Keeping Time on Your PC

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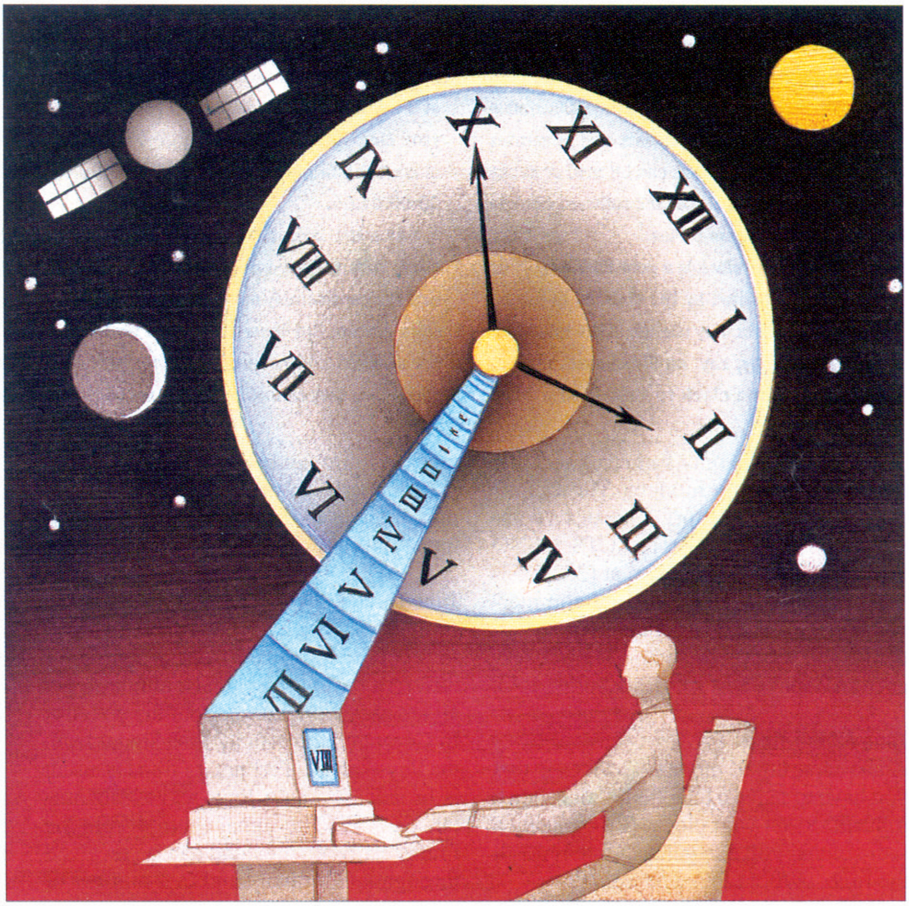
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If you've ever relied on your computer's clock for timekeeping, you know that it's not particularly accurate. Most people aren't concerned if their computer's clock is off by a few seconds (or even minutes, or hours) so long as they can tell when a file was last revised. However, many applications, such as manufacturing process control, synchronous communications, and financial recordkeeping, require timekeeping that's accurate to the nearest second or better.

How can you make your computer keep accurate time? The answer lies in setting your clock to a reliable time source and then frequently polling that source for time updates and resetting your clock as often as necessary.

Accurate time information is easy to get through your modem or a network time service. You can also "keep time all the time" using a radio clock or a precision real-time clock board to capture accurate time information broadcast by government agencies. Whatever method you choose, you no longer have to be satisfied with your PC's marginal timekeeping abilities.

Your PC's clock was never meant to be an accurate timepiece. But that doesn't mean you can't turn it into one.

Accurate Time by Modem

Since 1988, the National Institute of Standards and Technology, or NIST, a branch of the U.S. Department of Commerce, has operated ACTS (Automated Computer Time Service) out of Boulder, Colorado. Anyone can access ACTS through a modem and simple telecommunications software (see the text box "How to Set Your PC Clock by Modem"). When you connect to ACTS via modem, it sends out a highly accurate and reliable time code that you can use to set your computer clock to the correct time according to NIST's clock.

