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January 1999

Section 1

PC System Timekeeping Devices

Introduction

To understand how an IBM Personal System will transition and work in the Year 2000, it is important to understand the PC system timekeeping devices and how they interact with each other. The following are the four PC timekeeping subsystems:

- Hardware
- Basic Input Output System (BIOS)
- Operating system
- System and application software

Each PC timekeeping subsystem has the ability to control the date. They are described in detail in the following paragraphs.

Hardware

Clock signals are generated in two independent subsystems in the hardware. The first, the Real Time Clock (RTC) can be visualized as a digital watch residing in the hardware. The second, is a Programmable Interval Timer which simply generates ticks at a preset interval similar to a second hand of a clock.

Real Time Clock (RTC)

The Real-time Clock/Complementary Metal Oxide Semiconductor (RT/CMOS) RAM chip (Motorola MC146818™ or compatible) contains the Real Time Clock circuitry and at least 64 bytes of CMOS RAM. In addition to providing a clock, it provides calendar functions.The internal clock circuitry uses 14 bytes of this RAM, and the remainder is allocated to storage of system configuration information. The date and time in PC's are maintained in a battery-backed Real Time Clock (RTC) chip. The contents of all bytes in CMOS RAM are maintained by a small battery when power to the system is removed. The RTC chip stores seconds, minutes, hours, days-of-the-month, months and years. It also handles the leap year exceptions in its internal logic. This means that the RTC represents each two-digit value (00-99) and remembers it regardless of the power state of the system. The BIOS uses a portion of this memory to store the century part of the year (e.g., 19, 20).

The standard CMOS RAM data areas are accessed through I/O ports 0070h and 0071h. Good programming practices dictate updating CMOS contents via BIOS or operating system services. Attempts to manually update the CMOS RAM should be avoided; as it may lead to corruption of the contents of the 64 bytes of CMOS RAM.

Location of the Real Time Clock (RTC)

Table 1 describes the portion of the RAM allocated to the RTC and the units of time in the CMOS RAM data area. They present the CMOS RAM data definition for real-time clock information

Table 1: Real-time Clock (RTC) Data Definitions

Address	Byte	Units of Time
00h	0	Seconds
01h	1	Second Alarm
02h	2	Minutes
03h	3	Minute Alarm
04h	4	Hours
05h	5	Hour Alarm
06h	6	Day Of Week
07h	7	Date Of Month
08h	8	Month
09h	9	Year

RTC CMOS Century Byte

The CMOS century byte is not part of the internal clock circuitry of the RTC. Therefore it can reside in various locations of CMOS. In the original IBM PC/AT Model™ the century was at byte 32h. When IBM PS/2 MicroChannel™ architecture was designed, the century byte was placed in byte 37h. In most of the newer Year 2000 hardware ready IBM Personal System, the century byte can be found in byte 32h.

Programmable Interval Timer

The Programmable Interval Timer (PIT) is a hardware device that creates clock signals. This timer tick is generated at 18.2 times per second. The device invokes the INT 08h System Timer Interval Service Routine (ISR), which maintains ticks in the system time counter.

Basic Input Output System (BIOS)

BIOS provides the interface between the operating system and the PC hardware. A function of BIOS includes reading and writing both CMOS registers, as well as the timekeeping counter in BIOS system memory.

System Time Counter

A software timer is kept in BIOS, independent of the Real Time Clock. The system time counter resides in volatile reserved memory location addresses 40:6Ch to 40:6Eh in the BIOS Data Area (BDA). This counter increments with every timer tick generated from the hardware's interval timer. It also maintains a software mechanism to keep track if a new day or a 24 hour period has expired.

System Timer and Real Time Clock Services INT 1Ah

The System Timer and Real Time Clock Services INT 1Ah typically provide system and application software with the ability to read and set the date or time in the RTC. It also provide similar services to the BIOS System Timer. Table 2 lists the system-timer and real-time clock services of INT 1AH.

Table 2: INT 1Ah System Timer and Real Time Clock Services

Function	Description
00H	Read System-Timer Time Counter
01H	Set System-Timer Time Counter
02H	Read Real-Time Clock Time
03H	Set Real-Time Clock Time
04H	Read Real-Time Clock Date
05H	Set Real-Time Clock Date

Operating Systems

Operating systems provide their own Time of Day Services similar to BIOS, including:

- Operating system counters
- Commands to access

Refer to Table 3 for sample Operating Systems Timing Services.

Table 3: Operating Systems Timer Services

Commands	Description
GET_DATE	Returns operating system date
GET_TIME	Returns operating system time
SET_DATE	Sets date, operating systems and RTC
SET_TIME	Sets all timers, operating systems, BIOS and RTC

System and Application Software

System software such as a network operating system can also have a similar timer subsystem. It can manage not only the server but can also synchronize workstations across the network. Additionally, applications such as schedulers and calendar programs may also have its own independent timer subsystem. It is critical that the operating system and all applications running on a PC have been checked for Year 2000 readiness.

