal syncs. Additionally, the application does not need to disable video while accessing the refresh buffer. The LCD controller automatically resolves any memory contention without affecting the display. Disabling video during an access may result in faint scan lines at the top and middle of the display panel.

Keyboard and Keyboard Controller

The keyboard consists of 78 keys, a printed circuit board, a cable and a connector to attach the keyboard to the system board. The system board supplies the drive and sense lines for the key switches.

The keyboard was designed to be smaller in size to facilitate portability; yet it provides full size typing keys, convenient cursor operation and full scan code compatibility with the IBM Personal Computer. The reduction in width was accomplished in part by providing the numeric keypad function as an overlay in the typing area.

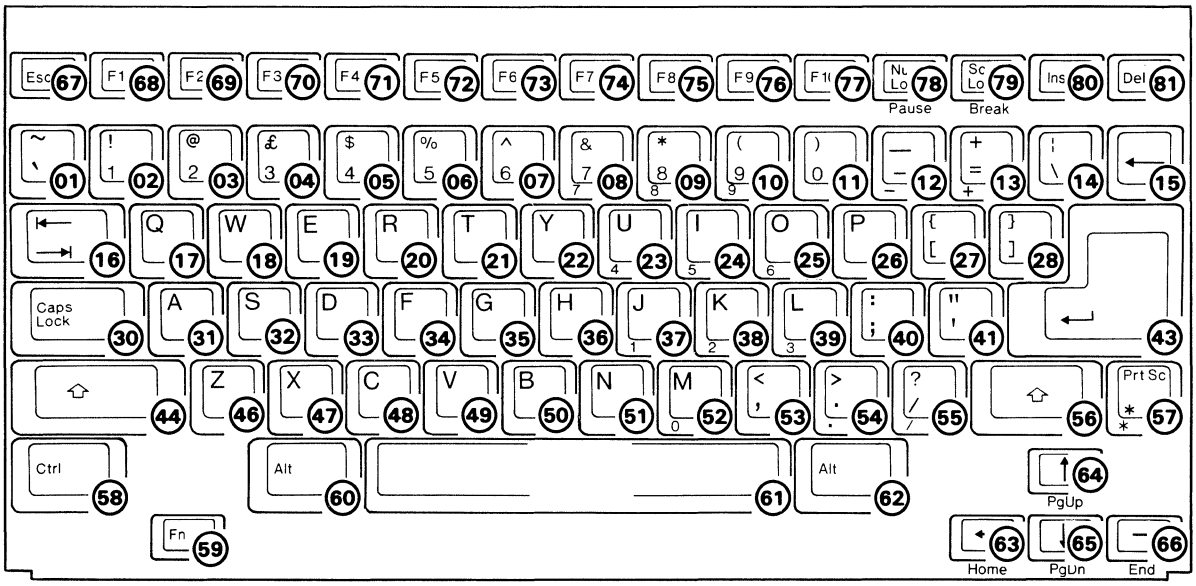

Figure 6. U.S. English Keyboard

The keyboard controller logic provides key detection, debounce and typematic functions for the keyboard. The system processor provides scan code buffering (up to 16 codes) while the keyboard interrupt (hardware level 1) or CPU interrupts are disabled. The BIOS keyboard preprocessing routines also provide translation of the keyboard codes into IBM PC Family compatible scan codes and generation of a hardware level 1 interrupt.

When the keyboard controller detects a keystroke, the BIOS keyboard preprocessing routine is activated by a NMI. The row/column coordinate is read and either buffered or translated to a compatible scan code and written to keyboard data port 60H. Writing the scan code to port 60H generates a hardware level 1 interrupt request to the conventional keyboard interrupt handler.

The keyboard and BIOS preprocessing routine allow all 83 IBM Personal Computer Family scan codes to be keyed along with System Request, F11 and F12. As shown in Figure 6, the keyboard layout and usage is somewhat different from previous IBM PC systems. The Function (Fn) key is used with other keys to generate scan codes normally found in the keypad section of other IBM Personal Computers.

For example, holding the Fn key and pressing the cursor movement keys will generate Home, End, Pg Up and Pg Dn. The keypad numerics, the plus sign (+), the minus sign (-), the multiply sign (*) , the divide sign (/) and the decimal point (.) are generated by pressing the corresponding key with the Fn key held down or while in keypad-active state.

Note that the keypad functions and the cursor movement keys have been separated onto different keys. Since these functions were previously on the same keys and distinguished by the Numeric Lock state, the BIOS preprocessing function controls the Numeric Lock state on a per key basis. This is accomplished by the preprocessor changing the state of the NUM_STATE flag in the KB_FLAG data area to cause the conventional keyboard interrupt routine to process the keys with the intended function. The state of this flag may be changed at any time by the BIOS preprocessing routine due to translation of keys, except when the keyboard interrupt (hardware level 1) routine is active. During this time, the NUM_STATE flag will reflect the correct state for the scan code currently being processed. When scan codes to be interpreted as keypad functions are received, BIOS

will set the NUM_STATE flag. When cursor movement functions are required, the BIOS preprocessing routine will reset the NUM_STATE flag. When the NUM_STATE flag has no bearing on the scan code being processed, the flag will indicate the activation state of the Inboard Keypad. This numeric keypad section may be activated and deactivated by a toggle function of the Fn + NumLock key combinations.

Diskette Drive and Controller

The IBM PC Convertible diskette drive supports 3.5" (90-millimeter) double-sided, double-density diskettes with a formatted capacity of 720K bytes.

The diskette drive uses modified frequency modulation (MFM) to read and write digital data, with a track-to-track access time of 6 milliseconds.

The diskette is loaded by inserting it into the slot. Guides in the slot ensure that the diskette is in the correct position. When the drive is selected, the servo-controlled DC drive motor starts and drives the hub at a constant speed of 300 revolutions per minute (RPM). The head positioning system, which consists of a stepper motor and its associated electronics, moves the magnetic head to the desired track of the diskette. The stepper motor assembly uses one step-pulse to cause a one-track linear movement of the magnetic head. During a write operation, a 0.115 millimeter (0.0045") data track is recorded with a 0.1875 millimeter (0.0073") spacing (center-to-center) between the tracks. This allows 135 tracks per inch (TPI).

Data is read from the diskette by the data-recovery circuitry, which consists of a low-level read amplifier, differentiator, zero-crossing detector and digitizing circuits. All data decoding is done by the diskette controller.

The diskette drive also has the following sensor systems:

- A track 00 sensor that detects when the head/carriage assembly is at track 00
- The write-protect sensor that senses the position of the write-protect tab
- The diskette-changed sensor that detects when a diskette has been removed from the drive
- The index sensor that detects the index marker

The diskette controller consists of custom logic and a NEC μPD765 Floppy Disk Controller (or equivalent) that resides on the system board. The diskette controller attaches to the diskette drives through an internal interface. The timings and signal sequences are similar to the industry standard 133.4 millimeter (5.25") diskette drive specification.

The diskette controller supports double-density, modified frequency modulation (MFM)-coded diskette drives and uses write precompensation with an analog phase-lock loop for clock and data recovery. The diskette drive parameters are programmable. In addition, the controller supports the diskette drive's write-protect feature. The controller uses direct memory access (DMA) for record data transfers. Interrupt level 6 is used to indicate when an operation is complete and that a status condition requires processor attention.

In order to conserve power, power to the controller is removed whenever the diskette drives are powered off. Any attempt to access the diskette controller when power is off causes an NMI to be signaled to the processor. BIOS then restores power to and initializes the controller before returning control to the requesting program.

Audio Controller and Speaker

The audio controller is used to drive the speaker. The controller receives control signals from both the I/O register and the system timers. The channel from the system timers is programmable within the functions of the timer with a 1.19 MHz input frequency. The speaker connects to a connector on the system board. The audio controller programming interface is compatible with the IBM PC single voice audio controller.

System Options

Serial/Parallel Adapter

The IBM PC Convertible Serial/Parallel Adapter provides both serial (RS-232C) communications and parallel printer interface adapters in a single external module. These adapters share a common system interface; however, the functions of these adapters are logically separate and are described in two parts.

The IBM PC Convertible Serial/Parallel Adapter provides the same basic functions as the IBM Personal Computer Asynchronous Communications Adapter. However, additional commands are provided to allow programming to control local power to the adapter. These commands are processed by the PC Convertible BIOS.

The serial adapter provides functions equivalent to those provided by an INS8250A Asynchronous Communications Element in conjunction with system and EIA interfaces. The Power-On Self

Test (POST) routines determine the presence of communications adapters by using the work (scratch) register within the INS8250A Asynchronous Communications Element. These routines will not be able to detect the presence of adapters that do not contain this register.

Applications that process multiple interrupt conditions from the INS8250A Asynchronous Communications Element must service and clear all interrupt conditions before exiting the interrupt service routine. Failure to clear all interrupt conditions can result in failure of the application program.

The serial interface is set to primary or secondary by BIOS. If the IBM PC Convertible Internal Modem is installed, BIOS sets the serial interface to secondary; otherwise, the serial interface is set to primary.

The adapter can be programmed to operate from 110 baud to 9600 baud through a BIOS function call (interrupt hex 14).