ACTS is referenced to an atomic clock located at NIST that functions as the U.S. national standard for civilian time and frequency. ACTS provides far more accuracy than your typical PC clock can handle (see the text box "The Clocks Inside Your PC"). It's capable of setting your computer clock to within 1 millisecond of NIST time. The software clock in your PC, however, ticks about once every 55 ms. Thus, you can be assured only that your clock has been set to within 55 ms of the correct time. Even then, your clock won't stay set properly for long. For example, a PC clock that gains 5 seconds per day advances 1 ms every 17 seconds.

You can also set your computer clock to NIST time through the Internet at the following address: time_a.timefreq.bldrdoc.gov (absolute Internet address 132.163.135.130). You can access the server and obtain the software and documentation needed to use the Internet time service. This service is less accurate than the modem service, since it is difficult to estimate network delays. However, it's well suited for keeping your clock set to the nearest second.

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The Clocks Inside Your PC

Every DOS-based computer has a built-in software clock. Generally, it's driven by a Motorola 146818 real-time clock chip, Intel 8253/8254 timer-counter chips, or equivalent devices. Your BIOS tells the chip to generate an interrupt every 54.936 milliseconds, or about 18.206 times per second. Another BIOS routine counts the interrupt requests and generates a time-of-day clock that can be read or set by other software. DOS uses the software clock to date- and time-stamp files.

The software clock is a poor timekeeper. Its accuracy is limited by the stability of the interrupt requests. Any change in the interrupt-request rate by, say, an ill-behaved application causes the clock to gain or lose time. Further, the clock's time can drift by a minute or more each day you leave your computer on.

Another problem is that your software clock cannot display all possible time-of-day values. Its resolution is limited to the interval between interrupts. Only times that are even multiples of 54.936 ms can be displayed. For example, your clock cannot display 00:00:01.00; the closest it can get to this is 00:00:00.98 or 00:00:01.04.

Since the 286, PC-type computers have come with battery-backed hardware clocks that are considerably more accurate than software clocks. But these, too, have problems. For example, they cannot display fractions of a second, so they cannot be read or set with any degree of accuracy better than a second.

A hardware clock's accuracy is determined by the quality of its time-base oscillator, which typically is a 32.768-kHz crystal. These crystals are economical, costing less than $1 in single quantities. However, they offer only marginal timekeeping performance, and they are sensitive to temperature changes, voltage fluctuations, and vibrations.

Even under the best conditions, these oscillators are not likely to be stable to better than 1 part per million—about 0.1 second per day. In actual operation, most hardware clocks seem to gain or lose time at a rate of about 1 to 15 seconds per day, with 5 or 6 seconds per day being typical.

ACTS isn't the only source of accurate time accessible by modem. The USNO (U.S. Naval Observatory) operates a computer time service similar to ACTS. USNO time is available via modem at (202) 653-0351 (1200 bps only). Several commercial software packages enable you to call the USNO service, including TimeChecker from Zephyr Services (Pittsburgh, PA).

Time All the Time

A shortcoming of modem services is that you have to make a telephone call (often a toll call) to set your clock. But by using a radio clock, you can get accurate time all the time, without the expense.

Radio clocks are designed to receive and decode time signals broadcast over radio by many national governments. Your applications can use the radio clock to constantly set your computer's clock, or they can get all timing information directly from the radio clock, ignoring your computer's clock entirely.

Radio clocks cost anywhere from as little as under $500 to as much as $5000 or more. Some are stand-alone devices with a digital display, while others are plug-in expansion cards. Stand-alone units connect to your PC, Macintosh, or other computer through RS-232, RS-422, or IEEE-488 interfaces.

All radio clocks provide enough accuracy for PC timekeeping, and most provide greater accuracy than ACTS. However, you need to make sure that the radio signal of the clock you choose can be received in your area. Also, nearly all radio clocks require an outdoor antenna to operate properly, so you'll need to make sure that you can mount the right type of antenna for your radio signal.

