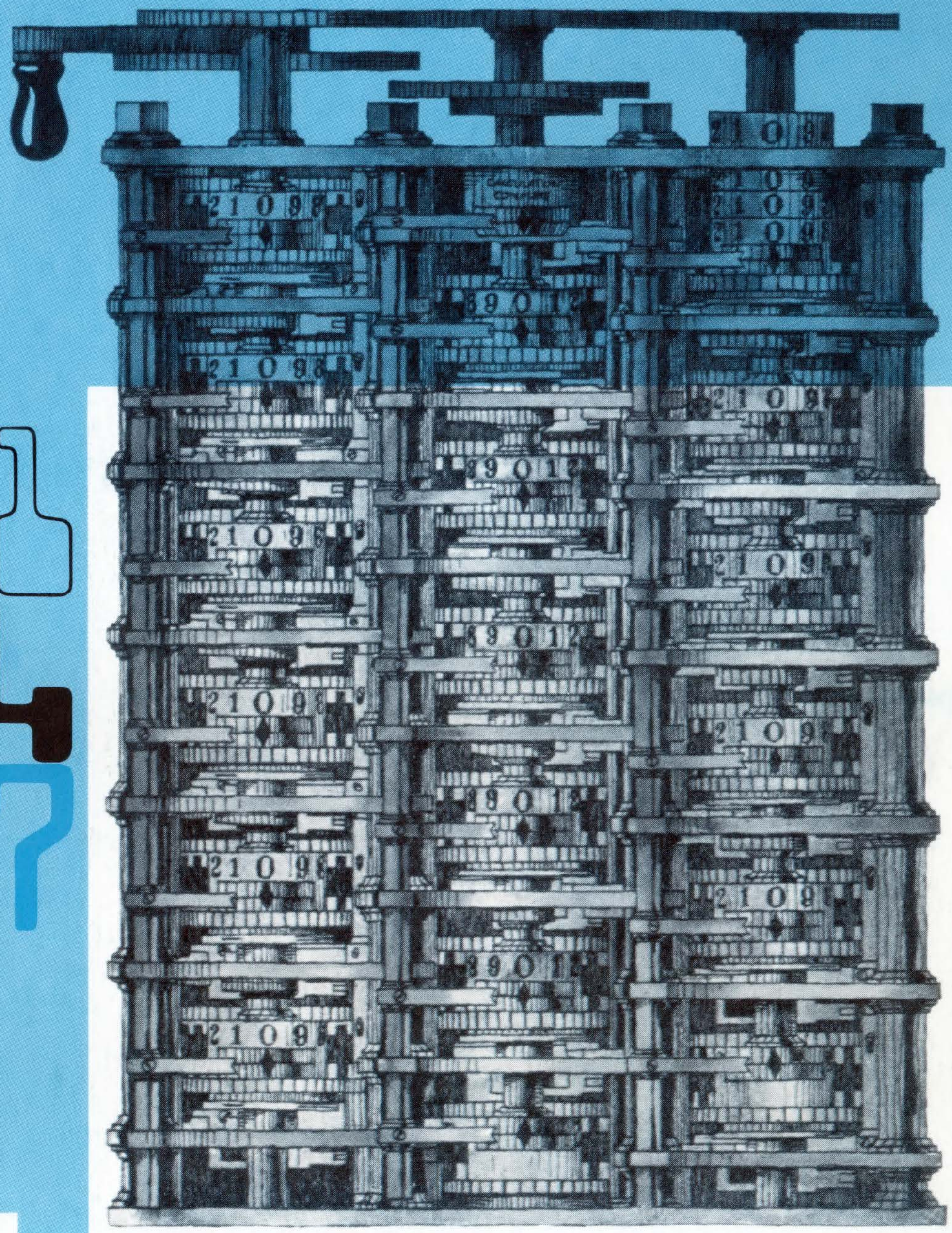


AMPEX

READOUT™

In this issue:

- Computerized F-111 Checkout
- Computer Aided Instruction
- Digital Techniques in Nuclear Medicine
- Integrated Ferrite Structures; Core Memory Trends

new F-111 aircraft

The F-111's wings are adjustable. Its pilot sets them to extend almost straight outward for takeoff. For high-speed flight, he swings them back to a swept-wing position. F-111's have flown Mach 2.5 at high altitude, Mach 1.2 during low on-the-deck maneuvers, and have landed at a speed of about 121 miles per hour. The F-111 is produced by the Fort Worth Division of General Dynamics.

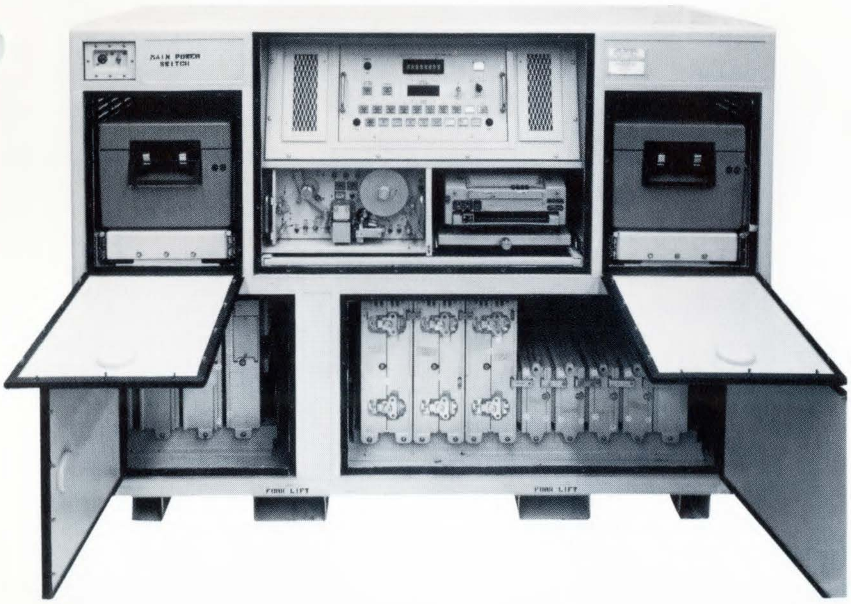
uses first computerized maintenance checkout

NOVEMBER 9, 1966 an unconventional aircraft dashed 150 nautical miles at low altitudes at supersonic speeds. This was the longest low level flight ever made at supersonic speeds up to that time. Half the time it flew in an automatic mode with the aircraft under electronic control, compensating for uneven terrain that included mountains as high as 8700 feet.