Section 2

Year 2000 Interactions
Hardware & BIOS

Introduction

An IBM Personal System identified Year 2000 hardware ready should:

- Boot to the correct date in and beyond the Year 2000.
- Process a correct date through BIOS Timer Service 1Ah
- Correctly track the date in the leap year in and beyond the Year 2000
- The PC's setup/configuration must reflect an accurate date.

The following section describes the interactions of BIOS with the hardware, for both Year 2000 hardware ready systems, as well as those IBM considers as not ready.

Real Time Clock Limitation.

For most personal computers in the industry today, there is a limitation in the internal circuitry of the Real Time Clock. It increments each unit of time with the exception of the century. Setting the century becomes the role of BIOS through Timer Service 1Ah. Furthermore, because the mapping of CMOS is not standardized throughout the industry, the CMOS century byte can reside in a various number of locations.

BIOS Timer Service 1Ah

This BIOS Timer Service (INT 1Ah, Funct. 5) can set the RTC Century registers correctly in CMOS for both hardware ready and not ready IBM Personal Systems, since the IBM PC/AT model. A not ready PC may not have the ability to return the correct century using the Read CMOS Date (INT 1Ah, Funct 4). A hardware ready system should include the ability to return to the requesting function, the correct century on or after the year 2000. One method the BIOS may use that can update the century in hardware is by invoking Timer Service 1Ah, Read CMOS Date.

```
If year is greater than or equal to 00 and year is less than [xx]
      Read the century
      If century equals 19,
            Update century to 20
```

XX ranges from 05 to 80

This Service is invoked in one of the following methods:

- During a reset ("power on", or "ctrl-alt-del") of the system.
- A software application requests the date specifically using the BIOS Timer Service 1Ah.
- An operating system requests the date at operating system initialization.

Restarting the PC in the Year 2000

In an IBM Personal System that is hardware ready, it is imperative that on the first boot after the Year 2000, the RTC is accurate, including the century. If the IBM Personal System is not ready, the RTC century byte will remain at “19”. Normally, an operating system when loading will request the date from the RTC, using Timer Service 1Ah, Read CMOS Date. If a system is ready, this request will return “2000” as the year, otherwise this request might return “1900”.

Figure 1 illustrates the flow diagram of the Timer Interaction for the first boot (“power on reset”, or “ctrl-alt-del”), on 1-1-2000. This illustration shows the state of the RTC century byte to be initially “19”.