Local power to the serial/parallel adapter is controlled through system software. When the system unit is powered on and external power is being used, the serial/parallel adapter is automatically activated by the power-on routines. The system profile is used to determine if power is to be applied to the adapter when the system unit is operating on battery power.

The parallel interface (parallel printer interface) is specifically designed to attach printers that have a parallel interface. The interface can also be used as a general purpose input/output port for any device or application that matches its input/output capabilities.

Internal Modem

The IBM PC Convertible Internal Modem provides a phone line interface. The Internal Modem can be programmed to operate at line speeds of 1200, 300 or 110 bits per second. It is connected to the system board.

The Internal Modem consists of two major elements: a communication element (an INS8250A Asynchronous Communications Element or equivalent) and a modem (modulator-demodulator) element. The communications element is controlled through the system registers. The modem element is controlled by the modem commands that are passed to the modem element in the data stream. The modem commands are stripped from the data stream and executed; they are not transmitted to the receiving station.

The power-on routines initialize the communications element. The modem element is initialized automatically at power-on from parameters in the system profile:

- Baud rate: 110, 300 or 1200 (1200 is the default)
- Parity: Even, odd, mark, space or none (even is the default)
- Answer: Automatic or manual (manual is the default).

The default parameters can be changed through a system profile utility or through a BIOS function call (interrupt hex 15).

The Power-On Self Test routines determine the presence of communications adapters by using the work (scratch) register within the INS8250A Asynchronous Communications Element. These routines will not be able to detect the presence of adapters that do not contain this register.

Applications that process multiple interrupt conditions from the INS8250A Asynchronous Communications Element must service and clear all interrupt conditions before exiting the interrupt service routine. Failure to clear all interrupt conditions can result in failure of the application program.

Local power to the internal modem is controlled through system software. When the system is powered on and external power is being used, the internal modem is automatically activated by the power-on routines. The system profile is used to determine if power is to be applied to the internal modem when the system is operating on battery power. Applications can control power to the internal modem through a BIOS function call (interrupt hex 15).

All pacing of the interface and control signal status must be handled by the application program.

CRT Display Adapter

The IBM PC Convertible CRT Display Adapter provides the interface required to attach compatible direct drive and composite monitors to the IBM PC Convertible. It also allows a television set to be connected to the IBM PC Convertible when a radio frequency (rf) modulator is used.

The CRT display adapter is compatible with programs that use the IBM Color/Graphics Display Adapter. The operation and register interface of the CRT display adapter are similar to operation and interface of the Motorola 6845 CRT Controller.

The adapter contains 16K bytes of display storage (refresh buffer) and supports up to 256 different character codes. The refresh buffer is located at address hex B8000.

The adapter has two basic modes of operation, alphanumeric and graphics (all points addressable). In alphanumeric mode, the adapter uses a character generator to map character information to the display. Characters are displayed in an 8-by-8 dot matrix. Alphanumeric mode supports two resolutions, low resolution (25 rows by 40 characters) and high resolution (25 rows by 80 characters).

In graphics mode, the adapter maps the information to the display on a bit-per-pel (picture element) basis. Two resolutions are available in this mode, 320 pels by 200 rows (medium resolution) and 640 pels by 200 rows (high resolution). High resolution supports only black and white images.

The adapter is active only when the IBM PC Convertible is connected to external power. When the adapter is active and the LCD is attached, the LCD is configured to emulate the IBM Personal Computer Monochrome Adapter.

If the display attached to the CRT display adapter is the active display and the system is powered-off, the application that is operating in the system is not saved and cannot be resumed. The application must be reloaded after the next power-on if the application is to be run.

Printer

The IBM PC Convertible Printer is a low-power, serial dot matrix printer that attaches to the back of the system unit. An optional cable is available that allows the printer to be used near the system unit. Printing speed (in 10 pitch) is approximately 40 characters per second (cps) burst. In addition to the standard ASCII character set, the printer can print bit-image graphics.

The printer has a buffer than can store up to 2000 bytes of character and bit-image graphics data. This printer is designed to be compatible with the IBM Personal Computer Graphics Printer command set.

Monochrome Display

The IBM PC Convertible monochrome display is a 9-inch (measured diagonally) composite video monitor, which is attached to the IBM PC Convertible CRT display adapter. The monitor operates on AC only.

Color Display

The IBM PC Convertible Color Display is a 13-inch (measured diagonally) color monitor, which is attached to the IBM PC Convertible CRT Display Adapter. The monitor operates on AC only.

Application Selector and SystemApps

General Description

The Application Selector is an optional application module which provides the user with a menu driven interface and various SystemApps. Application programs and SystemApps may be loaded and executed via a single keystroke from the Application Selector menu. The Application Selector menu consists of icon representations of the functions assigned to the system function keys (F-keys). An application or SystemApp can be selected by depressing the F-Key assigned to it.

The Application Selector remains in memory coexistent with the application program while it is running. The user may suspend an active application program or SystemApp and return to the Application Selector menu via the function escape (Fn-Esc) keystroke sequence. While in the Application Selector menu, the user may execute any of the SystemApps and/or resume execution of the suspended application program. When an application program terminates, execution returns to the Application Selector menu. The user also has direct access to DOS by pressing the DOS F-key. This loads an additional copy of COMMAND.COM into memory and presents the DOS prompt. Here the user may run an application program or issue various DOS commands. The user may return from DOS to the Application Selector by using the DOS EXIT command.

The F-Keys in the Application Selector menu may be configured by the user through use of a tools SystemApp. Applications can be assigned in any order to both normal and shifted F-keys via the Set F-keys tool. The user can also specify the label that is to appear above the F-key icon.

The Application Selector and SystemApps require DOS 3.2 to execute.

SystemApps: The SystemApps are a logical extension of the Application Selector and provide the user with functions that are commonly used. The user can execute the SystemApps alone from the Application Selector menu or in the middle of the execution of an application via the Fn-Esc keystroke sequence.

There are four SystemApps which provide the following functions: Calculator, Notewriter, Schedule and Phone List. There is also a tools SystemApp that provides easy access to certain DOS functions and the System Profile Utility. The System Profile Utility provides for the selection of system options. These system options include setting the real time clock, selecting the display mode, control of various power savings options and control of modem states. The System Profile Utility is designed to also operate independent of the Application Selector and can be executed directly from DOS.

When a SystemApp is selected it is loaded into the memory allocated by the Application Selector specifically for the SystemApps. Once the SystemApp is loaded, it remains resident as part of the Application Selector until a different SystemApp takes its place. This feature allows the user to switch back and forth between an application and a SystemApp under the Application Selector.

Packaging and Installation

The Application Selector and associated SystemApps are shipped on the Start-Up Diskette packaged in the *Guide to Operations* for the IBM PC Convertible system. The Start-Up Diskette boots and displays an initial menu that allows the user to run either the Exploring Program, the Diagnostics or a Software Setup (install) program.

The Setup program directs the user through a step by step process of creating the Application Selector system diskette that will be the user's working copy. This process copies the Application Selector and SystemApps to the system diskette and gives the user the option of merging DOS with the Application Selector. Without DOS, the Application Selector cannot load and execute application programs, and the Tools Application cannot set F-Keys, Format or Print. When the user adds DOS via the Setup program, the following features are added to the Application Selector:

- The Application Selector menu displays empty diskettes for the normal and shifted F-keys that are available.
- DOS is assigned to the F7 function key.
- The Tools Application adds the Print, Format and Set F-Keys functions.

Initialization and Operation

Normally, the Application Selector is initiated by booting the system diskette created by the Setup program. The Application Selector performs the following when first loaded:

- A shell is created to interface to DOS.
- Memory is allocated and reserved for the SystemApps.
- The initial Application Selector menu is displayed.

At this point, the user may select a SystemApp or program application to run from the Application Selector menu.

The SystemApps are designed so that they may be run under the Application Selector or directly under DOS. All the SystemApps are COM files that contain relocatable code. The SystemApps may be executed under DOS by simply using the SystemApp file name. The SystemApps have no optional parameters.

Configuration: The Application Selector comes with a pre-configured menu that contains the F-keys already defined for the SystemApps shipped with the IBM PC Convertible system. The user may load and execute any of the SystemApps at this point or reconfigure the F-keys as required. In order to run an application, the user must first configure the F-keys to contain the desired applications by using the Set F-Keys program in the Tools Application. After the F-keys are configured, the user may exit the tool and return to the Application Selector to load and execute this application via an F-key. Configuring the F-keys stores the new information on the diskette in the Application Selector's APPSEL.COM file.

Termination: The Application Selector is terminated by re-booting the system with a regular DOS diskette. The Application Selector is then overlaid by DOS and is no longer accessible.

Technical Information

Memory Requirements: Application Selector adds 88K bytes to the memory required to run an application. Together with DOS 3.2 at 44K bytes and the System Overhead at 2K, the memory requirement totals 134K bytes, as shown if Figure 7. If an application is loaded via Application Selector and there is insufficient memory, the Application Selector will automatically deallocate the memory space reserved for the SystemApps and reattempt to load the application. While this memory is deallocated, the Application Selector is not capable of application suspension.