In the air the F-111 is most decidedly an unconventional aircraft. The most obvious difference is the variable-sweep wing. The F-111's wings are adjusted by the pilot for maximum efficiency. At takeoff the wings are extended straight outward for maximum lift. For high speed flight of Mach 2.5 (two and one-half the speed of sound) at high altitudes the wings are moved back to form the swept wing angle characteristic of supersonic fighter aircraft.

On the ground the unconventional F-111 provides unconventional maintenance and service problems. In answer to these problems, an automatic support system called CENPAC (Central Processor and Controller) was developed by the Defense, Space and Special Systems group of Burroughs Corporation. The CENPAC System was conceived for use in the Air Force F-111A armament and electronic shops. It represents the first digital computer application for automatic checkout of avionics electronics packages for a production air-borne system. Checkout program source is provided by two Ampex ATM-13 magnetic tape transports.

ON THE COVER: *Charles Babbage completed this segment of his Difference Machine in 1833. Earlier calculators were primitive adding machines. Babbage's was the prototype of today's digital computers. (This and the other drawings in this issue of early computing devices are reproduced from the collection of Planning Research Corporation.)*



CENPAC (Central Processor and Controller) developed and produced by Burroughs Defense, Space and Special Systems Group, provides automatic computerized checkout procedures for the Air Force's F-111 sweep-wing fighter/bomber. Important features of the system are two Ampex ATM-13 magnetic tape units (shown at left and right), a control console (upper center), paper tape reader (left center), keyboard (right center) and Burroughs D84 computer (lower right).

F-111: Wings that Move. The F-111 is a two-seat multipurpose fighter primarily developed and produced by the Fort Worth Division of General Dynamics. Several versions of the F-111 include the F-111A, a fighter version used by the Tactical Air Command, the FB-111A, a bomber version to be used by the Strategic Air Command, and the F-111C, a strike aircraft used by the Royal Australian Air Force.

The most revolutionary feature of the F-111 is the use of variable-sweep wings to ensure optimum performance throughout the entire speed range. Specifications call for a maximum speed of about Mach 2.5, capability of supersonic speed at sea level, and short take-off and landing capabilities from rough airfields. To provide this performance, the wings can be moved in flight through sweep angles from 16 to 72.5 degrees. With wings extended virtually straight out at 16 degrees, the F-111 can make slow takeoffs and landings (at about 121 miles per hour). Tucking the wings back 72.5 degrees into a delta shape reduces drag to a minimum. This enables the aircraft to fly at Mach 2.5 or at supersonic speeds (over Mach 1) during low "on-the-deck" maneuvers. The wing can be positioned at any intermediate point to perform any specified mission with peak efficiency.

A terrain-following radar set (TFR) allows the F-111 to penetrate defenses by controlling the aircraft automatically (or manually) over the terrain at low altitudes. At supersonic speeds, day or night, the F-111 can follow the contour of the earth's surface to minimize detection. The TFR system checks itself and if anything does not function properly it will automatically cause the aircraft to climb for safety at higher altitudes.

AVIONICS: The Aircraft's Electronic Control Systems. Integrated avionics systems on board the F-111 insure operational effectiveness for training and combat. Communications, navigation, terrain following, and other system capabilities are included in the avionics designated Mark I (Mark II will further improve navigation and weapon delivery by incorporating advanced development and state-of-the-art techniques). The F-111 crew may select combinations of avionics subsystems that best suit the mission requirements. Included in the choice are four basic subsystems: primary flight instrumentation, mission and traffic control, fire power control, and penetration aids.

F-111 AVIONICS MAINTENANCE: A New Requirement. The F-111 had to meet perhaps the most stringent maintainability and reliability requirements ever laid down by the Air Force for a manned aerial weapon system. The F-111 maintenance approach is to keep ground maintenance time and equipment at a minimum.

Flight line maintenance is performed by using self testers which are built into the aircraft subsystems. These subsystems are modular and can be removed and replaced if defective. Most subsystems are located in the lower sections of the aircraft and provide easy access and service.

CENPAC: A New Shop Approach to Automatic Checkout Systems. Burroughs Corporation developed the central control computer for the automated support system, CENPAC, in response to General Dynamic's stringent maintainability and reliability requirements for the F-111. As the CENPAC system was phased into the Air Force F-111 testing procedures it was proven that it could provide an even faster than anticipated avionic system turnaround time.

CENPAC is limited initially to check out of airborne line replaceable units (LRU's) and modules. Its job is to send test programs to the test stations which in turn apply test stimuli to many of the F-111's avionics subsystems. These programs contain test sequences that activate and analyze the aircraft subsystems. Up to ten test stations may be controlled by the CENPAC System at the same time, providing an ability to simultaneously test a variety of aircraft subsystems or modules. Airfields servicing F-111's will have at least one CENPAC System, but CENPAC is also designed to be easily moved from airfield to airfield. Components were chosen not only for their performance and reliability, but for their compactness and low weight.