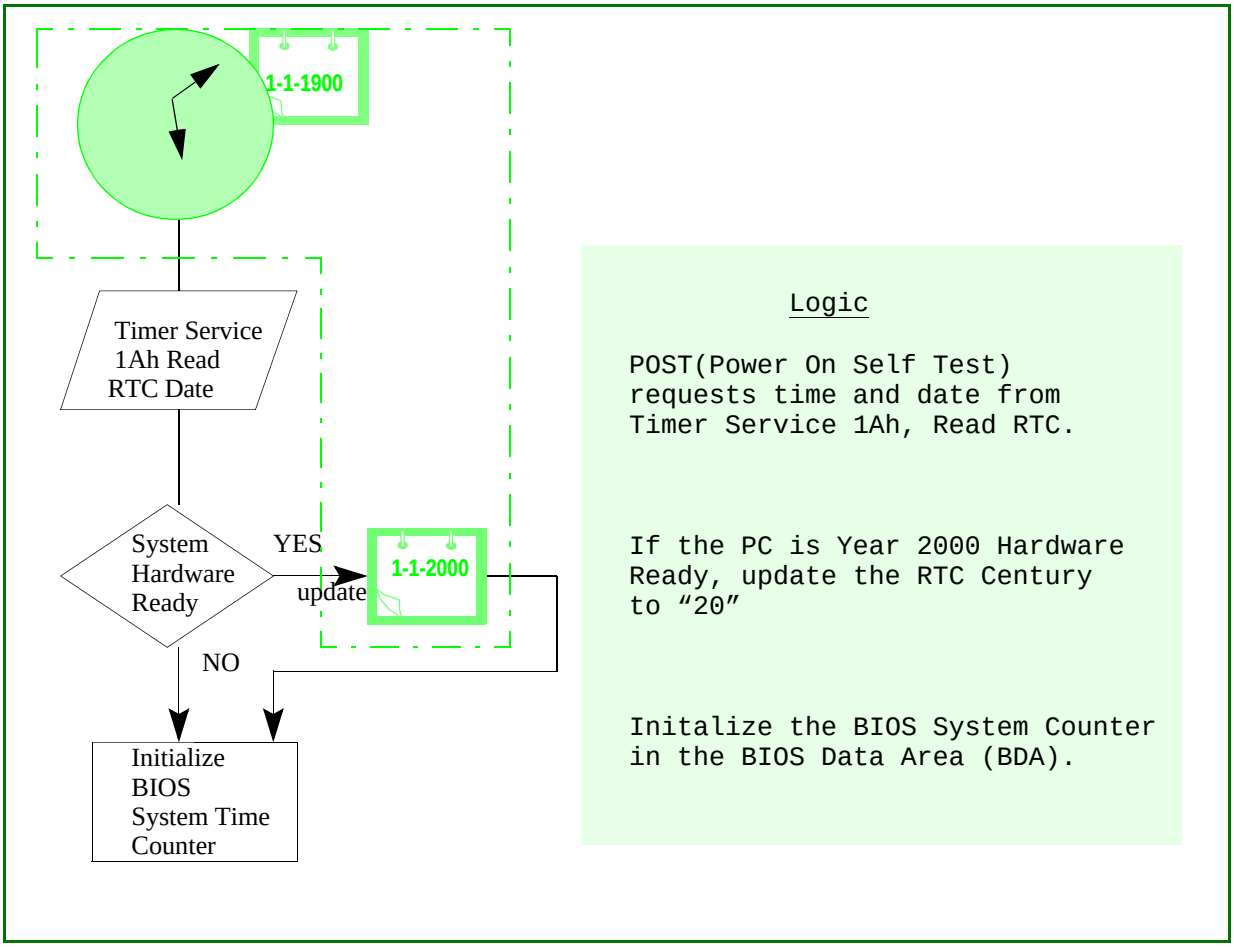

Figure 1: First Boot on 1-1-2000

Transition into the Year 2000

There is a possibility that if a hardware ready IBM Personal System is left running during the transition into the next century, that the RTC century register will not get updated until a reboot of the system occurs. This, however, should not pose a problem if the applications used on that system are well programmed to use either the BIOS or a Year 2000 ready operating system to request the date. Because the RTC Century can reside in any location, applications should only request the date using BIOS or the operating system. If an application requests the date directly from the RTC registers, however, the data from the RTC CMOS century byte may be "19". Figure 2 illustrates the following methods of requesting the date:

- Method 1 - Using the operating system
- Method 2 - Invoking timer service 1Ah
- Method 3 - Accessing the RTC directly