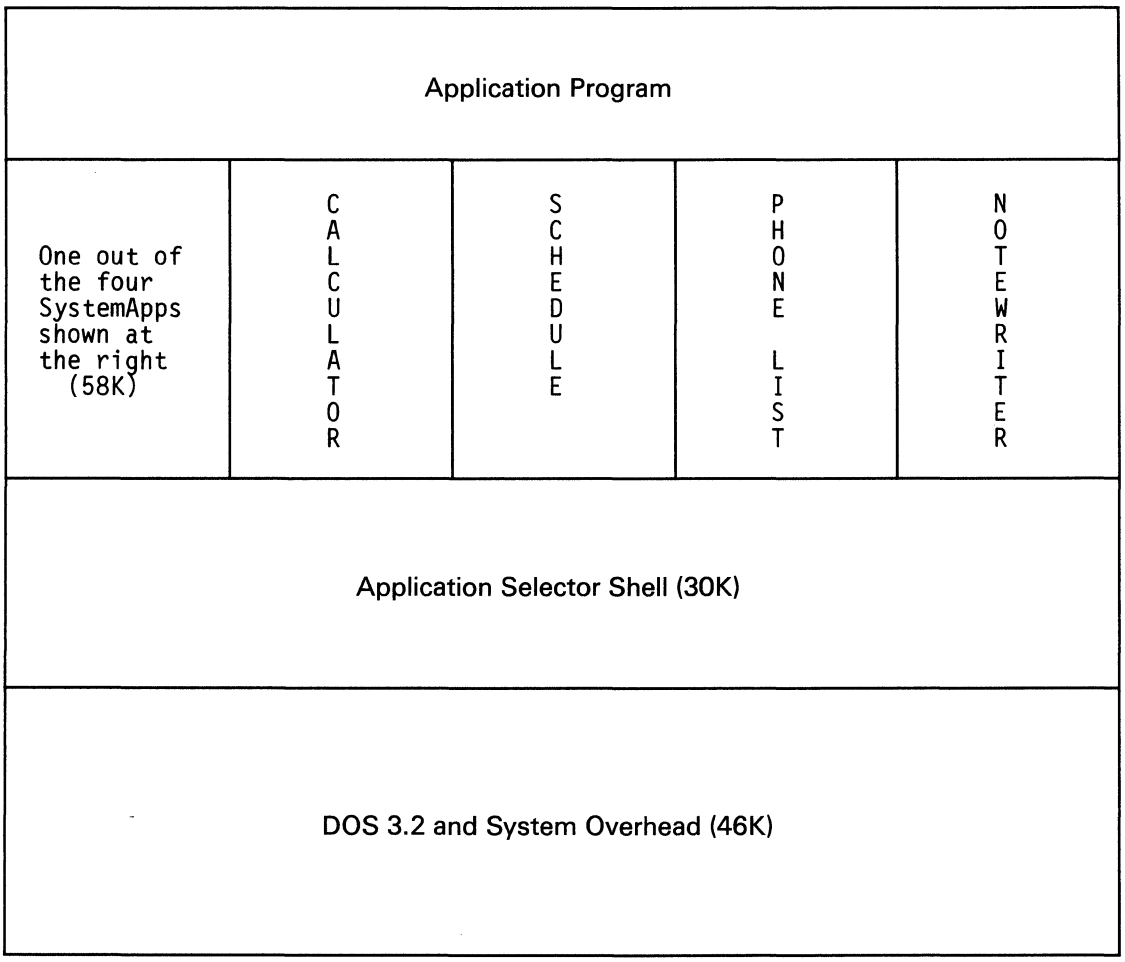

Figure 7. Application and DOS in Memory

Data Set Conventions: Standard DOS naming conventions are used for files in the Application Selector and the SystemApps. The Notewriter and Phone List SystemApps append an optional extension to the file name when no extension is specified. Notewriter files and Phone List files may be accessed by each other and other application programs using standard ASCII files (files that use CR/LF to separate lines). The files used by the schedule program should not be accessed by other applications due to their internal format.

SystemApp	Type of File	File Name	File Size
Notewriter	Text file containing ASCII characters.	User defined filename with an optional extension. Default extension of .NW is used when none is specified. Path names are supported.	Limited to work buffer of 12K bytes.
Phone List	Text file containing ASCII characters.	A default of PHONE.LST is initially selected and used. The user may select a different filename to use via the GET F-Key. User defined filename with an optional extension. Default extension of .LST is used when none is specified. Path names are supported.	Limited to work buffer of 12K bytes.
Schedule	Binary file containing ASCII text and numbers. File uses a special internal format.	The file names for the schedule program are self generated. The schedule program uses files with no extension. File names have the format of a 2 digit year. (Example: "021985" for February 1985) No path names are supported.	Limited to work buffer of 4K bytes per day schedule. The minimum file size is 1K and the maximum file size is 128K.
Calculator	Not applicable	Not applicable	N/A

Figure 8. Data Set Naming Conventions

Reserved File Names: The Application Selector uses reserved file names to identify the SystemApps. Figure 9 lists the reserved file names used by the Application Selector and the SystemApps:

Program	File Name	Purpose
Application Selector	APPSEL.COM	The Application Selector Shell
Notewriter	NOTEWTR.COM	Notewriter SystemApp
Phone List	PHONELST.COM	Phone List SystemApp
Schedule	SCHEDULE.COM	Schedule SystemApp
Calculator	CALC.COM	Calculator SystemApp
Tools	TOOLS.COM SYSPROF.COM	Tools Application System Profile Command
General	COMMAND.COM FORMAT.COM PRINT.COM DISKCOPY.COM	Standard DOS COMMAND.COM DOS Format command DOS Print command DOS Diskcopy command

Figure 9. Reserved File Names

System Request: The Application Selector makes use of the system request interrupt that is generated by pressing function escape (Fn-Esc). The system request interrupt is used to suspend an application program or SystemApp and return the user to the Application Selector menu. While in the Application Selector, the system request interrupt is ignored.

Diskette Interfacing: The Application Selector and SystemApps make use of DOS I/O function calls to access the diskette drives. The Application Selector and SystemApps use the diskette drives to store and load various files. Files used by the Application Selector and SystemApps may be accessed at the current directory level or with an optional path if specified. The user may specify an optional path in the Notewriter or Phone List SystemApps. The Schedule SystemApp always uses the root directory to store and load schedule files. The Calculator does not store or load any files.

The Application Selector automatically searches both diskette drives to load a SystemApp or program application when no drive ID is specified. The default drive is searched followed by the remaining system drives (A - D). This feature may be overridden by specifying the drive ID for the application when the F-keys are defined in the Define F-keys tool. If the application to be loaded is initiated by a batch file, a copy of COMMAND.COM must be on the same diskette with the application.

Limitations on Application Suspensions: Certain limitations are applicable to the application suspension function in the Application Selector. Only one application can be suspended at a time and only SystemApps are available for execution while an application is suspended. If the execution of another application or the Tools SystemApp is attempted during suspension of an application, an alarm will sound indicating the function is not currently available. Application Selector also monitors application progress for system conditions that would make suspension inappropriate. These conditions are:

- Communication activity
- Direct access of the diskette hardware
- Greater than 20 files open
- Deallocation of the reserved memory for the SystemApps
- Redirection of the INT9 keyboard interrupt vector
- Deletion of an open file

If any of these conditions have been detected, the Application Selector will disable the suspension capability and will sound an alarm if the Fn-Esc key sequence is depressed. In the case of direct access of diskette hardware, the Application Selector will re-enable the suspension capability if a normal DOS diskette access is detected.

IBM Personal Computer 3.5-Inch External Diskette Drive Architecture

Description

There are two models of the IBM Personal Computer 3.5" External Diskette Drive. One model is for use with the IBM Personal Computer, IBM Personal Computer XT and IBM *Portable* Personal Computer. The other model is for use with the IBM Personal Computer AT. Both models provide the capability to exchange information between the system with which they are used and the IBM PC Convertible.

The model that supports the IBM PC, PC XT and *Portable* Personal Computers consists of a 3.5" drive assembly which attaches to the external diskette drive D-shell connector on the back of the IBM 5.25" Diskette Drive Adapter. This model also contains a power cable that routes power from the internal power supply to the power connector of the external drive. The model for the IBM PC AT requires an additional adapter card that provides the connections from the IBM PC AT internal diskette drive adapter card to the external drive cable. A power cable associated with this card routes power from the internal power supply to the external drive through the D-shell connector. Since the 3.5" drive in both models is based on CMOS technology, both models contain a CMOS to TTL converter card that is packaged under the covers of the external drive assembly.

Diagnostics and Setup instructions are also provided with both models. A device driver (DRIVER.SYS) is supplied with DOS 3.2 that enables DOS to properly access the external drive. A separate 5.25" diskette is shipped with the PC AT model which contains a BIOS routine that is required to support the PC AT configuration (EXDSKBIO.SYS).

Technical Information

DOS 3.2 is required to support the 3.5" external drive feature.

Both models of the 3.5" external diskette drive are accessed by DOS through an installable device driver (DRIVER.SYS). This device driver is installed each time DOS is booted via a command in the CONFIG.SYS file. The IBM PC AT also requires a BIOS routine (EXDSKBIO.DRV) to be installed via CONFIG.SYS which enables the PC AT system to access drives with physical identifiers other than 0 and 1. The internal configuration switch settings are not affected by this system implementation. Both models utilize the existing internal floppy diskette controller for all drive control functions.