The principle elements of CENPAC are a punched tape reader, a control panel, provisions for a teletypewriter, a digital computer and two ATM-13 magnetic tape units. The initial program material is entered by the optical eight-channel punched tape reader. The operator communicates with CENPAC through the teletypewriter.

The heart of the CENPAC System is a compact, rugged, efficient D84 Computer made by Burroughs Corporation. It is a synchronous, parallel stored program machine which uses fixed or floating point programmable binary arithmetic. The computer includes a working memory packaged in four modules of 4096 words of 25 bits each. It is a homogenous, destructive readout, random access type.

The computer is dependent on two ATM-13 magnetic tape drives for the program material. Designed for airborne and field use, Ampex's ATM-13 was chosen for CENPAC for its small, rugged configuration and its reliable performance in field and mobile environments. It is the only unit of its type capable of recording blocks of digital data suitable for conventional computer format with no need for intermediate processing.

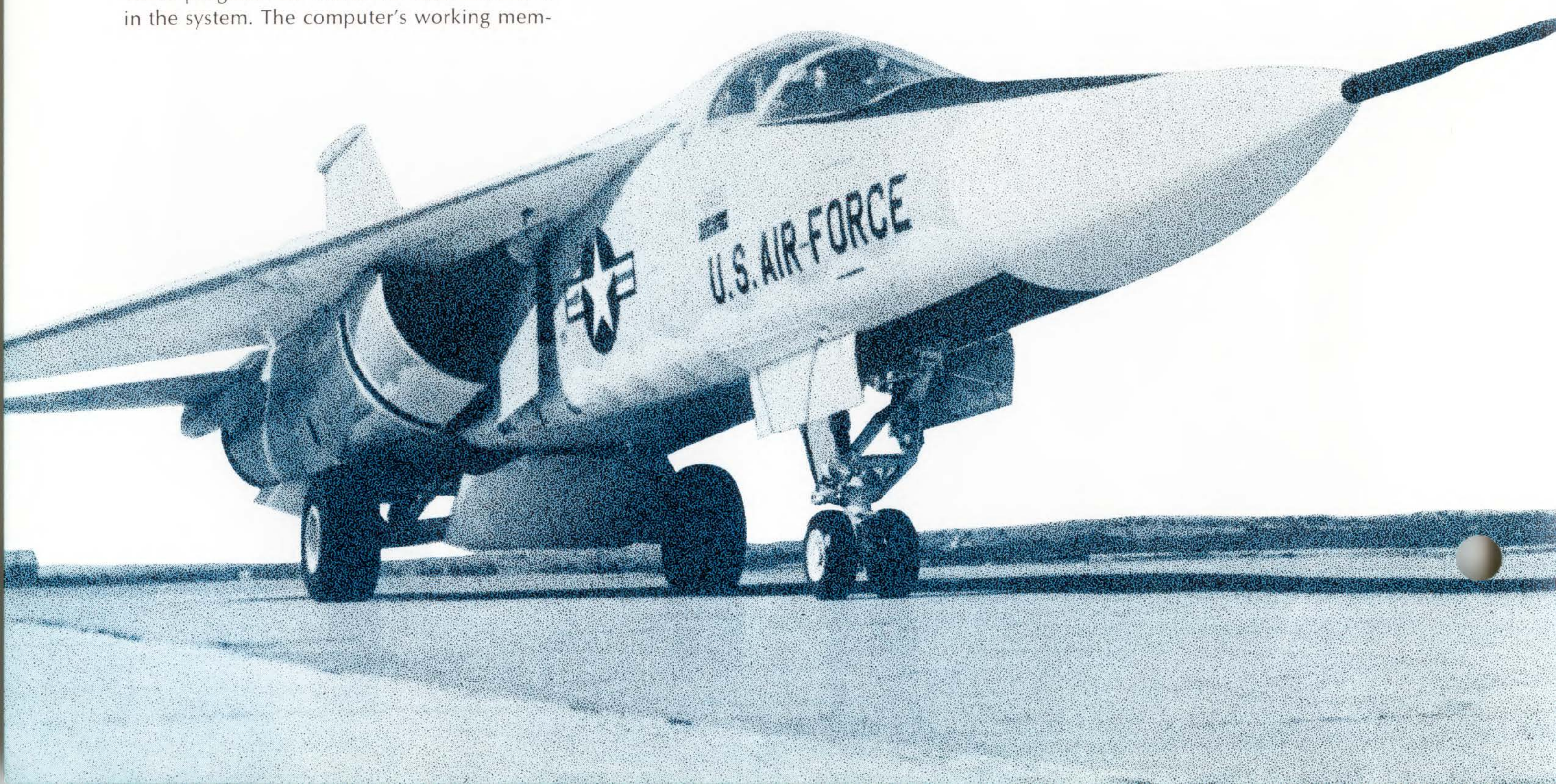
For CENPAC use, the Ampex ATM-13's operate at a standard tape speed of 75 inches per second in both forward and reverse directions. Although the units will read tapes of different packing densities, information stored in the CENPAC is set at 800 bits per inch. Usable tape life is greatly extended through the use of vacuum column chambers and a unique capstan drive in contact with only the base side of the tape.

The test programs are compiled onto a mylar punched tape and entered into the CENPAC through the punched tape reader (not actively used during actual test procedures). These programs are stored on both ATM-13's in the system. The computer's working memory is replenished from the magnetic bulk storage. The two ATM-13's work together to supply test routines and sub-routines almost instantaneously upon demand. As one ATM-13 is supplying the computer with a test program, the other is readying itself for the next series of program transfers, thus reducing access time. The D84 computer provides the test stations with the test routines and makes self checks on the system's operation and program material for errors. Test stations may work in conjunction with external test equipment. Fault determination and procedural decisions are made at the individual test stations.