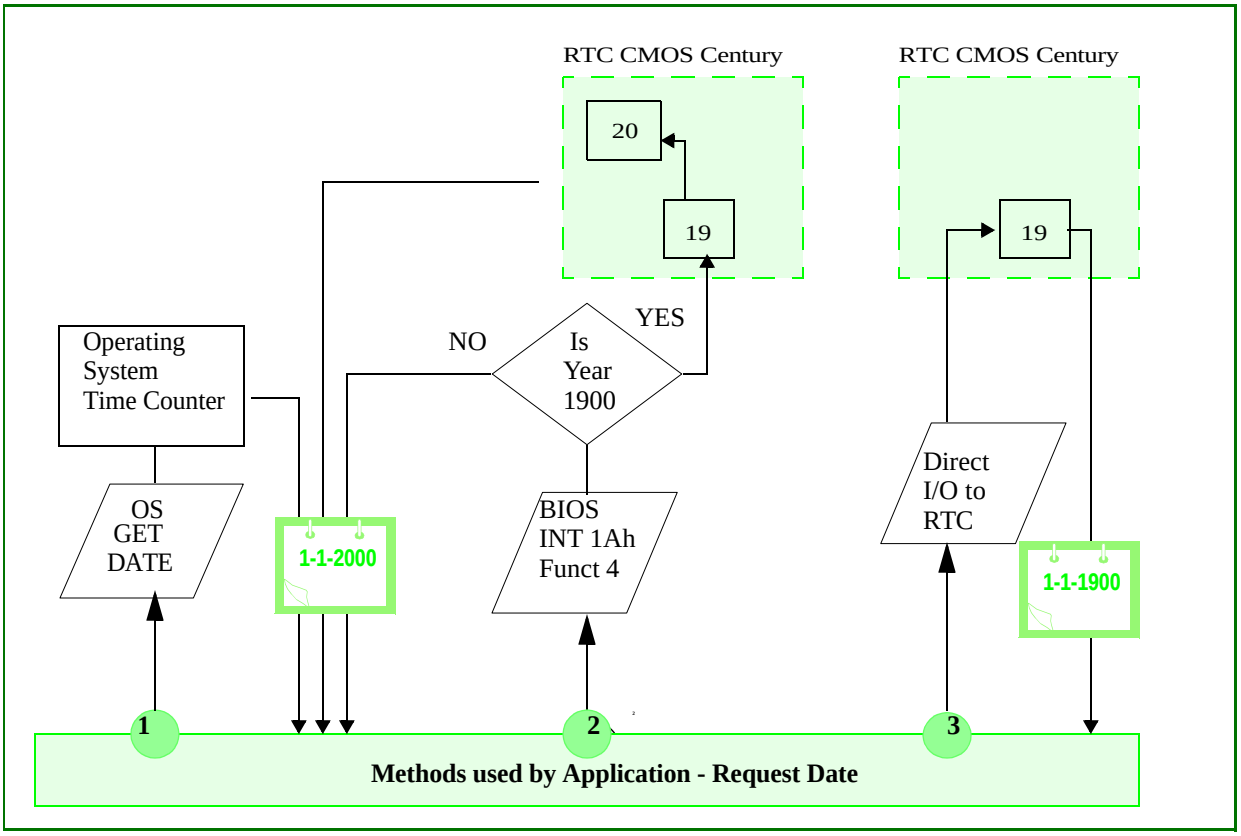

Figure 2: **Application requesting date in the year 2000.**

RTC Century Intervention

To enhance the capability of many IBM Personal Systems, additional logic was added in BIOS to update the RTC century when the Year 2000 occurs while the system is left running. In one case, the BIOS will use the Interval Service Routine (ISR) to accomplish this. Using the 24 hour flag associated with the BIOS System Timer in the BDA, conditional logic has been added to check if the RTC century is “19” and the year is “00”. In this condition, as seen in Figure 3, an update to the century register will occur.

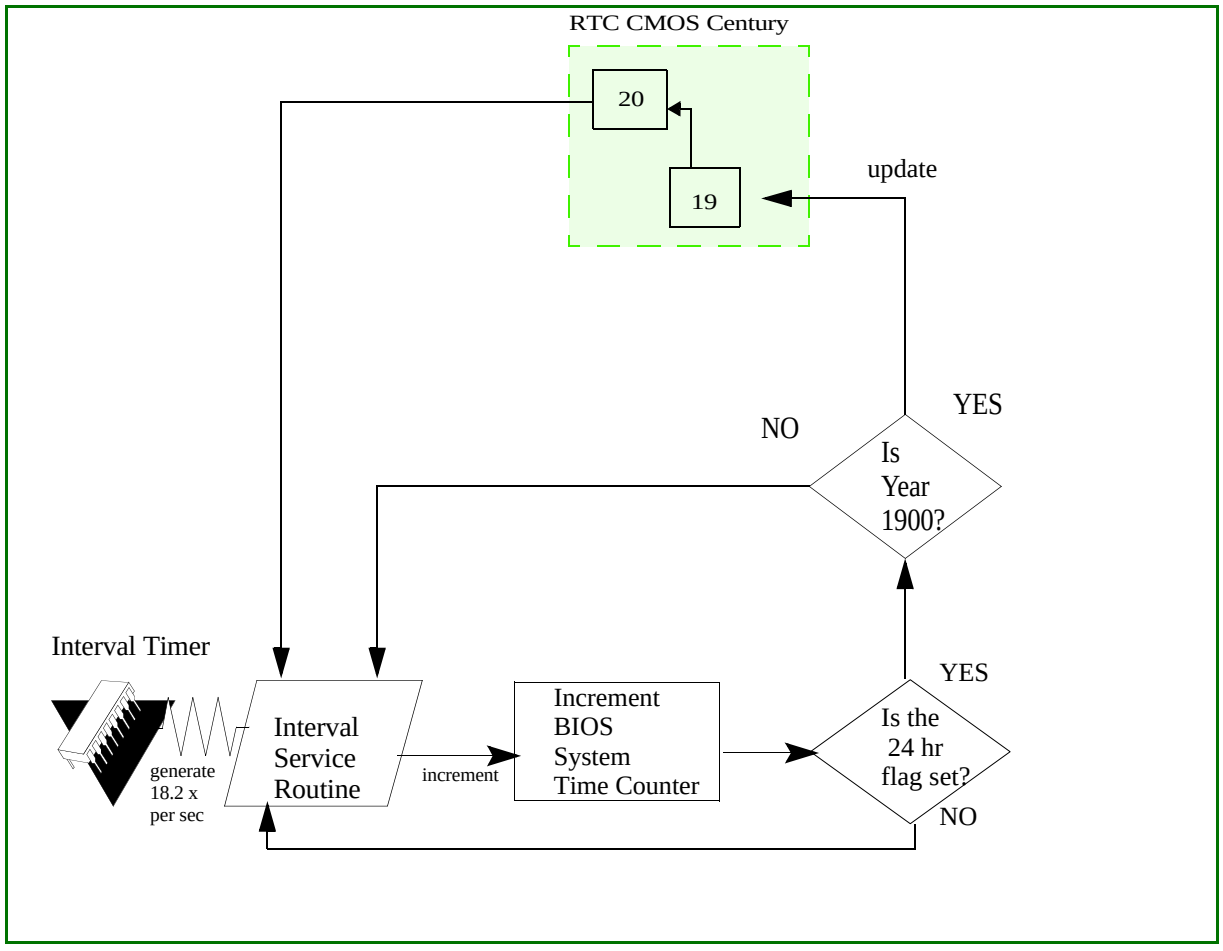

Figure 3: Updating Real Time Clock with Interval Service Logic

Leap Year Calculations

A problem can arise if the algorithm in the firmware or software uses the wrong divisor. For example, 1900, which is not a leap year, and 2000 are both divisible by 4. The algorithm must include a conditional that if the year is on the century boundary, the divisor should be 400.