The external diskette device driver (DRIVER.SYS) installs the external diskette drive at the end of the active device chain. As a result, the logical drive identifier for the external drive will change depending on the machine configuration.

Packaging

Both models contain a 3.5" drive assembly, a power splitter cable, setup instructions and a 5.25" diskette containing the feature diagnostics. Additionally, the PC AT model contains an external diskette drive adapter card and the PC AT BIOS routines (EXDSKBIO.DRV) on a separate 5.25" diskette.

Installation

The external drive attaches to its system by connecting to the D-shell connector provided at the back of the system unit. This connector is on the back of the IBM PC, XT and *Portable* Personal Computers' diskette controller card. Since the PC AT does not have this connector, an additional card that cables the diskette control signals from the diskette adapter is required on the PC AT. Both models require the installation of a power splitter cable. The PC AT model supplies power through the D-shell connector while the PC model has a separate power connector.

Once the hardware is connected, a software installation procedure must be performed. Both models require that the device driver (DRIVER.SYS) be installed by including it in the CONFIG.SYS file. The PC AT model also requires the installation of the BIOS routines (EXDSKBIO.DRV) that are also installed by the CONFIG.SYS file.

IBM Personal Computer Disk Operating System (DOS) Version 3.2

The IBM Personal Computer Disk Operating System (DOS) Version 3.2 provides all of the functions contained in the prior version of DOS (3.1), plus enhancements for support of the IBM PC Convertible and the IBM Personal Computer 3.5 Inch External Diskette Drive. The specific relationship of DOS 3.2 to DOS 3.1 and prior releases of DOS is described in this section.

The purpose of this section is to provide an overview including pertinent technical information regarding DOS 3.2. If further information is required, please refer to the DOS documentation listed at the end of this section.

Highlights

DOS 3.2 provides the same application support that previous versions of DOS have provided as well as the following additional functions:

- Supports the IBM PC Convertible and the IBM Personal Computer 3.5" External Diskette Drive
- Supports APA graphics printing from the IBM PC Convertible Liquid Crystal Display to the IBM PC Convertible Printer via GRAPHICS.COM
- Provides a new command (REPLACE) to replace all occurrences of a file on a disk, making installation of application programs easier.
- Provides a new command (XCOPY) to allow copying of files and sub-directories
- Provides logical drive support which permits a physical drive to be referenced by more than one drive identifier
- Removes default drive capability on FORMAT. FORMAT will not proceed until the drive identifier is entered by the user.
- Enhances several existing DOS commands for improved use and error recovery.

New Commands

There are two new commands with DOS 3.2. These commands are extensions of the copy command in that they work in a subdirectory environment. In addition to working with the current directory, the user can now replace and copy files in subsequent subdirectories. The two new commands are REPLACE and XCOPY.

The REPLACE command selectively replaces all occurrences of a file on the target with files of the same name from the source. This command is also capable of adding files from the source which do not currently exist on the target diskette. There are parameters associated with this command that specify searching all directories, read only files, prompting before updates and waiting for diskettes.

The XCOPY command selectively copies groups of files which can include lower levels of subdirectories. There are parameters associated with this command that specify coping subdirectories, verifying the copies, archival control, date checking, creating empty subdirectories, prompting before updates and waiting for diskettes.

New Functions

DRIVER.SYS:DOS 3.2 provides a new device driver called DRIVER.SYS. DRIVER.SYS supports both external devices and logical devices. It provides support for 3.5" external diskette drives and allows a physical drive to be addressed by more than one drive letter. With the DRIVER.SYS parameters, the user can specify the physical drive number, the number of tracks per side, the number of sectors per track, the maximum number of heads, diskette changed support, nonremovable block (example: fixed disk) and form factor.

Enhanced Commands:Several of the existing DOS commands were enhanced for DOS 3.2. The first command is the ATTRIB command. Previously, this command was used to set or reset a file's read only attribute. In DOS 3.2, this command has been extended to allow the setting and resetting of the file's archive attribute bit. This bit is used in conjunction with the BACKUP and the XCOPY commands to indicate when a file should be backed up.

The next enhanced command is the COMMAND.COM file which is used to start a secondary DOS command processor. A parameter has been added to allow expansion of the system environment. The parameter is a base ten integer and expands the environment from 128 to 32,768

bytes. The environment is an area reserved in memory to store information available for use by all commands and applications.

The FORMAT command has been updated to require a drive letter designation for the drive to be formatted. This capability will eliminate erroneously erasing the default drive diskette or hard disk when executing a format command by omitting the proper logical drive identifier. A volume label must also be specified when formatting a fixed disk if one has been defined.

Finally, the SELECT command has been updated to work with fixed disks as well as diskettes when installing DOS on a new system. The SELECT command calls the FORMAT command and the XCOPY command to add DOS to the new system. When using the SELECT command for loading DOS, the country code and the keyboard layout must be specified to define the type of keyboard and the date and time formats that DOS is to use. The source and target designations can also be specified in the SELECT command when installing DOS.

Enhanced Functions: There have been a number of enhancements made to DOS 3.2 in the disk interface area, making it more general and easier to use. Information on DASD media can now be obtained through the BIOS Parameter Block which allows a wider use of media types than was possible through the File Allocation Table Identification Byte (FAT ID). In addition, a higher-level interface to BIOS is provided through DOS 3.2 via the IOCTL or Function Call 44 subroutines. These routines will make an easier transition for new DASD devices as well as provide the higher-level access to those devices.

BASIC Interpreter 3.2

The BASIC Interpreter has been updated to Version 3.2 and is shipped with DOS 3.2.
The Interpreter has been updated to support the following products and functions:

- The IBM PC Network and the IBM Token Ring LAN through the OPEN statement
- The IBM Extended Graphics Adapter through the PALETTE, PALETTE USING, COLOR, SCREEN and PCOPY statements
- DOS Extended Error support through the EXTERR(n) statement
- Restricted file access through the LOCK and UNLOCK statements
- Additional keyboard trapping through the ONKEY and KEY(n) statements

Relationship to Prior Versions

DOS 3.2 is an upward compatible enhancement to DOS 3.1 and requires a minimum of 44KB of user memory compared with 36KB for DOS 3.1. DOS 3.2 offers function not available in previous levels of DOS while maintaining standard functions and interfaces. Where standard programming procedures have been employed, most programs should run under Version 3.2 without change. Examples of nonstandard procedures include access of absolute memory locations in DOS and direct calls to BIOS. DOS 3.2 uses more memory than previous levels of DOS which may increase the memory requirements of some programs. In these cases, a program may have to be divided into smaller segments or more memory may have to be added to the system.

Installation and Operation

There are two ways to install DOS 3.2. The SELECT command should be used to install on a diskette-based system or a fixed disk system for the first time, and the SYS and REPLACE commands should be used when upgrading a current level.

The SELECT procedure calls the FORMAT command to format the media on which the user is going to install DOS. This procedure defines the keyboard layout, country code, formats for date and time, currency symbol and the decimal separator. This procedure also copies DOS onto the media just formatted using the XCOPY command.

For currently installed versions of DOS, the REPLACE command replaces the existing level with DOS 3.2 by copying the DOS commands into the specified directory or all subdirectories if required. The new DOS 3.2 commands can be added by using the adds new commands parameter on the replace command.

DOS is initially set up to prompt for the time and the date each time DOS is loaded via a system restart. On the IBM PC Convertible, the current time will be automatically displayed from the real-time clock. This time and date will be used to identify the most recent update to a file. If 'unattended' operation is desired, the AUTOEXEC.BAT file supplied with DOS can be modified so that the date and time prompting can be bypassed during IPL. DOS updates the time and date from the real-time clock automatically each time the PC Convertible is turned on.

Packaging

The IBM Personal Computer DOS Version 3.2 is available on either 5.25" or 3.5" diskettes. The DOS product package consists of diskettes of one of these diskette types, a Read This First card, a Quick-Reference card and the manuals.

Publications

DOS 3.2 is described in the following publications which are part of the DOS 3.2 package:

- *IBM Personal Computer Disk Operating System Users Guide (Level 3.2)*
- *IBM Personal Computer Disk Operating System Reference (Level 3.2)*

A *DOS Technical Reference* manual intended for application programmers is also available separately for purchase.

Compatibility with the IBM Personal Computer Family

Compatibility Overview

The IBM PC Convertible differs from the other computers in the IBM Personal Computer family. Even though it is different, the IBM PC Convertible can run many applications designed for other IBM Personal Computers without requiring modifications to those applications. It is also possible to create applications for the IBM PC Convertible that will run without modifications on other IBM Personal Computers. In order to create such programs or to assess if current programs are compatible, you must understand the differences among the IBM Personal Computers and know the proper way to communicate with them.

Normally, it is not possible for a program written for one computer to run on a different computer, because the processors are different and the language of the application cannot be executed by different processors. In this case, the application would have to be rewritten entirely in the language of the other processor. Because the IBM PC Convertible and the IBM Personal Computers use similar architecture and processors, most assembler language programs need not be modified.

