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THE JOURNEY INSIDE

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Chip Shots: The Photography of Integrated Circuits

The integrated circuits found in many of today's consumer electronics products, such as TVs, stereos, telephones, and computers, have revolutionized the way we work and play. High-speed computers are now very affordable, allowing us to do things that were all but impossible only a few years ago. Modern television and sound systems will soon serve as vehicles for interactive video and audio on the Internet. Cellular telephones allow us to communicate with relative ease regardless of where we go, and it will not be long before someone devises a direct communication mechanism between cyberspace and the portable telephone.

All of this has been made possible by the general-purpose microprocessor. Many of the same microprocessors that powered small, relatively expensive computers only a decade ago are now found in such common devices as VCRs, video game systems, cellular phones, and automobiles. Advancements in microprocessor performance and reduction in their cost have been major factors in their proliferation to almost every aspect of our lives.

Since the microprocessor's first introduction by Intel engineers in 1971, progress has followed a surprisingly predictable path. This is known as Moore's Law (though it is more an observation than a law), which states that microprocessors become roughly twice as fast every 18 months. The increase in the speed of microprocessors is linked, in part, with their size. As new fabrication techniques have been developed, chips have become smaller and more densely packed with transistors. Since electric current has shorter distances to travel in a small chip, the chip is able to produce the results of an instruction more quickly.

Also essential to the speed of a microprocessor is the sophistication of its design. Computer scientists and electrical engineers constantly develop new techniques to make microprocessors more efficient. One such technique is *pipelining*. Pipelining operates much like a factory assembly line. The processing of an instruction is broken down into pipeline stages. When an instruction has been processed by the first stage, it moves to the next stage in the pipeline. This allows processing to begin on a new instruction at the first stage. While this does not speed up the execution of an individual instruction, it does increase the rate at which the microprocessor can complete the execution of a set of instructions, since there may be many instructions in the pipeline at any given time. More advanced microprocessors employ a superscalar design, meaning that they have multiple independent pipelines that can process instructions concurrently.

Sophisticated designs such as these require that the microprocessor contain millions of transistors etched on the chip in intricately detailed and, often,

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Chip Shots

A new book featuring a collection of *photomicrographs* (photographs taken through a microscope) of various types of computer chips is now available. The book, *Chip Shots: The Hidden Beauty of Integrated Circuits*, is available from Amber Lotus (1-800-326-2375).

For a preview of some of the photomicrographs, visit Michael Davidson's Web site by pointing your Web browser to **http://micro.magnet.fsu.edu/micro/gallery/chips/chipshots.html**.

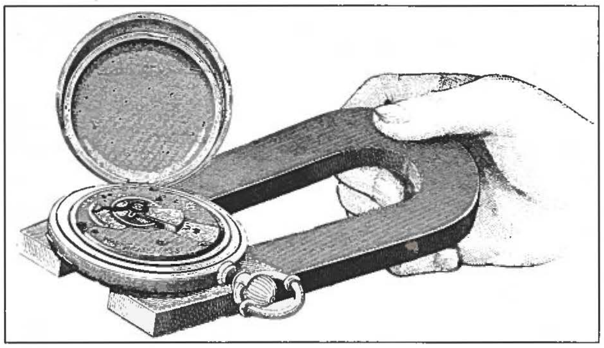
Inside This Issue

A joint publication of Intel Corporation and the International Society for Technology in Education (ISTE).

Science Fairs

Local, Regional, International

There are many science fairs held each year across the country. However, the Super Bowl of them all is the International Science and Engineering Fair (ISEF) held each spring for the last 47 years. In 1995, the fair was attended by nearly 1,200 high school students, teachers, and scientists from more than 40 countries. Of the group of finalists, 160 have patents pending for their work. Hundreds of thousands of dollars in prize money and scholarships are awarded. The grand prize winners receive a trip to the Nobel Science Awards Ceremony in Stockholm, Sweden.



Intel Corporation has recently agreed to become the major sponsor of the ISEF. Over the next 3 years, Intel will invest several million dollars to enhance student awards and teacher programs. Efforts will be made to expand the visibility and impact of the ISEF events. This sponsorship is one of Intel's efforts to advance science, math, and engineering education, and encourage innovation among our next generation of leaders. ❑

For more information on ISEF and local affiliated fairs, contact:

Science Service
1719 N Street NW
Washington, DC 20036
Phone: 202-785-2255

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Please note: As of November 1, 1995, ISTE's area code changed from 503 to 541.