IBM Personal Systems use the internal logic in the hardware's RTC that correctly identifies the leap year.

Section 3

Year 2000 Interactions
Hardware & Operating Systems

Introduction

Operating Systems can have as crucial role in maintaining the integrity of the Year 2000 date data, as that of BIOS. For this reason it is important that a personal computer is running on a Year 2000 ready operating system platform. As stated earlier, operating systems have their own software timer, that tracks both date and time. Many operating systems such as PC DOS™, use BIOS to update the date, and time, other operating systems such as Windows NT 4.0™ replace many of the services in BIOS, with system drivers than may provide equivalent date and time functions. Some recently released operating system software such as PC DOS 2000™, intercept BIOS timer functions and correct the date if invalid.

To clearly understand year 2000 roles of operating systems, the characteristic of the operating system are generalized as follows:

- **Year 2000 Aware:** An operating system that intentionally corrects the date in the year 2000
  This correction only can occur on PCs with the typical RTC CMOS century locations (byte 32h or 37h)
- **BIOS Dependent:** An operating system that depends on BIOS for reading and updating the date.
- **Independent of BIOS:** An operating system that replaces BIOS with system drivers to read and set the date.

Operating Systems & the RTC

During an operating system initialization which starts after POST is completed, the operating system will request the date typically by issuing a call to BIOS Timer Service 1Ah, Read CMOS Date. In a hardware ready PC, as explained earlier, the system will have already updated the century, and will correctly return to the operating system an accurate date.

In a not ready PC, however if the year requested from the real time clock is considered invalid, like “1900”, it will set various dates depending on its own internal logic. If this date set is incorrectly, it is possible that it can be undetected by the user and the system will run using an erroneous date. This could cause problems with applications and processes that are date dependent

Operating Systems & Timer Service 1Ah

The BIOS Timer Service as seen earlier plays a major role in a Year 2000 hardware ready system. For operating systems with logic that executes independent of BIOS, it is necessary that the equivalent operating system timer functions return the year 2000 date correctly. As such, it is important that the operating system software be Year 2000 ready.

Starting the Operating System in Year 2000

When an operating system loads in a PC that is not ready for the year 2000, the operating system date is dependent on the specific platform. One of the steps an operating system invokes is a call to Timer Service 1A, Read RTC.
The date returned in a not ready system will typically be “1-1-1900”. Depending on the operating system this date is usually processed with two different results.

```
If the Operating System is Year 2000 Aware
    Update the RTC century to “20”
    Initialize Operating System Date to 1-1-2000
else
    Consider date as invalid
    Initialize Operating System to default date (usually 1-4-1980)
```

Figure 4 shows the initial flow of how the operating system loads in a not ready system on 1-1-2000.