Compatibility among processors alone is not enough, because the applications normally take advantage of device services (BIOS) and operating system (IBM DOS). In order for the applications to be compatible, the IBM PC Convertible has maintained all BIOS system interrupts and uses IBM DOS. This means that applications that use BIOS and IBM DOS interrupts on other IBM Personal Computers will operate in the same manner on the IBM PC Convertible.

Note—The BIOS microcode of the IBM PC Convertible is not identical to that of the other IBM Personal Computers. If an application bypasses the BIOS interrupt-calls and directly accesses routines and storage locations in one system, the application may not run in the other system. Some routines may be similar and some BIOS storage locations may be the same; however, it is strongly recommended that applications use only BIOS and IBM DOS interrupt interfaces in order to achieve compatibility in the IBM Personal Computer family.

Using the same language and the BIOS and IBM DOS interfaces goes a long way in achieving application compatibility. However, there are still several factors which need to be taken into consideration; this section describes those factors.

Compatibility with the IBM PC AT

The IBM Personal Computer AT has capabilities that are not supported on the IBM PC Convertible. Refer to the *IBM Personal Computer AT Technical Reference* for additional compatibility considerations.

Special Programming Considerations

In general, applications intended to run on any IBM Personal Computer family product should use programming practices that maximize code compatibility. One such practice is to use IBM DOS interfaces instead of going directly to the hardware, since hardware interfaces are likely to be different across the IBM Personal Computer family. As a result, compatibility must be considered in the design of an application. Applications that use these programming practices should have no problem running on the IBM PC Convertible. However, those applications that do not use these preferred programming practices must closely observe the compatibility exceptions.

Altering the Nonmaskable Interrupt (NMI) Vector: The IBM PC Convertible uses the NMI and its vector to access routines based in ROM. Routines, such as the keyboard, diskette controller power-on, real-time clock alarm processing and system suspend are crucial to the operation of the system. Modifying the NMI vector prevents normal system operation, and the IBM PC Convertible will not operate with programs that alter the NMI vector.

Stack Manipulation: Certain compatibility aspects for the IBM PC Convertible require that the NMI be used to support normal operating functions and events. For example, a compatible keyboard interface is presented at I/O address hex 60 through a scan code preprocessor built into the NMI level. As a result, consideration must be given to sections of an application that manipulate the stack through the stack-segment and stack-pointer registers, to ensure that these two registers contain valid data when interrupts are possible. Masking the interrupts in this case is not sufficient on the IBM PC Convertible, because the interrupt mask has

no effect on nonmaskable interrupts. Applications that manipulate the stack registers must ensure that the instruction that modifies the stack pointer (SP) immediately follows the instruction that modifies the stack segment (SS) as shown in the following example:

```
MOV SS, STACKSEG_VAL
MOV SP, STACKPTR_VAL
```

By following this rule, an application can prevent nonmaskable interrupts from interfering with the modification of the stack location.

In addition, the application must not use the stack pointer for any purpose other than pointing to the stack. The stack pointer must not be used as an intermediate register.

Failing to observe these rules may result in program malfunctions or loss of data.

Stack Space: Applications must reserve a minimum of 256 bytes on the program stack for BIOS. This area is used to process interrupts. Any applications that use the real-time clock BIOS interrupt 15 (functions hex 83 and 86) should reserve an additional 30 bytes on the program stack for BIOS. This stack area is in addition to the area required by the application.

Idle Loops and Power Conservation: The BIOS used on the IBM PC Convertible provides a sleep mode that is used to conserve power during periods of time when no specific processing is being done. BIOS automatically provides this function for applications that use BIOS to interact with the hardware. For example, BIOS automatically provides the sleep mode function for applications that use interrupt hex 16 to wait for keyboard activity and interrupt hex 13 to access the diskette drive.

However, applications that do their own idle processing while waiting for external events must observe special programming practices; otherwise, the application consumes as much power during the idle period as it does during normal processing. In this case, the application should use interrupt hex 15 (function code hex 41). See the BIOS listings for specific information concerning this function code.

Timing Dependencies

The internal storage in the IBM PC Convertible does not require refresh. Because the processor is not interrupted periodically to refresh memory, more processor cycles are available in a given period of time, and the processor appears to operate faster. This may affect a program that goes into a timing loop for delay.

Unequal Configurations

In designing an application to run on both the IBM PC Convertible and other IBM Personal Computers, ensure that the required hardware configuration is available on all machines. This means that all systems must meet the application's minimum requirements before the application can run properly.

Hardware Differences

To be able to run on any computer without change, an application using a specific I/O device must have access to identical devices or devices with identical operating characteristics and interfaces.

The following paragraphs describe the IBM PC Convertible-supported hardware functions and I/O devices that may differ from other IBM Personal Computers.

Clocks and Timers

System Clock: The IBM PC Convertible uses a system clock that supports sleep mode. Sleep mode is used to conserve battery power.

Time of Day: The IBM PC Convertible contains the circuitry to provide the time of day.

Timers: The IBM PC Convertible provides only timer channels 0 (modes 0, 2, 3, and 4) and 2 (all modes). Timer channel 1, dynamic memory refresh timing, is not required on the IBM PC Convertible.

Configuration Switches: The IBM PC Convertible does not contain configuration switches. Configuration is determined by power-on routines.

Cassette: The IBM PC Convertible does not support cassettes.

Liquid Crystal Displays

Memory Mapping and Switching: In order to be compatible with applications written for color/graphics and monochrome displays, the IBM PC Convertible uses two address ranges for control registers, one for color/graphics operations and one for monochrome operations. The address ranges can be selected by modifying the initial video mode bits in the BIOS equipment word and issuing a set mode function call (interrupt hex 10), if no other displays are attached. The default area for the LCD is the color/graphics area, if the IBM PC

Convertible CRT display adapter is not installed. The default area is the monochrome area, if the IBM PC Convertible CRT Display Adapter is installed.

RAM Fonts: The LCD controller uses two fonts in RAM for character generation. Both the main and alternate fonts are loaded during power-on with the standard IBM Personal Computer character set stored in system ROM. Font selection is accomplished through a BIOS function call (interrupt hex 10).

Color Mapping: Color is mapped on the LCD as follows:

- Alphanumeric mode:
  - White foreground with black background: Normal video
  - Black foreground with white background: Reverse video
  - Any color foreground with a different color background: Reverse video
  - Any color foreground with the same color background: Solid reverse video
  - Black foreground with black background: Nondisplay
  - Intensified characters: See "Intensity"
- Graphics mode (medium resolution):
  - Background: Gray
  - Cyan or green: Dark gray 1
  - Magenta or red: Dark gray 2
  - White or brown: Black

LCD Aspect Ratio: The LCD displays 640 pels horizontally with a pel density of 2.44 pels per millimeter (62 pels per inch) and 200 pels vertically with a pel density of 2.27 pels per millimeter (57.7 pels per inch). Cathode-ray displays typically have a lower vertical resolution pel density. This means that an image that appears as a square on an LCD appears as a vertical rectangle on a cathode-ray display. A BIOS function call (interrupt hex 15) allows applications with a scaling algorithm to adjust for physical display parameters.

Intensity: The intensity attribute of the cathode-ray tube display cannot be mapped properly onto the LCD, because there is no direct method of making a character darker on an LCD. A programmable mapping of this attribute is provided through a BIOS function call that allows translation of the intensify attribute into reverse image, underline, select alternate font, or no attribute.

Monochrome Emulation: Monochrome emulation is supported through the LCD and LCD control logic and uses an 8-by-8 character box instead of a 9-by-14 character box. This support includes video buffer mapping and control ports. The IBM PC Convertible does not support the intensify attribute; see "Intensity" for additional information concerning this attribute.

Color/Graphics Emulation: The color/graphics emulation is supported through the LCD and the LCD control logic. This support includes video buffer mapping and control ports. The IBM PC Convertible LCD supports only two colors. The IBM PC Convertible LCD does not support the intensify attribute; see "Intensity" for additional information concerning this attribute.

Accessing the Refresh Buffer: Applications that directly access the refresh buffer do not need to synchronize the access with vertical and horizontal syncs. Additionally, the application does not need to disable video while accessing the refresh buffer. The LCD controller automatically resolves any memory contention without affecting the display.

Faded scan lines across the top and center of the display may occur if the application disables video during frequent updates to the refresh buffer.

Direct Memory Access

Channels: The IBM PC Convertible has three DMA channels instead of four. The DMA channels supported are 1, 2 and 3.

Control Modes: The IBM PC Convertible does not support the entire set of DMA control modes, but this does not affect compatibility if the applications use built-in BIOS and DOS routines to access the DMA channels. DMA channel 1, dynamic memory refresh timing, is not required on the IBM PC Convertible.

Memory: The IBM PC Convertible can support up to 512K bytes of user read/write memory. The IBM PC Convertible does not use this memory for the screen buffers. Therefore, the IBM PC Convertible video architecture does not affect the amount of user memory in the same way as that required by certain applications on other systems.

Communications Adapters

Synchronous Communications: The IBM PC Convertible does not support synchronous communications.

Asynchronous Communication: The IBM PC Convertible supports two coresident asynchronous-type adapters. One is the IBM PC Convertible Internal Modem and the other is the IBM PC Convertible Serial/Parallel Adapter. The modem adapter is always COM1 and the RS-232 will be either COM2 or COM1, depending on whether the IBM PC Convertible Internal Modem is installed.