Time Through Airwaves

In the U.S., you can set your radio clock to receive broadcasts from at least four different radio time signals, although not all are receivable throughout the country. In Germany, the official time signal from the Physikalisch-Technische Bundesanstalt is broadcast over a long-wave transmitter, DCF 77. The signal is aired from the Frankfurt/Main area and can be received throughout Germany and in a number of neighboring countries.

In the U.S., NIST broadcasts time information over radio stations WWV and WWVH in Colorado and Hawaii, respectively. You can tune in to either station with an ordinary shortwave radio set to 2.5, 5, 10, or 15 MHz. WWV is also aired on 20 MHz.

Under the right conditions, WWV and WWVH can be heard just about anywhere in the world, including the Southern Hemisphere. However, 5, 10, and 15 MHz are allocated for time and frequency stations by international agreement. Consequently, at least 15 other stations broadcast on these frequencies, often blocking out WWV's signals. For example, near India you'd hear the Indian Republic's broadcast, not WWV, on 5 MHz.

When you tune in to a WWV/WWVH broadcast, you hear audio tones that sound like a clock ticking. At the beginning of each minute, a voice announces the current time. WWV and WWVH also broadcast a binary-coded decimal time code on a 100-Hz subcarrier that can be read and decoded only by a radio clock. The time code provides the current hour, minute, second, month, day, year, and other information. The time is accurate to within 1 to 50 ms, depending on your distance from the transmitter and signal-propagation conditions.

Radio clocks designed specifically to receive WWV/WWVH signals, such as those from Odetics (Anaheim, CA), are an economical source for obtaining accurate time. However, they have limitations. One potential shortcoming with using a WWV/WWVH radio clock is that you may need a large outdoor antenna to get good reception.

Another limitation is that, since these stations use shortwave radio signals, reception can be difficult during some parts of the day. As a general rule of thumb, frequencies above 10 MHz work best during daylight hours, while lower frequencies work best at night. Some radio clocks, such as the one from Chrono-Log (Havertown, PA), get around this problem by taking advantage of the fact that WWV and WWVH broadcast on several frequencies. They scan these frequencies and tune in on the one currently providing the best reception.

Other Time Sources

Some radio clocks, such as those from Spectracom (East Rochester, NY) and

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How to Set Your PC Clock by Modem

You can dial in to ACTS (Automated Computer Time Service) at (303) 494-4774. Set your communications software for 300 or 1200 bps, with 8 data bits, 1 stop bit, and no parity. The 1200-bps time code is transmitted every second (see "The 1200-bps ACTS Time Code"). It contains more data than the 300-bps time code, which is transmitted every 2 seconds.

After you connect with ACTS, it sends you a simple ASCII time code. The last character in the time code is an asterisk (*), which is called the OTM (on-time marker). The time values sent by the time code refer to the arrival time of the OTM. In other words, if the time code says it is 12:45:45, this means it is 12:45:45 when the OTM arrives at your computer.

ACTS assumes telecommunications delays between the time the OTM leaves Colorado and when it arrives at your computer. Consequently, it sends the OTM out 45 milliseconds early. This 45-ms figure represents the sum of the following conditions: 8 ms for transmitting the OTM at 1200 bps, 7 ms to allow for the OTM to travel to the average caller in the U.S., and 30 ms for modem-processing delays.

The 45-ms OTM advancement typically removes most telecommunications delays. Say you are calling ACTS from Chicago, and the actual delay is 50 ms. The OTM then arrives at your computer only 5 ms late, with about 90 percent of the delay already removed.

But if you are making an overseas call or if your call goes through a satellite, the delay can be 300 ms or more. Fortunately, ACTS lets you measure the actual line delay, so you can remove as much of the delay as possible.

To measure your actual delay, your software must return the OTM to ACTS after receiving it. Each time the OTM is echoed back, ACTS measures the actual delay. After four consecutive measurements, ACTS begins advancing the OTM by an amount of time equal to the delay. Thus, if your actual delay is 50.4 ms, ACTS sends out the OTM 50.4 ms early instead of 45 ms early. Once ACTS begins using the measured delay, the OTM changes from an asterisk to a pound sign (#). Now the OTM arrives at your computer within 1 ms of the correct time.