The ATM-13, one of the Ampex high environment series, is a lightweight, closed-loop digital tape drive employing a variation of the Ampex single capstan tape drive and patented electronic servo control. Two vacuum chambers (underneath the two tape reels) provide uniform tension to hold the tape in constant contact with the capstan drive, ensuring positive head-to-tape contact. The ATM-13 is the only unit of its type capable of recording blocks of digital data suitable for conventional computer format.

CENPAC'S FUTURE ROLE

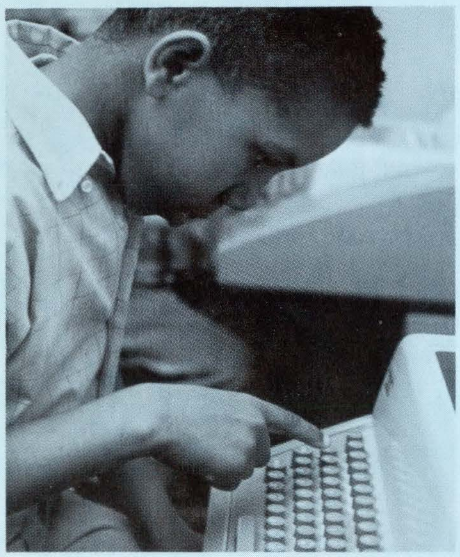
CENPAC's general purpose design provides flexibility for expansion. The expanded CENPAC System has the capability of being completely independent as both a processing and testing system. Applications such as inventory predictions and control, failure data storage and analysis, and high level testing on airborne digital computers can be accomplished with additional programming. And applications need not be restricted to F-111 fighter aircraft, for commercial airlines will find the CENPAC System just as attractive as the military did. Likewise, other transportation such as railroads and trucking companies will p[...] that the aircraft industry isn't the only in[...]try requiring fast, up-to-date, computerized maintenance. ■



Computer-Assisted Instruction:

New Face in the Classroom

Major research program at Stanford University is exploring sophisticated new forms of computer-assisted instruction which may someday revolutionize the educational process.

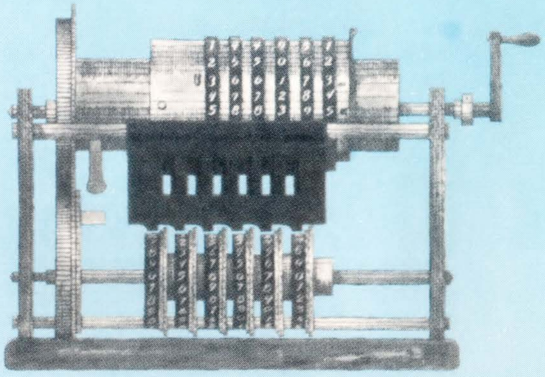


Student at Brentwood School is one of 5000 taking part in an experimental program of instruction by computer around the country. Students find the terminals easy to operate, requiring only that they type their name and number to identify r pre-determined lesson plan according to ious performance. Initial studies have shown improvement in learning by children, particularly in areas requiring reinforcement of conceptual information. Students find the method more fun and more interesting than traditional methods and use the computer an average of 5-10 minutes daily.

Computer-assisted instruction permits a teacher to spend more time with the individual student because much of the time-consuming drill required by subjects can be performed by the machine rather than the teacher. The machine is used to reinforce concepts introduced by the teacher. The second-grader above from East Palo 's Brentwood School is helped with his ele- ary mathematics lesson by William Rybensky, project director of the Stanford-Ravenswood Computer-Assisted Instruction Project.

EDUCATION TODAY: A Basic Process in a State of Flux. Perhaps the most difficult problem facing concerned educators today is how to best educate the student according to his individual abilities, particularly at a time when the student population is dramatically growing. Educators are increasingly hard put to keep pace with rapid change. On the one hand, student population is quickly outdistancing the supply of qualified teachers, classroom facilities, and the tax dollars needed to match that growth. On the other hand, the demand today by students and parents is for more "individualized" instruction based on programs and techniques personally tailored to a student's unique learning abilities. Current mass instructional methods using standardized course materials, large classes, uniform curricula, too few teachers, crowded classrooms and other factory methods designed to move students through the educational plant are not only increasingly unpopular but are impractical. For education, as the fundamental means of constantly regenerating a democratic society, will be of value to that society only as long as the process remains dedicated to the growth of the individual. Collective education, as an alternative, will produce a collective, and ultimately stagnant, society.

Every educator would like to be able to offer individual instruction to every student. The classic tutorial system, where every student is matched to a suitable private tutor tuned to the student's particular style, interests and abilities, has long been regarded as an educational ideal since Aristotle tutored Alexander the Great. Since then, the wealthy and the aristocratic who could afford it have long preferred the tutorial method to public education, which is necessarily geared to the common denominator of the majority. Oxford and Cambridge colleges, for example, are today regarded by many as academic ideals not only for the quality or variety of their programs but because they have remained true to the teacher-student tutorial system.



Grant's Arithmetical Calculator (1880)

The tutorial system, however, is more dream than reality in a mass society. Teachers cannot handle large class loads without slighting the individual. Programs must be designed to accommodate average students, and therefore teachers find it difficult to provide for slow or bright students, or for a creative approach within those programs. Teachers, attracted to less frustrating or higher paying industries, are in critical supply. Costs are up and taxpayers are increasingly reluctant to share those costs.

The recent information explosion generated by expanding scientific research has made it difficult for teachers to assimilate, evaluate and disseminate knowledge. The problems are deep and many. Education—and society—is in a state of crisis.

COMPUTER-ASSISTED EDUCATION: Technology Frees Teaching Time to Boost Instruction. While the computer is sometimes thought of as a mere gadget, diabolically designed to rob people of their individuality, the reverse tendency appears to be taking shape in computer-assisted instruction. Farsighted educators are coming to think of the computer as a valuable tool that may one day be one means of help- to free the educational process from the tyranny of rigid mass techniques, and return it to individual tutorial efforts.