The Power-On Self Test routines determine the presence of communications adapters by using the work (scratch) register within the INS8250A Asynchronous Communications Element. These routines will not be able to detect the presence of adapters that do not contain this register.

Applications that process multiple interrupt conditions from the INS8250A Asynchronous Communications Element must service and clear all interrupt conditions before exiting the interrupt service routine. Failure to clear all interrupt conditions can result in failure of the application program.

Printers: The IBM PC Convertible supports the IBM PC Convertible Printer through the I/O connector. Other printers, such as the IBM Graphics Printer, can be attached by using the IBM PC Convertible Serial/Parallel Adapter.

The IBM PC Convertible Printer is always LPT1 and the parallel interface interface is either LPT2 or LPT1, depending on whether the PC Convertible Printer is installed.

Serial interface printers can be attached through the serial port. These printers are designated as either COM1 or COM2 by DOS and BASIC.

IBM PC Convertible Printer Aspect Ratio: The IBM PC Convertible Printer is designed to support the IBM Personal Computer Graphics Printer command stream. However, due to differences in the physical dimension of the print head, bit-image graphic prints documents about 20 percent longer in the vertical direction.

Diskette Drives: The IBM PC Convertible uses 3.5" (88.9-millimeter) drives instead of the 5.25" (133.4-millimeter) drives used on other IBM Personal Computers. The format and timing for the The following sections describe the modifications made to the BIOS interfaces to support the hardware differences on the PC Convertible.

3.5" drives is compatible with the 5.25" drives so that most applications function properly.

The IBM PC Convertible can support up to two 3.5" diskette drives that are capable of storing 720K bytes each. The interface to the diskette drives is based on the NEC μPD765 architecture and is compatible at this interface. The IBM PC Convertible also uses direct memory access (DMA) for data transfers to and from the diskettes. The IBM PC Convertible is capable of overlapped diskette I/O and other device I/O.

Keyboard: The IBM PC Convertible uses a 78-key keyboard that is capable of generating all 83 IBM Personal Computer scan codes along with System Request from the IBM PC AT keyboard, F11 and F12. In order to support this function, the BIOS provides a keyboard preprocessing function activated by a Nonmaskable Interrupt (NMI) that translates the key combinations into compatible scan codes. The compatible scan code is then presented at the keyboard data port (60H) and a hardware level 1 interrupt is generated.

Identification Byte: The IBM PC Convertible provides a byte in read-only memory that distinguishes an IBM PC Convertible system from other IBM Personal Computers. This byte is located at hex FFFFE and contains the value of hex F9.

ROM BIOS Compatibility

The BIOS microcode for the IBM PC Convertible is not identical to other IBM Personal Computers. If an application bypasses the BIOS interrupt calls and directly accesses routines and/or storage locations, it may not run properly on the PC Convertible. Application developers are strongly recommended to use only BIOS and DOS interrupt interfaces in order to achieve compatibility within the IBM Personal Computer family.

The BIOS interface (interrupt and function codes) were maintained for the IBM PC Convertible to ensure a high degree of compatibility. New function codes were added to support the unique features of the IBM PC Convertible and to mask any system hardware differences.

Additional areas in the ROM BIOS data area (segment address hex 40, offset 0 through hex FF) were also defined to support hardware differences.

Copy Protection: Copy protection may work differently on the IBM Convertible for the following reasons:

- Track density for the 3.5" diskette drive is 135 TPI.
- Track-to-track access time and head settle time parameters are overridden by BIOS if minimum drive requirements are not met.
- BIOS insures that the drive motor is allowed 500 milliseconds for startup on both read and write accesses as required by the drives.
- The diskette changed signal may not be reset if BIOS is bypassed.

Interrupt Hex 5: The Print Screen BIOS code was enhanced to sound the alarm for printer error during printing and to stop printing when a CTRL BREAK key combination was depressed.

Interrupt Hex 10: Two new video BIOS functions were added to the interrupt hex 10 interface. The "LCD Request" function allows application programs to load a new main or alternate character font into the LCD RAM font. The LCD controller can support up to 512 different characters by using the intensity attribute to select the alternate font. The application program also may request a reload of the default character fonts stored in ROM. The "LCD Request" function also allows applications to select the effect of the high intensity attribute on the LCD display.

The second new function "Return Physical Display Description" allows application programs to determine the type and characteristics of the active display and whether any alternate display is available.

Video BIOS also provides the "Write Character String" function calls found on the IBM Personal Computer AT.

Interrupt Hex 13: New functions were added to the diskette BIOS interface to support the diskette changed function and to allow the application to determine the maximum format capacity of the diskette drives. These functions are provided by the "Check Change Line Support", "Read Diskette Changed Status" and the "Read Drive Parameters" function calls. The diskette changed support is similar to that provided by the IBM Personal Computer AT for the 96 TPI drive.

The diskette change line associated with the 3.5" drives will latch an indication whenever a change occurs in a given drive. This change line has been implemented to reduce the risk of erroneous I/O to or from a diskette that has replaced the one known to have been inserted. This also may improve performance by allowing buffers, i.e., directory and FAT, to remain valid as long as the diskette has not been removed or changed.

Diskette BIOS will only support diskette changed error returns if the operating system or application program performs the "Check Change Line Support" function call. DOS 3.2 does this during DOS initialization. This allows programs written before change line support to function normally without having to handle the new diskette changed error return. When the diskette changed function is supported and a diskette changed indication is detected by BIOS, the next request for diskette I/O to that drive will fail with an error return of hex 06 (diskette changed) in register AH. At the same time BIOS will clear the changed indicator. Retrying the I/O will allow the requested function to occur normally. If there is no diskette in the drive, the BIOS request will fail with a "Timeout" error rather than a "Diskette Changed" error. The "Diskette Changed" status may be interpreted as either an error or as an expected status depending on the circumstances. A new function call allows the "Diskette Changed" status to be interrogated and reset.

Interrupt Hex 15: The interrupt hex 15 (Cassette I/O BIOS) was redefined to include support for some new features of the IBM PC Convertible and to provide some features found on the IBM Personal Computer AT. The function code values do not conflict with the cassette control functions or functions found on the IBM Personal Computer AT that are not provided on the IBM PC Convertible.

The IBM PC Convertible supports a system profile area that is retained across all power on/off cycles unless all power fails (including battery). This profile controls system setup, internal modem setup, and battery power saving modes. Users may access and change this profile with a utility program shipped with the system. A new interrupt hex 15 function provides profile read and modify functions for application program access.

Note—Programs modifying the profile must be aware that the profile will remain in effect across future power on/off cycles until changed or until the default profile is reloaded by BIOS due to a complete power loss.

A new "Wait for External Event" function call has been added that allows the CPU clock to be stopped until a specified external event has occurred. An external event is defined as any hardware interrupt or DMA request. BIOS uses this function call internally when waiting for a keyboard

entry, waiting for diskette motor startup and while waiting for a diskette controller interrupt. The function allows the system to save battery power when the processor is idle while waiting for the completion of some I/O. Programs should make use of this function during idle conditions to conserve battery power. A wide varity of event determination schemes can be supported using this BIOS function.

An additional interrupt hex 15 function is provided to power off the system. The application may specify a normal execution of the system profile on the subsequent power-on or may specify a Resume Mode Profile Override. If the system is Resumed on the next power-on, control will be returned from the BIOS function call, otherwise the system will IPL.

A "Read System Status" function call is provided that allows the application program to determine the present system state. A program can determine battery low, external power operation and power previously lost status conditions. The program may also determine if the system was powered on by the Real Time Clock Alarm (unattended mode), the power state of the internal modem and external Serial/Parallel Adapter and whether the LCD is attached or detached. An additional function call allows the internal modem to be powered on or off by the application program. If the modem is powered on, BIOS will set the modem up according to the setup instructions stored in the system profile.

A limited provision for multitasking has also been added to BIOS routines, where possible, similar to those found on the IBM PC AT. Included are provisions for exiting busy (wait) loops and interrupt service routines. BIOS uses the diskette wait and keyboard wait function calls to invoke the "Wait for External Event" function call to conserve battery power. Programs taking advantage of these multitasking hooks should utilize the "Wait for External Event" function call when no other tasks are active in order to conserve battery power.

The IBM PC Convertible supports the SYS REQ key in the same manner as the IBM PC AT. Suggested use of this key is described in the *IBM PC Convertible Technical Reference Manual*. An additional application program "hook" is provided by the BIOS keyboard interrupt handler (interrupt 9 - hardware interrupt 1). This routine will invoke a interrupt hex 15 function call to indicate that a scan code is being processed by the BIOS. Application programs making use of this interface may process the scan code themselves and return control to the BIOS routine to reset the interrupt, or may indicate that BIOS should process the scan code normally.

Access to a system description table is also provided through an interrupt hex 15 function call. This table provides a detailed description of the level of BIOS, the machine type, and whether or not certain special functions are supported by BIOS. Refer to the *IBM PC Convertible Technical Reference Manual, Volume II* for a detailed description of this table.

Interrupt hex 16: The BIOS "Wait for Key" function call internally invokes the "Wait for External Event" function to conserve battery power when no key is present. Control will be returned from BIOS when a key is present in the keyboard buffer.