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beautiful patterns. The precise organization, and yet overwhelming complexity, of these microprocessors makes them a fascinating subject for *microscopy*—an investigation using a microscope—as can be seen by the intricate patterns that microscopy reveals on the surface of the Intel Pentium® microprocessor illustrated in Figure 1.

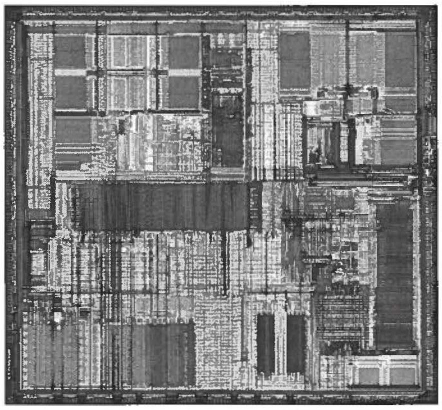

Figure 1. The Intel Pentium® microprocessor.

The examination of integrated circuits is one of the simplest microscopy projects that can be incorporated into the curriculum of middle school and high school science programs. The majority of microscopes found in public schools are of the transmitted-light variety commonly used in biological laboratories. The microscope design in Figure 2 details the common features of these types of microscopes. It is very easy to examine integrated circuits using the lowest power objectives (1x to 10x). The trick is to provide enough oblique illumination to adequately reflect the necessary amount of light from the chip surface up into the microscope objective in order to visualize it in the eyepiece tube.

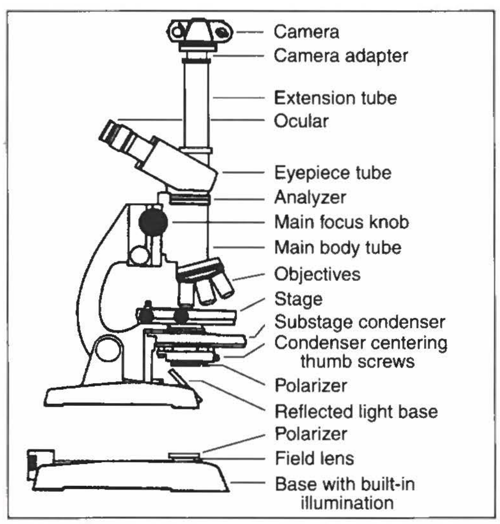

Figure 2. Schematic diagram of a transmitted-light microscope.

This can be done with fiber-optics illumination devices or any other high-power illumination source. The integrated circuit is placed on the microscope stage and illuminated at approximately a 45° angle, with adjustment of the position of the light source to achieve the maximum illumination.

Examination of integrated circuits with reflected light can serve many purposes. For instance, details of a particular circuit structure, such as cache areas, data buses, memory storage areas, and logic units, are readily apparent. Also, by observing differences in the architecture of various integrated circuits, students can develop an awareness of the complex electronics involved in modern devices.

There is a wide variety of places to get integrated circuits for microscopic examination. These silicon chips are generally packaged by molding them into an epoxy resin case or cementing them into a ceramic case. It is virtually impossible to recover an integrated circuit from an epoxy resin case. During the manufacturing process, the resin flows into the etched microstructure. When the epoxy cases are broken or cracked open, the silicon fractures through the center of the integrated circuit and all surface detail is lost. The cement in a ceramic case can, however, be scored with a hacksaw and split with a fine chisel to reveal the internal chip. Most **P**rogrammable **R**ead **O**nly **M**emory (PROM), microprocessors, math coprocessors, and some **R**andom **A**ccess **M**emory (RAM) integrated circuits are protected with ceramic cases. It should be possible to build a substantial collection of integrated circuits using discarded computer parts or cheap packaged chips from local electronics dealers.