A sophisticated, nationwide computer teaching system currently in experimental use by the Institute for Mathematical Studies in the Social Sciences at Stanford University is driv-

Programming of the instructional system is accomplished at a single keyboard adjacent to the PDP-10 computer. Systems analyst Martin Clinton, standing, and computer operator Bob Winn study a horse displayed on a Philco READ display tube. Visual material was used in an experimental art class for young students, which may be incorporated in the program later.

ing towards a return to individual instruction by making the most of a computer's unique assets. The computer offers large information storage capacity, near-instant recall, and the ability to deliver this information quickly and clearly to large numbers of students at the same time, and at great distances. Time sharing techniques permit information to be shared at a number of remote points via telephone lines. Fast recall allows virtually simultaneous operation at many locations. Efficient core memories hold vast amounts of information—instantly available—that a faculty of teachers couldn't possibly assimilate.

The computer becomes an impartial, and highly efficient, "teacher" which is programmed, in a sense, like a human teacher has been programmed with information more tediously derived from the traditional educational process. Both function as information sources. The computer, however, is tireless and always on call and ideally suited for routine, time consuming teaching uses. The human teacher, relieved of these duties, can thus spend more time on more pressing problems with his students, particularly in developing the much sought after teacher/student relationship. He can become a *manager* of the learning situation, rather than function as an information storage and retrieval device.

Computer-assisted instruction is not designed to replace the teacher or to impersonalize instruction, but to re-establish him in the role of learning guide instead of lecturer. His material may be geared more directly to the individual student's abilities rather than to a class average. Repetitious exercises required in disciplines such as reading, mathematics and languages can be handled as efficiently by a computer. The teacher can then devote his time to individual tutoring.

COMPUTER-STUDENT INTERACTION: Three Information Approaches According to Need. Computer-assisted instruction efforts attempted so far by Stanford have been in three areas: *drill-and-practice, tutorial, and dialog* systems. Each is designed to handle particular teaching needs in an appropriate discipline according to the kind of information required by the curriculum.

Drill-and-Practice. The most-used form of computer-aided instruction, the drill-and-practice technique, is designed to complement the teacher's program plans. It is particularly pertinent in learning areas such as elementary mathematics, spelling, reading and languages, where it is necessary to memorize large amounts of repetitive information. This system does not "teach" but merely *reinforces* what the teacher is stressing, functioning as a review tool.

After a teacher introduces lesson material in the usual book, blackboard and lecture method, the computer is used to provide a review of those basic concepts and skills. The student is seated at a teletype and types in his name. The computer then prints out a selected lesson plan which has been pre-determined by the teacher based on the student's past efforts (which the machine has scored and memorized). The machine asks simple questions which the student responds to by typing the correct answer. The machine then indicates whether the answers are correct, scores the effort, and informs the student of his progress.

The particular advantage of the drill-and-practice system—the most widely used so far—is that the teacher is eased from much of the routine of reinforced learning and can devote more time to other matters. The machine, and not the teacher, follows a particular problem at the *student's own pace* until he has grasped it. "Teaching" matches the student's speed and ability. Brighter students can receive more advanced material. Significantly, instead of the student being placed on one track at the start of school and held there the rest of the year, a student can be instantly reclassified if the machine indicates that he is doing better work than previously indicated.

Stanford is currently doing extensive work in this area through funds granted by Federal agencies. Through telephone line hookup, some 5,000 students are connected nationally to a central Stanford computer for daily computer-assisted instruction. More than 60 schools in California, Kentucky, Mississippi, Tennessee, Ohio, Washington, D.C., and Iowa are using the system, each school using from 1 to 30 teletype readout machines. Students like the system and use the machine from 5 to 20 minutes daily, according to the subject matter. Initial reports indicate that learning has improved in many areas.

Although the drill-and-practice system does not use the real-time branching capability of a more flexible computer tutorial system, individualization is accomplished through later computer update where the performance of each student is examined and the appropriate material is selected based on previous performance records.

Tutorial System: The tutorial system is more flexible than drill-and-practice since it is designed to introduce concepts which in some ways will approximate the action a private tutor would take with an individual student. A rich branching structure allows immediate, real-time instructional decisions to be made on what material is to be presented next, based on the student's last response or upon an evaluation of some subset of his total response history.

As currently developed, structured subjects such as reading and mathematics are handled by tutorial systems. For example, the student may proceed from a machine-given hypothesis to a given proof through any one of several paths. The computer tutorial system will evaluate the validity of the inference the student makes from a logical path. The computer will not show a prefence for any one path, but will check the *soundness* of each step along the path and tell the student if he has made any mistakes in logic. Thus, the computer acts as a private tutor which keeps pace with the student's ability in a real-time situation. The teacher, again, is able to spend more time with any individual student having problems with his subject material.

Dialog System. Ideally, a computer should be able to understand spoken or written questions and answer back as well as a teacher. This system, however, is still in the developmental stage. Essentially, the technique calls for nothing less than having the student ask a question, have the computer understand the *meaning* of that question, and respond accordingly with a reasonable answer.

While technical problems remain in this area, it is noteworthy that educators are striving toward an ideal dialog situation where the computer functions as a near-human participant, and are not content to remain with a simple, one-sided instructional conversation.

COMPUTER-TERMINAL NETWORK: Core Memory Provides Large Information Capacity. The large scale, nationwide computer information system managed by Stanford necessarily requires a large memory capacity and a fast computer for a high degree of modular flexibility to service a large information network efficiently. The heart of the system is a Digital Equipment Corporation PDP-10 central process computer with a memory capacity of 196,608 36-bit words and a 1.0 microsecond memory cycle time. The extensive memory is comprised of six Ampex Model RG core memories to provide fast word access time and wide capacity range. The modular expandable memories provide access to stored data in 350 nanoseconds and have a capacity of more than 5 million bits. Memory units with ferrite cores were selected because of their large capacity and modular approach, permitting expansion and upgrading of the system when needed to serve a growing national student body. The system also uses two IBM 2314 disc packs.