BIOS provides a click sound on the speaker each time a key is depressed. The user may enable/disable the clicker via the Fn + Caps Lock key sequence or an application program may enable/ disable the clicker through an interrupt hex 16 function call.

Interrupt hex 19: The bootstrap loader, interrupt hex 19, is not identical to other IBM Personal Computers. If no diskette is in the drive, the screen will be cleared and an animated "Insert Diskette" icon will be presented on the LCD, or the CRT if the LCD is detached. Pressing the F1 key will invoke an additional attempt to boot from the diskette. If BIOS determines that no diskette is in the drive, control is passed to ROM BASIC. The screen is cleared before passing control to the booted routine or ROM BASIC.

Interrupt hex 1A: As in the IBM Personal Computer AT, the IBM PC Convertible BIOS provides function calls to Read and Set the Real-Time Clock time, date and alarm. Two new functions have been added to allow applications to Set the Real-Time Clock Alarm to power-on the system and to allow the program to read the alarm time and current alarm mode.

Keyboard BIOS Changes: The keyboard interrupt 9 handler was modified to support the application keyboard processing hook and the SYS REQ ,F11 and F12 keys. The BIOS keyboard preprocessing routine, which is activated by an NMI, handles all translations of the keyboard scan codes to IBM PC family compatible scan codes at the port hex 60 interface. Programs that hook the interrupt 9 handler should insure that key processing is performed while the interrupt is in service to prevent interference from the keyboard preprocessing routine. In particular the NUM__STATE flag in the KB__FLAG data area is modified by the BIOS preprocessing routine to insure that the interrupt 9 routine processes the keys properly. When a keypad function is selected, the BIOS preprocessing routine will set the NUM__STATE flag. When a

cursor movement key is depressed, BIOS will reset the NUM_STATE flag. When the NUM_STATE flag is not used for the particular key depressed, BIOS will set the NUM_STATE flag to reflect the activation state of the inboard keypad.

Machine Identification: The IBM PC Convertible is a member of the IBM Personal Computer family by way of its strong architectural compatibility. The highest degree of application compatibility can be achieved by using a common high level language, and/or accessing the system only through BIOS and DOS interrupts. It is not recommended to go below the BIOS level even though there is a high level of compatibility. When it is necessary to design for particular computer differences, the application should determine at execution time which particular computer it is using. This can be done by inspecting the ROM memory location at segment address hex F000 and offsetting hex FFFE for the following values as shown in Figure 10. Once determined, multiple paths would handle any differences.

Hex	Machine Identification
0FF	IBM Personal Computer
0FE	IBM Personal Computer XT IBM *Portable* Personal Computer
0FD	IBM PC*jr*
0FC	IBM Personal Computer AT
0F9	IBM PC Convertible

Figure 10. IBM PC Family Machine Identification Bytes

Results of Compatibility Testing

IBM performed extensive compatibility testing during the development of the IBM PC Convertible. This effort resulted in a system architecture that has achieved a very high level of compatibility which enables most applications to port to the PC Convertible without modification. In summary, the results of the compatibility testing indicate the achievement of IBM's compatibility objectives.

Summary

The IBM PC Convertible is designed to be a member of the IBM Personal Computer family. The highest degree of compatibility can be achieved by using a common high-level language or accessing the system only through BIOS and DOS interrupts when designing an application for this family. Going below the BIOS level is not recommended, even though there may be compatible hardware on the different systems. When it is necessary to design for particular system differences, multiple paths can be built into the application, and the application can determine at execution time the particular system it is running on. This can be done by inspecting the byte at ROM location hex FFFFE for a specific value; this value will be hex F9 on the IBM PC Convertible.

Once the application has determined the IBM Personal Computer it is running on, the application can take the appropriate path.

Compatibility Guidelines for Application Development

This section summarizes the compatibility guidelines for application development. They are guidelines only and are not guarantees to ensure compatibility nor are they prohibitions of any kind. You are free to use any programming techniques you wish in writing your software. However, if you follow these guidelines, your program will have a much better chance of running correctly on the different systems in the IBM Personal Computer family.

The Software Implementation and the IBM PC Convertible section of this Proceedings describes how certain software implementations will affect the IBM PC Convertible system.

Programming Techniques for Machine Independence

The purpose of this section is to briefly describe the programming techniques that will facilitate porting applications to many different machines. In general, applications that are implemented using the architected interfaces of a computer family have the best chance of running properly on all members of the family. The following programming techniques and interfaces are presented with a focus on their effect on portability.

High Level Languages

Applications written in a high level language have the best chance of running on a wide range of machines. IBM offers a library of high level languages that are supported across the IBM PC family. Applications written in these languages have a very good chance of porting to any of the computers in the PC family. A secondary benefit of high level language implementation is the possibility of source level compatibility (recompile and republish) in the case that object compatibility was not achieved.

Unfortunately, the language an application is written in does not guarantee that transportability will be achieved. Many high level languages provide the capability of going directly to the hardware and thus around certain architectural interfaces. As a result, programming techniques in high level languages can still degrade the portability of software.

DOS Function Calls

Applications that take full advantage of the services provided by DOS function calls also have a very good chance of successfully porting across the PC family. IBM makes every effort to preserve the compatibility of these function calls even when the underlying hardware changes dramatically. Applications that are implemented this way are shielded from changes at lower levels of the system.

BIOS Function Calls

BIOS is the last level of software that exists as a buffer between an application and the actual hardware interfaces. IBM also makes every effort to preserve these interfaces but hardware differences are more likely to be reflected in the functions provided at this level.

Direct Hardware Interfacing

Applications that interface directly with the hardware are the most likely to have difficulty porting to different systems. IBM attempts to preserve as many of the hardware interfaces as possible. However, the continuing demand for increased performance and capability will certainly impact the ability to achieve this goal. Application developers should consider the trade-off between the advantage of direct hardware interfacing and the disadvantage of limited portability.

Approaches to Avoid

Applications should avoid the use of reserved or unpublished DOS and BIOS functions and data.

Programs should not resort to techniques such as PEEK and POKE or make reference to any absolute memory locations.

Programs should not use instruction loops for time dependent operations.

Programs should not be machine sensitive unless the opportunity created by optimizing to a specific machine characteristic outweighs the opportunity lost as a result of limiting the program to specific IBM Personal Computer family members.

Software Implementations and the IBM PC Convertible

In previous sections of this Proceedings, the descriptions have focused on the implementation and behavior of the IBM PC Convertible System. The following section is designed to shift the emphasis to software implementation and behavior and its effect on the PC Convertible, with a focus on the programming techniques that should be avoided. The information in this section is presented without the technical detail that might be required for a full analysis. If a subject requires further investigation, please refer to earlier sections of this publication or the *IBM PC Convertible Technical Reference* for a complete technical description.

System Unit

Sleep Mode: This system has been implemented with a sleep mode feature that conserves battery power while the system is idle. Applications that utilize BIOS and DOS for keyboard and diskette services (INT16 and INT13) will take advantage of this feature automatically. Applications that do their own keyboard and diskette processing or that are idle in other instances should consider using the new 'wait for external event' service (INT15) to take advantage of this battery savings feature.

NonExistent Input/Output Devices: Since the PC Convertible is the first Personal Computer family member to utilize CMOS technology to a large extent, the behavior of the I/O bus is different when nonexistent I/O devices are read. On other members of the PC family, a data byte of 'FFH' is returned on the I/O bus when a nonexistent device is read. Since the PC Convertible I/O bus is based on CMOS, the PC Convertible I/O bus will return random data. As a result, applications that do presence testing by reading I/O ports of the targeted device may determine erroneously that a device is present when in fact it is not. Application developers should pay specific attention to how the system configuration is determined when porting code over to the IBM PC Convertible.

System Configuration Determination: The PC Convertible BIOS automatically determines the system configuration at each IPL or system resume which eliminates the need for the 'under-the-covers' configuration switches. As a result, applications that directly read these switches are subject to the characteristics of nonexistent I/O devices. To avoid this problem, applications should poll the system BIOS for the configuration information on standard system components. In general, application developers should review their configuration testing algorithms before porting code to the PC Convertible.

Liquid Crystal Display (LCD)

Applications that display graphics information may be affected by the aspect ratio of the LCD screen. The aspect ratio differs from most IBM PC displays in that the pels on the LCD are almost square and not taller than they are wide. This characteristic results in graphic displays being flattened when they are ported to the LCD without modification. Applications that wish to compensate for aspect ratio can interrogate a new BIOS function provided on this system that returns information on the model number and aspect ratio of the current display. With this information, an application can compensate for aspect ratio of the LCD and still achieve machine independence.

Application developers should also consider the following aspect of LCD screen refreshing. The LCD controller emulates certain CRT adapter characteristics, including the horizontal and vertical synchronization pulses associated with the screen refresh process. These pulses are provided to support software that makes use of them for the synchronization of memory refresh buffer changes to the actual redrawing of the display. One key difference between LCD and CRT technologies is that Liquid Crystal Displays do not require a delay when beginning a refresh at the top of the display. As a result, some part of the LCD screen is being redrawn during the entire refresh cycle. Furthermore, the 'sync' pulses will be shorter than they are on other PC family members.