Microscopy can be a very effective tool for educators because it provides an immediately rewarding experience for students, who often have short attention spans in the study of science and technology. Since complex sample preparation is not required, the microscopic study of integrated circuits is ideal for students at the middle school and high school levels. Most importantly, the examination of integrated circuits can be used to spark the interests of students in the study of the physical sciences, mathematics, and computers. ❑

Michael W. Davidson
R. Paxton Mason
Sean D. Finke
National High Magnetic Field Laboratory
Florida State University

Intel's Teacher's Corner

Be sure to visit the Teacher's Corner on the World Wide Web (**www.intel.com/intel/educate/index.htm**) and check out two brand new areas. High-tech career profiles can be found in I Can Do That: A Look at Jobs at Intel. More than 30 profiles of Intel employees in careers ranging from a fab manufacturing technician to the Intel webmaster are included. You and your students can learn what these careers are all about; what background, education, and skills are useful as preparation; and what the future holds in each person's career. This site also has a *Life at Intel* article summarizing common skills among jobs. Use these creative ideas and tools to expand *The Journey Inside* education kit curriculum while taking a peek behind the scenes at careers in the high-tech industry.

Be sure to look for the link to the Industry Initiatives for Science and Math Education (IISME) home page in I Can Do That: A Look at Jobs at Intel. The IISME page provides helpful lesson plans designed specifically for mathematics and science. Use them to expand *The Journey Inside* material.

New Ideas

A major area in *The Journey Inside* section of the Teacher's Corner is the Idea Notebook. This is an ongoing compilation of helpful ideas and tools contributed by teachers using the education kit. These suggestions provide creative and fun ways to expand the lesson plans and help your students gain a full understanding of each unit. Please add to this list if you have an idea or hint to make the learning process easier and more fun. You will find an easy-to-use online form for submitting your ideas. We look forward to hearing from you.

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Diane Clark
Intel Corporation

25th Anniversary of the Microprocessor

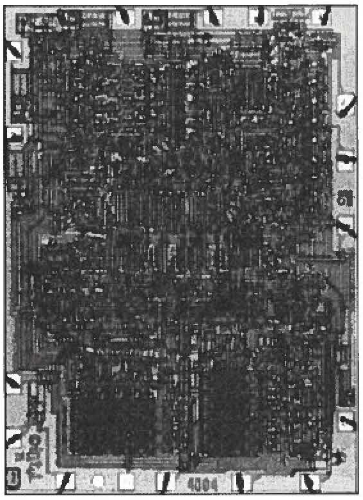
In 1971, the field of electronics was very different than it is today. No one had heard of the microprocessor or desktop computer. Few people could have dreamed that before the end of the century, information technology would affect every aspect of their lives. These technology advancements have been made possible by Intel's invention of the microprocessor—the most complex mass-produced product ever.

Today, powerful microprocessors are bringing multimedia to the Internet, videoconferencing to desktops, and interactive education into the home. Current technology trends point toward an even more amazing future. Intel scientists project that by the year 2010 everyone could be using microprocessors that dwarf the capabilities of today's most powerful supercomputers.

How It All Began

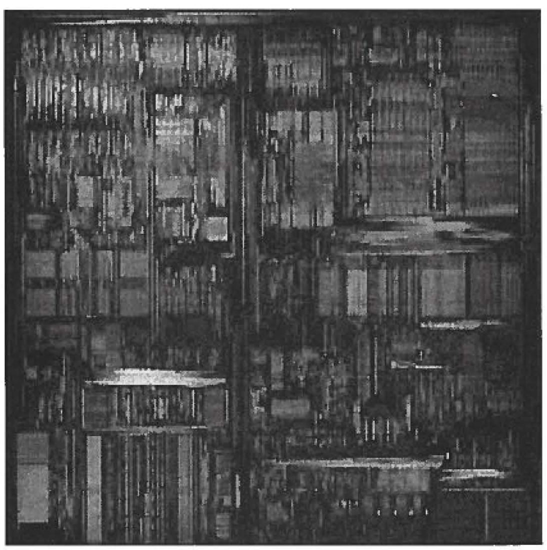
The development of the microprocessor began in 1969 when Busicom, a Japanese calculator manufacturer, asked Intel to design a set of microchips for a special line of calculators. Busicom's original plan called for at least 12 chips, each with a separate function. This design would have required a staff of engineers to develop. Instead, Intel engineer Dr. Ted Hoff came up with the concept of a single general-purpose information processor. Dr. Hoff, along with Dr. Federico Faggin and Stan Mazor, designed and built this central processor, replacing the multichip design. Intel negotiated the rights to market the general-purpose chip for noncalculator applications. This proved to be a historic agreement for Intel and the computing industry.

In 1971, Intel introduced the world's first commercial microprocessor—the 4004. Primitive by today's standards, this single-chip device provided as much computing power as the ENIAC, the world's first electronic computer, which filled an entire room when it was built in 1946.