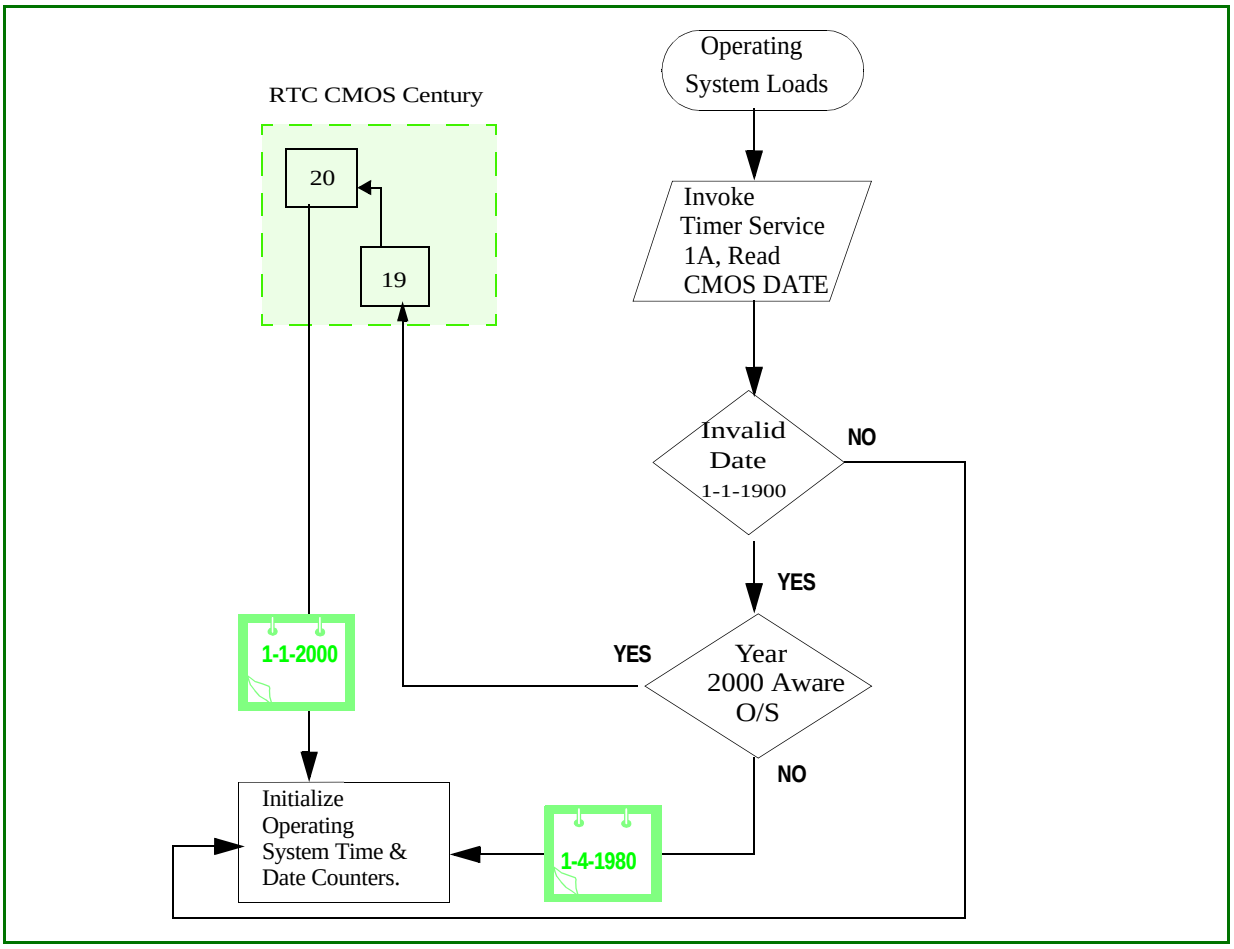

Figure 4: **First time Operating System Load on 1-1-2000**

Table 4 describes the behavior of IBM Operating systems that interact with not ready IBM Personal Systems The table describes the date the PC will start with on or after the year 2000, what the Timer Service 1Ah, Read CMOS Date function will return, and if the CMOS century register in the RTC will be updated.

Table 4: IBM Operating Systems' Interaction with Not Ready Hardware.

Operating System	Starting Operating System Date	BIOS Timer Service INT 1A Date	RTC Century updated
PC DOS 7.0	1-4-1980	1-4-1980	NO
PC DOS 2000	1-1-2000	1-1-2000	YES
OS/2 Warp 3.0	1-4-1980	1-1-2000	NO
OS/2 Warp 3.0 w/ FixPak 35	1-1-2000	1-1-2000	YES
OS/2 Warp 4.0	1-4-1980	1-1-2000	NO
OS/2 Warp 4.0 w/ FixPak 5	1-1-2000	1-1-2000	YES

An Operating System Session in the Year 2000

If the personal computer is running during the transition into the year 2000, and the operating system is Year 2000 ready, Figure 2, Method (2) illustrates that an application request, will return the correct date. The Timer Service or operating system equivalent service will also return the year 2000 properly.

The intervention of the Real Time Clock to immediately update the century when the system is left running could be influenced by the specific operating system. The Interval Service Routine (ISR) may be independent of BIOS and provided by the operating system. In this case the logic as seen in Figure 3 may not be included.

An example of a system driver replacing the ISR is that of the OS/2 Warp Operating Systems™. Now, both versions OS/2 Warp FixPaks have the logic to update the RTC Century while the system is left running. This logic used is similar to that seen in the BIOS RTC Intervention in Figure 3. Table 5 shows these operating systems, if the RTC century will update while the system is left running into the year 2000, which system owns the ISR function.

Table 5: IBM Operating Systems' RTC update with Ready Hardware.

Operating System	RTC Century (system left running)	Dependent on (BIOS, OS)
PC DOS 7.0	"19"	BIOS
PC DOS 2000	"20"	BIOS
OS/2 Warp 3.0	"19"	OS
OS/2 Warp 3.0 w/ FixPak 35	"20"	OS
OS/2 Warp 4.0	"19"	OS
OS/2 Warp 4.0 w/ FixPak 5	"20"	OS

Section 4

Year 2000 Solutions

Manual Reset of the Date

Regardless if an IBM PC is considered Year 2000 hardware ready or not ready, when an operating system's SET DATE command is invoked from a command line or graphical clock interface, the computer's RTC date will be updated correctly, including the century. This command must be executed on or after 1-1-2000. It will not require a reset or reboot of the system. Figure 4 illustrates the simplicity of the manual reset.