A problem can occur on the LCD screen if the following software behavior is encountered. An application which disables the video signal and makes refresh buffer changes during the emulated CRT 'fly-back' delay will cause the LCD display to 'wash-out' in certain sections since the application has stopped the video signal during actual screen refresh. This situation can be avoided if the video signal is not disabled during refresh buffer changes. Additionally, synchronization of refresh buffer changes is not necessary on the PC Convertible since there are no external effects that result from changing the refresh buffer during screen refreshes on either the LCD or the CRT adapters.

Keyboard

There are several characteristics unique to the IBM PC Convertible keyboard that application developers should consider:

- The function keys are arranged in a single horizontal row above the inboard numeric keys.
- The numeric keypad number keys have been mapped onto inboard alphanumeric keys. These number keys can be activated by either depressing the Fn key and the desired alpha key simultaneously or by locking the alpha keys into numeric mode by depressing the Fn and Num Lock keys simultaneously. When the alpha keys are locked in numeric mode, the BIOS numlock flag will be set so that applications that display a numlock indicator will also indicate the state of the inboard keys on this keyboard.
- The shift key has no effect on the state of the inboard keypad or the outboard cursor control keys.
- The Num Lock key without the Fn key has no effect on the state of the inboard keypad. The numlock state is generated automatically by the system BIOS as required by the actual key depression.
- The NMI interrupt is vital to the processing of keystrokes. Applications that affect the NMI vector will very likely stop any keystroke processing.

Diskette Drives

Interfacing with the diskette drives on the PC Convertible is very similar to interfacing with the diskette drives on the IBM Personal Computer. Both diskettes use 512 byte sectors with 9 sectors/track and both use the same format for the Boot Record, File Allocation Table (FAT) and Directory. The PC Convertible uses the same diskette controller that the IBM PC uses, and the timings of the drive control signals are compatible with the 5.25" drive. The major difference is in the additional capacity on the 3.5" media which is obtained by using 80 tracks rather than 40 tracks. The additional capacity also requires that the FAT increase from 2 sectors to 3 sectors. The media descriptor byte used by this media (F9) is the same as the descriptor byte used on the high density 5.25" media. Applications should refer to the media descriptor table on the boot record or interrogate the BIOS Parameter Block (BPB) to distinguish the two media types.

Serial/Parallel Printer Adapter

The PC Convertible Serial/Parallel Printer Adapter consists of an asynchronous communications adapter and a parallel printer adapter combined in one unit. There are several characteristics unique to the Serial/Parallel Printer Adapter that application developers should consider:

- The user has the ability to turn off power to the Serial/Parallel Printer Adapter while operating on battery power. In this case, the system BIOS will indicate that this adapter is present and also powered off. Applications should poll the system BIOS for both presence and power before attempting to access this adapter.
- The system BIOS presence test for the Serial/Parallel Printer Adapter accesses the 8250A scratch pad register. As a result, the presence test will not detect asynchronous adapters that utilize the 8250B UART chip which does not contain a scratch pad register.
- The UART (8250A) used by the Serial/Parallel Printer Adapter does not generate an interrupt line transition when an interrupt is pending and a new interrupt is detected. As a result, the system will not reinitiate an interrupt service routine if a new interrupt condition is encountered while a previous interrupt is being processed. Applications should ensure that all interrupt conditions have been serviced before exiting an interrupt service routine.
- The asynchronous adapter portion of this unit is capable of being remapped depending on the system configuration. Normally, this adapter will occupy the primary serial port I/O space of 3F8 to 3FE and is logically referred to as COM1. If the system BIOS detects the presence of the Internal Modem, the BIOS will remap this adapter to the secondary serial port I/O space of 2F8 to 2FE and will change its logical referencing to COM2.
- The Parallel Printer Adapter portion of this unit is also remapped depending on the machine configuration. Without the PC Convertible Printer attached, this adapter is logically referenced as LPT1. If the PC Convertible Printer is attached, this adapter is remapped to LPT2.

Internal Modem

The PC Convertible Internal Modem consists of an asynchronous adapter and a smart modem combined on one unit. The asynchronous adapter portion in the Internal Modem has the standard PC application interfaces and is always logically

addressed as COM1. The modem portion of the Internal Modem is capable of standard smart modem functions such as auto-dial and auto-answer. These functions are accessed via the IBM Command Set for smart modems which was first used by the IBM PC*jr* Internal Modem. Applications written to interface with the PC*jr* Internal Modem should work properly with the PC Convertible Internal Modem without any modification. Applications written for other smart modem protocols which have provisions for command set customization should also work properly. Consideration should be given to the data stream being sent through the modem in that certain non-ASCII data streams may contain the modem command delimiter character. This problem can be avoided by instructing the modem to go into transparency mode via the transparency command in the modem command set.

The process of changing certain modem settings is unique to the PC Convertible Internal Modem because the asynchronous adapter and the smart modem operate independently. As a result, a new BIOS function has been provided on the PC Convertible which applications should use for changing the format and speed settings of the Internal Modem. Additionally, the modem can be configured by the user before an application is executed by using the modem portion of the System Profile tool. This capability is analogous to setting the switches on a modem that uses switches for various modem controls.

There are several additional characteristics unique to the Internal Modem that application developers should consider:

- The system has the option of turning off power to the Internal Modem while operating on battery power. In this case, the system BIOS will indicate that the Modem is present and powered off. Applications should poll the system BIOS for both presence and power before attempting to access the Internal Modem.

- The UART (8250A) used by the Internal Modem does not generate an interrupt line transition when an interrupt is pending and a new interrupt is detected. As a result, the system will not reinitiate an interrupt service routine if a new interrupt condition is encountered while a previous interrupt is being processed. Applications should ensure that all interrupt conditions have been serviced before exiting an interrupt service routine.

- The system BIOS always initializes the Internal Modem according to the profile when the modem is powered on. If the user has not set the profile, the modem is initialized to 1200 BPS, 7 data bits, even parity and 1 stop bit.

CRT Display Adapter

The CRT Display Adapter presents the same application interface as the Color Graphics Adapter on the IBM Personal Computer. This adapter will affect the LCD interface by forcing the LCD adapter into its monochrome emulation mode. Additionally, the refresh buffer on this display adapter can be modified at any time during the refresh process without any detrimental effect to the information on the display.

The CRT Display Adapter will only operate while the system is on AC power.

Monochrome Display: The PC Convertible Monochrome Display is physically attached to the composite video output of the CRT Display Adapter. This display should be operated in black and white mode which can be set by the DOS MODE command or through the BIOS set mode interface. The System Profile tool that is provided with the system also allows the user to select the proper mode of operation for this display. When properly operated, the CRT Display Adapter will map color information into shades of green on the Monochrome Display.

Certain color combinations used by an application may be inappropriate on this display since they may map to the dimmer shades of green. Applications that use colors for highlighting should consider allowing the user to specify that a two-color display is being used and changing the highlighting techniques as appropriate.

System Printer

Aspect Ratio: The physical dimensions of the individual dots that a printer can print is a function of the physical characteristics of its print element. The physical characteristics of the print element in the PC Convertible Printer result in its dots being 20 percent larger vertically than dots on other IBM PC family printers. To preserve the continuity of graphics printing, the printer commands capable of variable line spacing (ESC A and ESC 3) were also adjusted to match the vertical size of the dots. This difference will cause bit image graphics printing to grow in the vertical direction.

These characteristics have some effect on the use of the printer. First, graphics printing that depends on a strict vertical-to-horizontal relationship, such as circles and pie charts, may have to be adjusted for the difference in aspect ratio. These characteristics also should be considered after a graph has been completed and the application resets the printer to the original line spacing increment. Text line spacing that is generated via the variable line spacing commands will also be affected.

Character Set and Control Commands: The PC Convertible Printer has a single character set which is based on Character Set 2 in the IBM Graphics Printer. This character set supports a large set of international characters and does not include the control characters that are duplicated in the upper half of Character Set 1. As a result, the PC Convertible Printer will print a character instead of performing a function if it encounters one of these code points.

The PC Convertible Printer was based on the command set used in the IBM Personal Computer Graphics Printer which enables most applications to print properly without any modification. However, this printer does not support the commands shown in Figure 11. If the IBM PC Convertible Printer encounters one of these commands in the print data stream, it will ignore the command:

Command	Description
Bell	Ring Bell
ESC 6	Select Character Set 2
ESC 7	Select Character Set 1
ESC <	Home Head (Carriage Return without Line Feed)
ESC G	Begin Double Strike Printing
ESC H	End Double Strike Printing
ESC J	Variable Line Feed (Single)
ESC U	Control Unidirectional Printing

Figure 11. Printer Commands Not Supported

Miscellaneous Programming Notes: The IBM PC Convertible Printer has a 2000-byte buffer for commands and characters that come from application output. As a result, the printer will appear to be finished at the programming interface long before the printer is actually finished printing. Applications should not attempt to reset the printer immediately after all data has been sent to the printer. If the printer is reset before it has finished printing, the print job will be cancelled before the job is completed.

The PC Convertible Printer is interfaced to an application as a standard parallel, 'LPT' type printer. However, its actual physical attachment is serial. As a result, bit image graphics printing will be slower on the PC Convertible Printer than on a parallel printer.

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