In rare instances, ACTS can't measure the actual delay. For example, if the modem connection goes by satellite (i.e., a long delay) in one direction and by land (i.e., a short delay) in the other direction, the standard 45-ms advancement is used, even if your software returns the OTM.

A number of commercial and shareware software packages are available for calling ACTS. Among them are TimeSet from Life Sciences Software (Stanwood, WA) and Time-Sync from SolaCamp Software (Lutherville, MD).

ACTS uses UTC (Coordinated Universal Time). UTC is a 24-hour clock based on the local time in Greenwich, England. It differs from your local time by an integral number of hours only; the minutes and seconds remain the same.

A call to ACTS takes just seconds (see editor's note). Since the time-setting process is so quick, ACTS limits your on-line time to 56 seconds, or 28 seconds if all incoming lines are in use.

Editor's note: *NIST-developed MS-DOS and QBasic programs for accessing ACTS are available electronically. See page 5 for details.*

The 1200-bps ACTS Time Code

After you connect with ACTS, your screen will display the following information, which is explained below:

JJJJJ YR-MO-DA HH:MM:SS TT L UT1 msADV UTC(NIST) <OTM>

JJJJJ is the MJD (modified Julian date). The MJD is the last five digits of the Julian date, which is simply a count of the number of days since January 1, 4713 B.C. To get the actual Julian date, add 2.4 million to the MJD.

YR-MO-DA is the date. It shows the last two digits of the current year, month, and day.

HH:MM:SS is the time in hours, minutes, and seconds. The time is always sent as UTC. An offset needs to be applied to UTC to obtain local time in the U.S. For example, mountain time in the U.S. is seven hours behind UTC during ST (standard time), and six hours behind UTC during DST (daylight saving time).

TT is a two-digit code (00 to 99) that indicates whether the U.S. is on ST or DST. It also indicates when ST or DST is approaching. This code is set to 00 when ST is in effect, or to 50 when DST is in effect. About 48 days prior to a time change, the code starts counting the days until the change. When ST is in effect, the code counts down from 99 to 51 in the 48 days prior to the time change. When DST is in effect, the code counts down from 49 to 01 in the 48 days prior to the time change.

L is a one-digit code that indicates whether a leap second will be added or subtracted at midnight on the last day of the current month. If the code is 0, no leap second will occur this month. If the code is 1, a positive leap second will be added at the end of the month. This means that the last minute of the month will contain 61 seconds instead of 60. If the code is 2, a second will be deleted on the last day of the month. Leap seconds occur at a rate of about one per year. They are used to correct for irregularity in the earth's rotation.

UT1 is a correction factor for converting UTC to an older form of universal time that is still used in navigation. It is always a number ranging from –0.8 second to +0.8 second. This number is added to UTC to obtain UT1.

msADV is a five-digit code that displays the number of milliseconds that NIST advances the time code. It is originally set to 45 ms. If you return the OTM four consecutive times, it will change to reflect the actual line delay.

The label **UTC(NIST)** is contained in every time code. It indicates that you are receiving UTC from NIST (National Institute of Standards and Technology).

The on-time marker **(OTM)** is a single character sent at the end of each time code. The OTM is first an asterisk (*). It changes to a pound sign (#) if ACTS has successfully measured the line delay.

Franklin Instrument (Warminster, PA), receive signals from WWVB, a NIST radio station transmitting from Colorado. WWVB is a low-frequency station, broadcasting on 60 kHz. No voice or other aural announcements are made on WWVB. WWVB broadcasts a time code capable of 0.1-ms accuracy.

The coverage area of WWVB is smaller than that of WWV and WWVH. However, you can receive its signals in nearly all of the contiguous 48 American states with only a small antenna and equipment that's easy to set up and use.