The 4004, with 2,300 transistors, was the world's first microprocessor.

By 1975, Intel's 8080 microprocessor was found at the heart of the very first personal computer—the Altair 8800. In 1981, IBM made a landmark decision and chose Intel's 8088 microprocessor to power its new product called the PC. The IBM PC helped to launch the personal computer revolution and helped establish the Intel microprocessor as the architecture standard.



A descendant of the 4004, the Pentium Pro® microprocessor has 5.5 million transistors.

The profound impact of microprocessor technology is simple. When Intel introduced the 4004 in 1971, the chip contained just 2,300 transistors to power a desktop calculator. Today, average Web surfers will use processors with more than 3 million transistors to access the Internet and experience the latest in online multimedia.

Opportunity for Learning

Earlier this year, Intel started a yearlong celebration commemorating the 25th anniversary of the microprocessor with an online journey. Join in and learn about the invention sparking the Information Age.

By visiting our *Teacher's Corner* on the World Wide Web (**www.intel.com/intel/educate/index.htm**), you and your students can learn more about the history of microprocessor technology and its impact on the world. Highlights from the 25th Anniversary section include an "if-you-were-there" style game, a celebrity question-and-answer session, and a photo gallery of processor history. Your students can join Intel's founders Gordon Moore and Robert Noyce and current CEO Andy Grove in the game *Interact With History*. In a journey back through time, players guess what decisions Moore and Noyce made in the days leading up to the invention of the first microprogrammable computer on a chip—the 4004 microprocessor. In addition, your students can explore the story of every Intel microprocessor from the 4004 to the Pentium Pro® and its impact on the world.

Another exciting microprocessor learning experience is the virtual museum exhibit *How Microprocessors Work*. This interactive exhibit will take your students through all the steps a microprocessor uses to solve a simple equation. This engaging exhibit cues students to move through the next steps via exciting animations and detailed explanations. The virtual museum is based on a real-life exhibit called *How Microprocessors Work* at the Intel Museum in Santa Clara, California.

Starting in November, Intel-produced articles will appear in consumer, business, and computing publications. These articles will provide a variety of information that can be used to supplement *The Journey Inside* kit. For example, one story profiles individuals from medicine, music, and computing discussing how computers have changed their lives and their work. Another story provides a description of what it might have been like to fall asleep in 1971 and wake up in 1996 to advanced technology.

Intel hopes these activities provide a number of alternatives for expanding *The Journey Inside* education kit curriculum. Join in our celebration of this major milestone and learn how microprocessor technology is changing the industry and our lives. ❑

Diane Clark
Intel Corporation

Robots—For Real

John Beckman's sixth-grade class at the Augusta Christian School in Augusta, Georgia, enjoyed a unique approach to making peanut butter and jelly sandwiches. John dons his plastic protection before having his students activate the unusual robots.

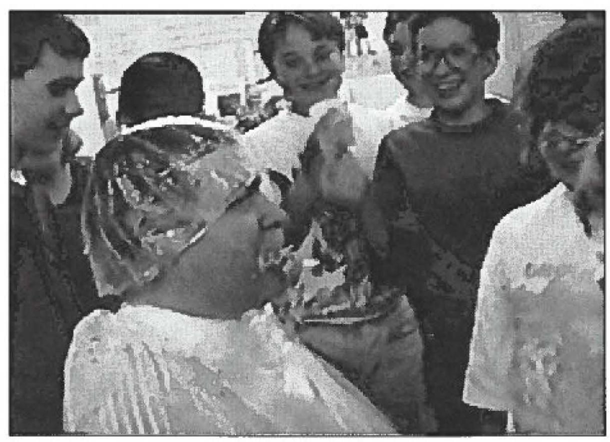
Teacher John Beckman instructs the class.

The two robots are dressed and ready to follow instructions provided by their "programmer."

It took awhile, but this robot has the jelly in the spoon—right where it is needed.

This robot made a wrong turn. But instructions are instructions. Quick, debug the program.

The robots try to place the sandwich in John's mouth, but exact instructions are scarce.



Not elegant, but finally, a hit. How would you like your peanut butter and jelly sandwich served?

This activity is a modification of the advanced-level activities for Unit 2. Having the robots wear plastic gloves and a blindfold adds to the challenge. Thanks to the students and staff of the Augusta Christian School for their videotape. ❏

What Is RAM and How Is It Measured?