The PDP-10 is connected to a PDP-8 at the Institute for Mathematical Studies in the Social Science Laboratory at Stanford, and is also connected by a private high-speed data telephone line to another PDP-8 in the nearby Brentwood CAI Laboratory of the Ravenswood High School District in East Palo Alto. Although the PDP-8's are computers, they are not used as processors. They monitor the flow of information between the PDP-10 and the student station teletypes. The PDP-8 computers are responsible for character-code conversion, acting as line connectors and buffers for all teletype information received from and sent to the individual student stations over ordinary telephone lines.

THE COMPUTER AS FACULTY: Electronic Teaching Assistants Approaching Tenure. Computer-assisted instruction has already leaped quickly from a pedagogical dream to a working model. While still in the experimental stage, Stanford's program is actively teaching real subject matter to real students at schools 2,500 miles distant. Some 200 terminals are already on line and new schools and terminals are added almost daily. Preliminary reports indicate that the technique is a real help in better-educating children and a boon to overworked teachers. Results have been particularly impressive with culturally disadvantaged students in rural areas.

While technology still needs refinement as the system become more sophisticated, it is felt that the biggest problem still to be solved lies in developing proper teaching curricula compatible with the latest direction in educational philosophy. In other words, technology is ahead of pedagogy—more needs to be learned about *how* students learn and *what* they should learn.

The biggest obstacle to wide-scale computer-assisted instruction is a question of cost. The technology is available. The question is whether or not society will be willing to invest in that technology to provide more individualized instruction, or whether it will subject its children to increasingly impersonal collective teaching methods. ■

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PLEASE TYPE YOUR NUMBER AND NAME.
21
PLEASE TRY AGAIN.
121 AMPEX READOUT
      DRILL NUMBER L201023
ADD
7 + 2 = 9
6 + 4 = 11
NO, TRY AGAIN
6 + 4 = 12
NO, ANSWER IS 10, TRY AGAIN
6 + 4 = 10
2 + 5 = 3
NO, TRY AGAIN
2 + 5 = 7
4 + 5 = 
TIME IS UP, TRY AGAIN
4 + 5 = 9
3 + 7 = 10
      END OF DRILL NUMBER L201023
20 MAR 1969
16 PROBLEMS WITH 81 PERCENT CORRECT
IN 158 SECONDS.
GOOD-BYE, AMPEX.
PLEASE TEAR OFF ON THE DOTTED LINE.
.....................
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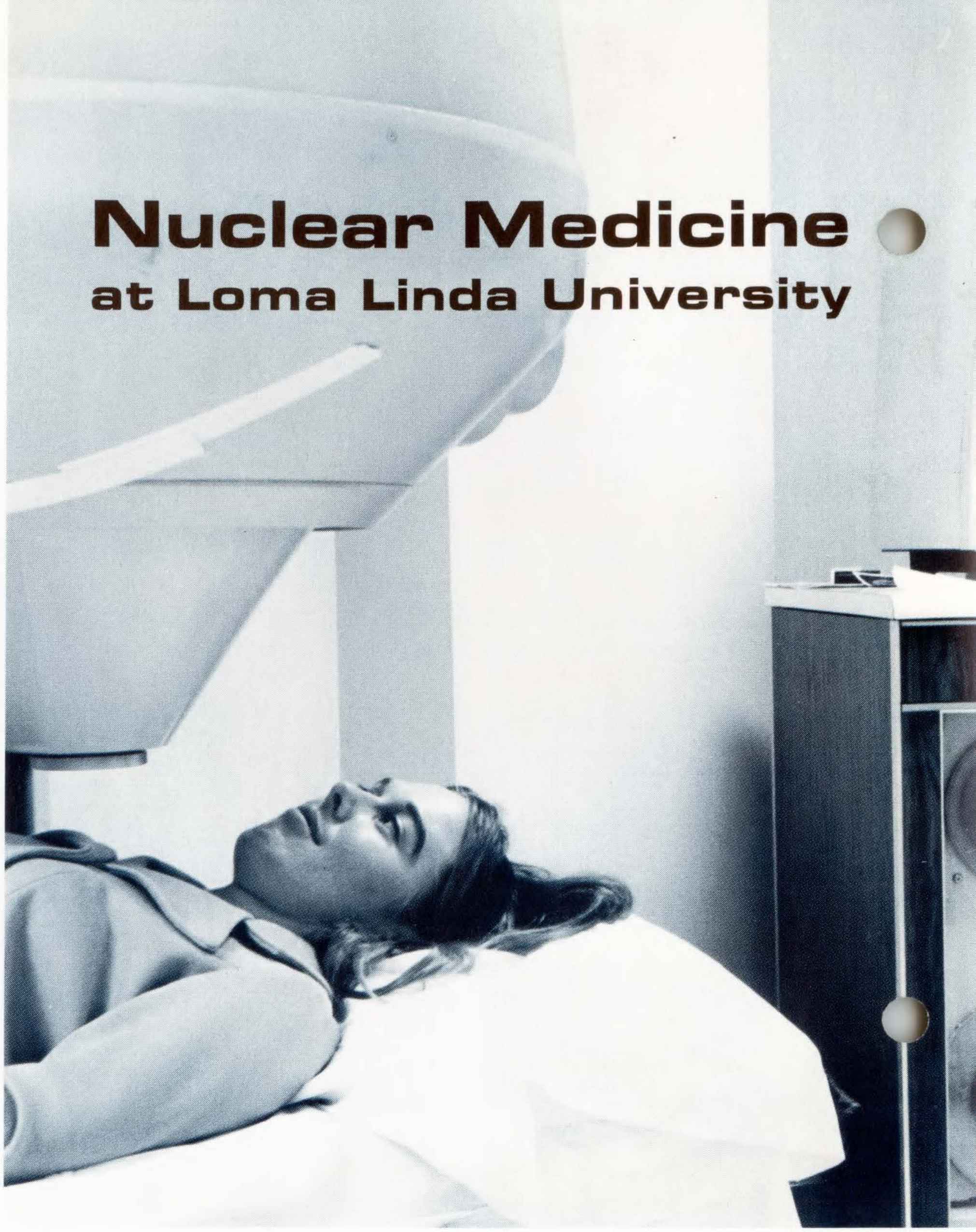
TELETYPE PRINTOUT: Condensed version of an actual drill-and-practice elementary mathematics lesson, left, is typical of those being taken daily by several thousand students around the country. To begin his lesson, the student types his first name and number, and is then identified by the computer and matched to his pre-assigned lesson plan. Each answer is evaluated as the student takes his drill. He is informed of his errors and the problem is repeated. If the second response is also incorrect, the correct answer is typed to the student and the problem is again reprinted. If no error is made he is presented with another problem. When the student has finished, he is given the date, his score, elapsed time in seconds, and a personal goodbye. The computer signs off, updates his record and determines the student's next drill from among the series previously selected by his teacher.