You can also get NIST time from GOES (Geostationary Operational Environmental Satellites), which is operated by the National Oceanic and Atmospheric Administration. GOES broadcasts from two different satellites on a frequency of about 468 MHz. Only a small antenna is necessary to receive the signal in most parts of North and South America. The signal includes a time code accurate to about 0.1 ms. Arbiter Systems (Paso Robles, CA) makes a radio clock that is capable of receiving GOES signals.

The most accurate radio clocks available can tune into signals relayed by the U.S. Department of Defense's GPS (Global Positioning System) satellites. GPS provides worldwide coverage. With the aid of only a small outdoor antenna, a GPS radio clock can receive time accurate to within less than 1 microsecond, which is about 1000 times the accuracy you can get from ACTS.

The price of GPS radio clocks has fallen dramatically over the past few years, to about $1000 from highs of well over $10,000, and their use is becoming widespread as a timing source for both computer and telecommunications networks. Many new GPS products have been released recently, ranging from hand-held navigation receivers to receivers that plug into a PC or AT expansion bus. In fact, a recent survey in the January issue of *GPS World* lists more than 50 manufacturers of GPS receivers, including Odetics and TrueTime (Santa Rosa, CA).

More Stable Clocks

To keep the most accurate time on a PC, you can replace its clock with a precision real-time clock board. These boards, such as those from Bancomm and Guide Technology (both in San Jose, CA), include high-quality time-base oscillators. They also let you use an external oscillator to get superior results. This means that if you have access to a frequency standard, such as a quartz, rubidium, or cesium oscillator, you can use it as your time base by connecting it to your real-time clock board.

APPLICATIONS FOR PRECISION TIMEKEEPING

ENTERPRISE	ASSIGNMENT	TASK EXAMPLE
Aviation	Air traffic control	Air traffic can be routed through air corridors at precise intervals
Finance	Record keeping	Provides a legal audit trail of the dates and times when transactions are completed
Laboratories	Data acquisition	Temperatures can be monitored over a defined time slice
Navigation	Position location	Locations can be determined by observing a star's position at precise times
Power utilities	Power flow	Synchronized power-flow networks send electricity where and when it is needed the most
Radio/TV	Communications	Satellite linkups for network news feeds can be coordinated
Surveying	Measurement	Provides the accurate time required to measure distances and locations
Transportation	Vehicle control	Synchronizes mass-transit vehicle dispatch, location, and schedule control

Precision clock boards greatly increase the stability of your PC clock, but you still need to set and check on the time using ACTS or another service. But if you use a good oscillator as a time base and your system is undisturbed, these boards will keep the correct time for many years. You may never need to set your PC clock again.

Precision clock boards are expensive, costing from $1000 to $2000. External frequency-standard oscillators can cost thousands of dollars more. But the potential performance of a precision real-time clock is unequaled. If you work in a laboratory or industrial setting where a frequency standard is already available, this may be the ideal method for getting accurate time.

Smarter Clocks

NIST recently invented its Smart Clock technology, the basic premise of which is simple: If a clock knows the rate at which it gains or loses time, it can correct itself. Clocks usually drift at about the same rate from day to day. A microprocessor-controlled Smart Clock, however, automatically corrects your clock's drift based on the clock's past performance. For example, if you call ACTS at the same time each day, you might discover that your PC's clock is always fast by 4 seconds. Using this information, your Smart Clock, working much like a memory-resident program does, would gradually move the time back 4 seconds per day (i.e., 1/6 second every hour).

Software that uses concepts similar to those of Smart Clock is starting to appear on the market. For example, RighTime from Air System Technologies (Dallas, TX) is a memory-resident program that automatically adjusts your PC's clock, keeping it on time to within a half-second per week.

Whether you use RighTime's algorithms, your modem, or a precision real-time radio clock board augmented with an external oscillator, it's easy to change your PC clock into a reliable timekeeper. But you have to adjust your clock and measure its performance against a trustworthy time source. That's the benefit provided by ACTS and other time services. ■

Editor's note: *NIST wants you to know that the mention of products in this article does not constitute a NIST endorsement.*

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