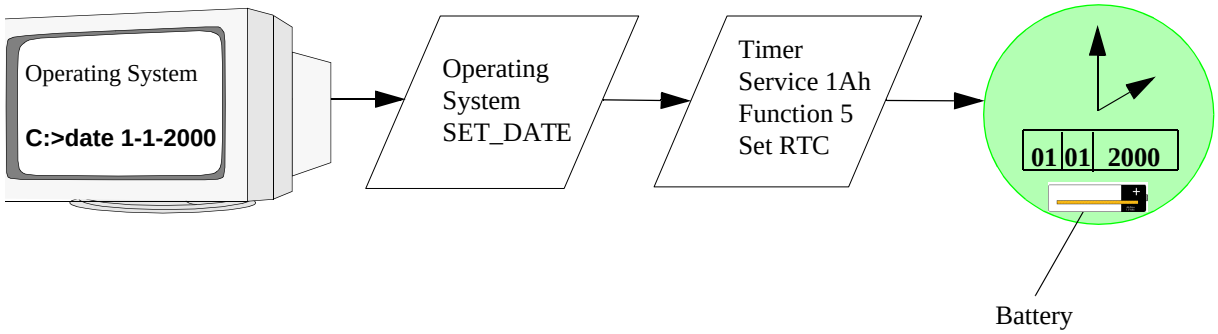

Figure 5: Date Command Logic

The importance of this manual intervention is that all IBM PC's since the IBM PC/AT model should be able to have the date accurately programmed into the PC. These systems have a battery that keeps CMOS including the RTC date and century regardless of the power state of the system. When the date is passed to the RTC registers, the timekeeping of the date will continue to update all the units of time. There is no need to reset the date more than one time unless the battery of the RTC needs to be replaced, and a reset to the date and time will need to be performed.

Appendix C lists steps for many operating systems date commands.

BIOS Upgrade

IBM systems that are capable of upgrading the firmware or BIOS using a flash upgrade utility, most likely have a flashable BIOS available that is Year 2000 Hardware Ready. A general time line to determine if a system is flash upgradeable is those IBM Personal Systems, most with 80486 processors, available from 1994 on. The IBM Product Readiness Database has information about the specific BIOS, and where to download it.

All website addresses including the Product Readiness Database and PSG Year 2000 Website can be referenced in Appendix D.

Year 2000 Device Drivers

If an IBM Personal System is not ready for the Year 2000, a device driver is available from IBM. There are several versions of the system driver, depending on the operating system platform. These drivers will add the following logic:

- Timer Service 1Ah Read Date will update the century.
- At OS load, update RTC Century to 20 prior to initializing the operating system timers.
- Update the RTC century if the system is powered on during the Year 2000 transition.
- Will not load if the year is greater or equal to the Year 2000.

These drivers can be downloaded on the PSG Year 2000 Website referenced in Appendix D.

Section 5

Year 2000 Testing

Hardware Testing

In order to accurately test the behavior of the PC hardware in the Year 2000, it is recommended that any test, whether manual or using a tool be performed in a Year 2000 Ready DOS operating system. The DOS operating systems depends on BIOS services and will give complete results of how the BIOS and the hardware interact. The target system under test should be also be detached from a network, to avoid incorrect test results caused by network hardware and software.

If date testing with the operating system or network system is required, this should be done after the initial hardware testing from a DOS platform. If any problems are then found, they can be better isolated.

Testing Tools

Many testing programs are available today on the market for purchase or on many internet sites as freeware that will test PC hardware and BIOS. A word of caution however, some tests may not output expected results and it may be beneficial to use more than one test when testing hardware.

IBM Evaluation Tool

IBM has provided an evaluation tool that will test:

- BIOS Timer Service 1Ah.
- First boot in the year 2000.
- Leap Year Tests.
- Real Time Clock update while system is left running.

It is available as freeware on the IBM PSG Year 2000 website. This website address can be found in Appendix D.

Manual Testing

Appendix B describes manual tests that a user can run to test year 2000 date processing. These tests should be performed in a stand alone environment booting from a DOS diskette as to not corrupt any processes, files, or logs that are on the production system.

If testing operating system interactions, it is recommended that these test be performed on a system that is not in production.

Software Testing

As seen in this paper, there are obvious roles that software including operating systems, can play in year 2000 date processing. It is key that the software be tested for Year 2000 readiness, as well as the proper interaction with the hardware.

Appendix A
Year 2000 PC Readiness Definitions

A.1 The following are the terms and definitions of Year 2000 Readiness.