Random **A**ccess **M**emory (RAM) is a generic term for internal main memory, which can hold information that can be accessed when needed. RAM represents the computer's primary work space and is often referred to as the *workbench* for the microprocessor. RAM is also called *read and write* memory because a user can read data from or write data to this type of memory. Before a computer can do anything useful, it must move programs from the disk where they are being stored into RAM. Also, any data files to be used by the software are written to RAM prior to use. From this type of memory, the microprocessor can access that data at lightning speed—much greater than the access rate from the hard disk storage area.

Data is stored in memory in units called bytes; one byte stores one character. RAM is referred to by the amount of data the memory chip can hold at one time—measured in megabytes (MB)—roughly 1 million bytes of memory space. For example, a computer with 4 MB of RAM can hold more than 4 million bytes of information. This amount of RAM used to be sufficient for most tasks. However, with new operating systems, such as Microsoft's Windows® 95 or Apple's System 7.5, 8 MB of RAM is the norm. Many computer setups require 16 MB.

Because RAM makes vital information available at lightning-fast speeds rather than at the slower rate of the hard disk, the amount of RAM directly influences your computer's overall working speed. The larger the workbench you create by installing more RAM, the more applications you can efficiently run at one time. Large amounts of RAM also help complex applications and extremely large files run faster. Additional RAM can usually be added to your computer, but it is a good idea to check out this option at the time you purchase your computer.

When you first turn on your computer, the microprocessor is unaware of what might be present in RAM. Therefore, RAM is cleared at the beginning of each session. The RAM is then loaded with the tools and information the microprocessor will need most often for the tasks at hand. RAM memory is volatile and needs electricity to maintain and refresh its contents. When the electricity of your computer is turned off, information in RAM is lost; therefore, you must remember to save your work to a disk prior to shutting down your computer at the end of a session.

DRAM and SRAM

There are two types of RAM commonly found in today's personal computers. **D**ynamic **R**andom **A**ccess **M**emory (DRAM) is the most common. This is often referred to as the *main memory*. DRAM is the slowest and least expensive type of RAM. The name Dynamic RAM refers to the fact that the information in the DRAM is not stored permanently. As a result, the microprocessor periodically refreshes the memory to keep the information current.

DRAM is physically packaged as a **S**ingle **I**nline **M**emory **M**odule (SIMM) or a **D**ual **I**nline **M**emory **M**odule (DIMM), or is sometimes soldered directly onto the computer board. And since all types of RAM can vary in speed and packaging, when you decide to add more to your system, be sure to match the requirements of your system.

The second type of RAM is called **S**tatic **R**andom **A**ccess **M**emory (SRAM). SRAM does not need to be constantly refreshed like DRAM, but it takes up more space and uses more power. Also, SRAM chips are significantly faster than DRAMs, but several times more expensive. SRAM chips are primarily used as cache—a holding place—between the microprocessor and the system's DRAM to create a small, superfast storage area for the most frequently used data and instructions in a program. If you think of the DRAM main memory as your microprocessor's workbench, then the SRAM cache would be your tool belt where you keep the most frequently used tools close at hand.

Enough Is Never Enough

Most of today's computers come with a standard 8 MB of RAM, which is adequate for operating systems and software. However, the amount of RAM, like the design of the microprocessor, impacts computer performance and is a very important purchase consideration. Memory systems, which are generally constructed from DRAM modules, can easily become a system bottleneck. For example, if the computer does not have enough DRAM, the microprocessor has to frequently retrieve information from the much slower hard disk. You can also experience system crashes when you open multiple windows. With up to 32 MB of RAM (and many new systems support as much as 256 MB of RAM), the computer can minimize hard disk accesses and efficiently use large applications and advanced operating systems. ❑

Diane Clark
Intel Corporation

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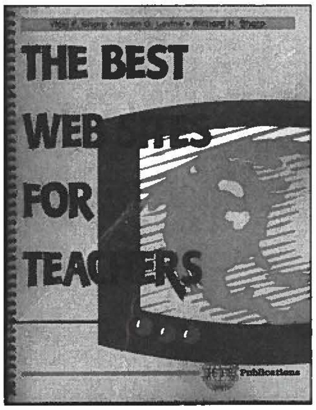

Museum of Science and Industry at
http://www.msichicago.org/

Astronomy at
http://zebu.uoregon.edu/.galaxy.html

Father of Light at
http://userwww.sfsu.edu/~markd/TheFatherofLight.html

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