Nationwide study program for computer-assisted instruction is managed by Stanford University's Institute for Mathematical Studies in the Social Sciences. Heart of the system is a Digital Equipment Corporation PDP-10 computer, using a large capacity, six unit RG core memory supplied by Ampex Corp. (left foreground). The memory provides fast word access time and large storage capacity, necessary to a large scale information system. The memory may be expanded as needs grow.

Nuclear Medicine
at Loma Linda University



Yoke assembly positioned above the patient in preparation for a lung procedure. Autofluoroscope provides both visual and quantitative capabilities in either static or dynamic studies. Because entire radioisotope distribution is viewed at one time, the time to do the study is reduced as compared with rectilinear scans.

Autofluoroscope and Digital Recording Perform Clinical Studies

THE MEDICAL CENTER at Loma Linda University near San Bernardino, California is using nuclear medicine in its Radiology Department to study the size, shape, and functioning of human organs. The purpose is to determine whether any symptoms of cancer or abnormality are present. Radioisotopes are introduced into the body and detected by a device called an Autofluoroscope. This device is a type of scintillation camera which views the entire radioisotope distribution at one time. By this method dynamic processes can be followed and organs visualized in the body while reducing the time required by a factor of ten. The system consists of scintillation detectors, a data transfer system and a data recording system. Serving as a fast access memory is an Ampex TM-7 digital tape memory which records frames of information in a standard computer format. Once recorded, the information can be repeated as many times as desired to recreate the procedure (without further patient dosage) for visual examination on the Autofluoroscope or for detailed computer analysis at the University's computer facility.

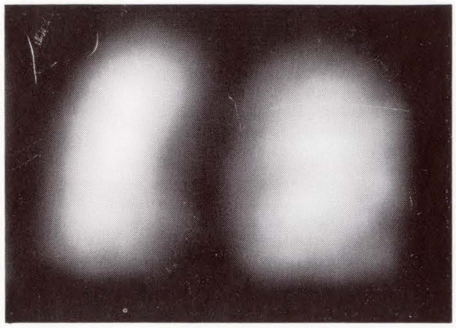
NUCLEAR MEDICINE: Clinical Uses at Loma Linda University. Two years ago the Department of Radiology at Loma Linda University opened a new section for nuclear medicine which is now under the direction of Dr. Carl Jansen. This section sees an increasing number of patients referred by physicians within the medical center complex as well as the entire Los Angeles metropolitan area. Clinical studies are carried on routinely with the brain, lungs, lymph glands, heart, spleen, kidney, and many bone and joint structures.

Basically nuclear medicine, which came into its own in the late 1950's, uses radioactive isotopes to diagnose and locate tumors, and study functions of body organs. All procedures in nuclear medicine depend on the knowledge that some recognizable difference exists between normal and abnormal tissues in the way in which they accumulate specific radioactive substances. A substance is chosen for use with a particular organ because is is known that it interacts with that organ.

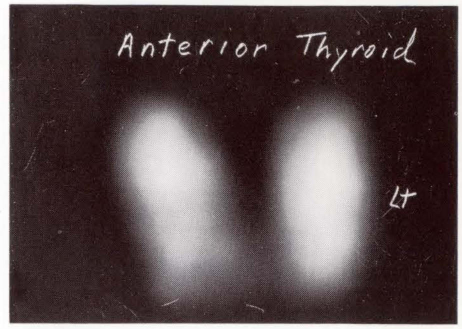
Substances are taken up by the organs or bones by a biological or chemical process and become localized in that area. For example, radioactive iodine is synthesized by the thyroid into a hormone. The degree in which it is synthesized varies in normal and abnormal tissue. The lungs are usually studied by injecting macro-aggregated albumin. This substance is tagged or identified by I-131 (radioactive iodine) which causes a short temporary blocking of some capillaries. This means that a picture can be taken of the radiation pattern caused by these temporarily blocked capillaries in the lungs.

Radioisotope detection in the body complements X-ray fluoroscopy. Both give a picture, but an X-ray is a photograph or a television picture of areas not blocked by a fluid or liquid. Isotopes on the other hand actually give off light energy (protons) as part of their radiation. In lung studies, for example, an X-ray displays the aerated distribution of air, whereas nuclear medicine shows the blood supply and any blockage of the blood vessels and capillaries within the lung structure.