Term	Definition
Hardware Ready	If the database report indicates that your PC is “Hardware Ready”, if you take a simple action, your model will be capable of updating its hardware clock correctly for the new century. Like most other Year 2000 Ready PCs throughout the industry, a reboot is recommended after the Year 2000 occurs in order to synchronize the hardware clock for the new century. The “Hardware Ready” designation in the database applies only to the IBM hardware content and does not apply to any software content (operating system or application programs) that may be pre-installed or otherwise provided by IBM with the purchase of the IBM PC.
Hardware Ready*	If the database report indicated that your PC is “Hardware Ready*”, then your model’s hardware can meet the criteria to be considered “Ready”, but only if you update your PC to the level of BIOS identified in the report. Like most other Year 2000 Ready PCs throughout the industry, a reboot is recommended after the Year 2000 occurs in order to synchronize the hardware clock for the new century. You are responsible for determining the applicability of the BIOS update, obtaining it from IBM and installing it.
Not Ready	If the database report indicated that your PC is “Not Ready”, then in order to avoid the PC providing potentially incorrect date information, you must manually reset the hardware clock one time after the Year 2000 occurs, before using the system. Instructions for resetting the hardware clock are available at the IBM website.
Not Ready+	If the database report indicates that your PC is “Not Ready+”, then your model is not ready, but a Year 2000 device driver is available from IBM that may be able to help you achieve Year 2000 hardware readiness equivalent function under selected operating systems. You are responsible for determining the applicability of the device driver, obtaining it from IBM, and installing it.

Appendix B
Year 2000 Manual Tests

Manual tests should be performed in a stand alone environment booting from a DOS diskette as to not corrupt any processes, files, or logs that are on the production system. The system should also be detached from a network since the network hardware and software can influence the output of the test. If testing operating system or network system interactions, it is recommended that these tests be performed on a non-production system.

B.1 Hardware's Real Time Clock with System Left On

1. Set the date to 12-31-1999.
2. Set the time a minute before midnight (23:59:00).
3. Keep the system running for that minute.
4. Reboot the system.
5. Check the date again.

B.2 Hardware's Real Time Clock with System Powered Off

1. Set the date to 12-31-1999.
2. Set the time for a minute before midnight (23:59:00).
3. Turn the system off for that minute.
4. Reboot the system.
5. Check the date again.

B.3 BIOS Timer Service (INT 1Ah)

1. Set the date to 12-31-1999
2. Set the time for a minute before midnight (23:59:00).
3. Wait one minute.

Using a software debugging program such as DOS debug.com, code the following:

```
mov   ah,04h          ;set up function 4, read cmos date
int   1ah             ;for timer service INT 1Ah
int   3               ;interrupt to break
```

Execute this code. Upon return, examine CPU registers.

CH = Century
CL = Year
DH = Month
DL = Day

B.4 Leap Year Test

1. Set the date to 02-28-2000.
2. Set the time for a minute before midnight (23:59:00).
3. Turn the system off for that minute.
4. Reboot the system.
5. Check the date for 2-29-2000.

Appendix C
Operating Systems' Date Command

C.1 Manually Resetting the Date in DOS

The following procedures must be done ON or AFTER January 1, 2000 and needs to be performed only once. The examples shown below will synchronize all the timer in the PC.

1. Boot to the DOS operating system
2. At the prompt C:\> type **DATE** [*month*]-[*day*]-**2000** and press "ENTER" (i.e., C:\>**DATE 1-1-2000**)

C.2 Manually Resetting the Date in Microsoft Windows 95™, Windows 98™, Windows NT™

In a Year 2000 ready operating system, the date can be manually reset in Windows'95, Windows '98 and Windows NT by following these simple steps:

1. Click on Start
2. Select Programs
3. Click on MS-DOS prompt
4. At the prompt C:\Windows> type **DATE** [*month*]-[*day*]-**2000** and press "ENTER" (i.e., C:\WINDOWS>**DATE 1-1-2000**)
5. At the MS-DOS prompt, type **EXIT** and press "ENTER".

IMPORTANT
If you are resetting the date in Windows NT on a PC server or PS/2 server, you need to reset the date in a DOS stand-alone environment.

C.3 OS/2 WARP Version 3

1. Double click on OS/2 System
2. Double click on Command Prompts
3. At the prompt C:\> type **DATE** [*month*]-[*day*]-**2000** and press "ENTER"
4. At the C:\> prompt, type **EXIT** and press "ENTER". This will return you to OS/2.

C.4 OS/2 WARP Version 4

1. Double click on OS/2 System
2. Double click on Command Prompts
3. At the prompt C:\> type **DATE** [*month*]-[*day*]-**2000** and press "ENTER"
4. At the C:\> prompt, type **EXIT** and press "ENTER". This will return you to OS/2.

C.5 Microsoft Windows 3.11™

1. Double click on the "MAIN" folder
2. Double click on the "MS-DOS" prompt icon
3. At the prompt C:\Windows> type **DATE** [*month*]-[*day*]-**2000** and press "ENTER"
4. At the C:\> prompt, type **EXIT** and press "ENTER". This will return you to Windows.

Appendix D

D.1 A list of the IBM website addresses are as follows:

Website	Address
IBM Corporate Year 2000 Website	http://www.ibm.com/year2000
IBM PSG Year 2000 Website	http://www.pc.ibm.com/year2000
IBM Product Readiness Database	http://www.yr2k.raleigh.ibm.com
IBM PC Readiness Database	http://www.ibm.com/year2000/ready
PC Systems Offering & Matrix	http://www.ibm.com/year2000/pc

Appendix E

E.1 Other Important Information

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