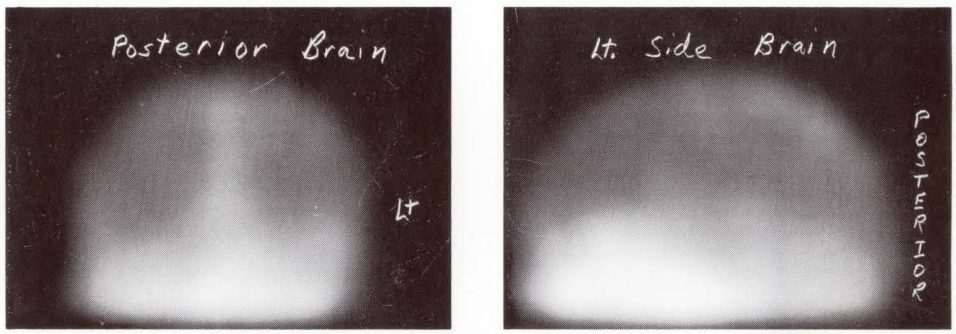
A recent device (1963) makes use of several new techniques in nuclear medicine. This is the Autofluoroscope developed by Drs. M. Bender and M. Blau of the Roswell Park Memorial Institute in Buffalo, New York. The



LUNG AUTOFLUOROGRAM POSTERIOR VIEW
Notice the smooth peripheral border on the left lung as contrasted with the scalloped, irregular border on the right. These are areas of decreased blood flow typically seen in pulmonary emboli.



THYROID AUTOFLUOROGRAM ANTERIOR VIEW
Normal thyroid gland taken with the pin hole collimator. It is not unusual to have a little asymmetry between the two lobes.



BRAIN AUTOFLUOROGRAM
Normal posterior and left lateral views.

Autofluoroscope is manufactured by Baird Atomic Corporation of Cambridge, Massachusetts. It is adding a new dimension in radio/pharmaceutical visualization and quantitation.

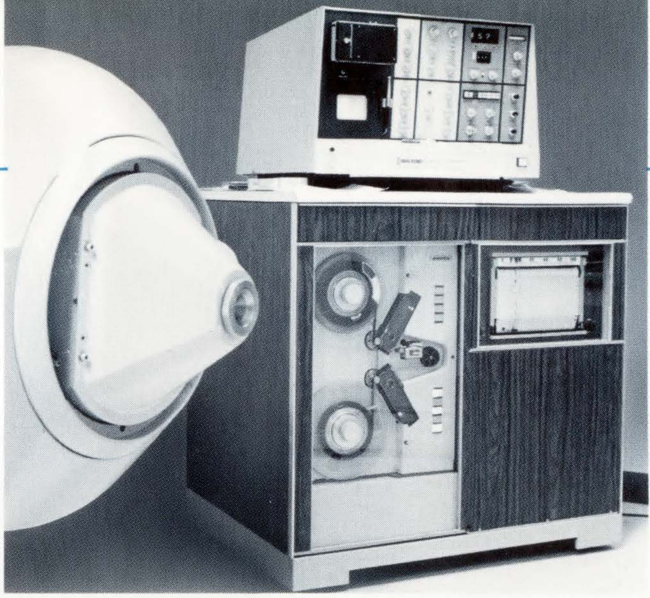
TYPICAL PROCEDURE: Less Than One Hour With New Isotopes. A typical procedure in nuclear medicine lasts less than an hour. During this period, patient exposure to radiation averages about 15 minutes. Isotopes with shorter half lives soon to be available will re-reduce the time required for some of these procedures. For example, with one type of isotope, it now takes eight minutes to get the one thousand counts needed to give an adequate sampling of the radiation. Newer isotopes will give a greater count in the same unit of time, requiring only about 30 seconds for one thousand counts. These will be easier to use and have less effect on the patient.

A typical procedure involves positioning the Autofluoroscope camera to take several views from different angles. Brain and lung studies usually have four views. Liver, lymph, kidney and the heart usually have three views. The area photographed on the patient is six by nine inches or, by using a pin-hole type camera (as shown in the accompanying photographs), can be as large as 17 to 18 inches.

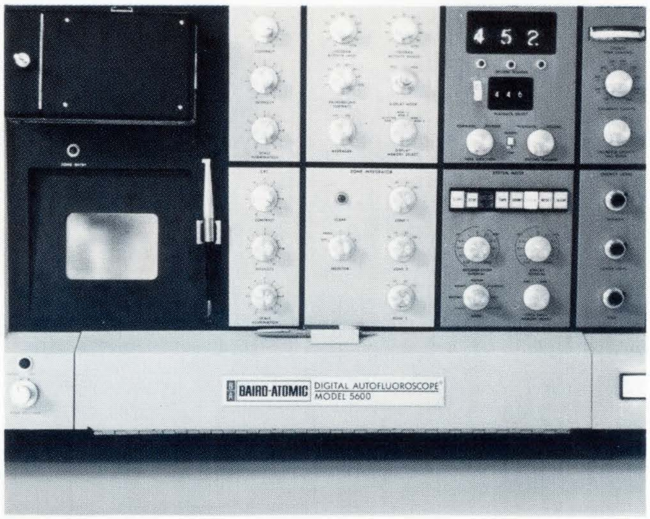
AUTOFLUOROSCOPE: Detector, Data Transfer, and Data Recording. The Autofluoroscope developed by Drs. Bender and Blau uses a scintillation camera specifically designed for quantitative imaging. Scintillation cameras have the principle advantage of viewing the entire radioisotope distribution within an organ or area of the body at one time without scanning. Because of this, examination time can be reduced by a factor of ten while still maintaining comparable accuracy and allowing dynamic processes to be followed while they are taking place.

The Autofluoroscope detector is made up of a mosaic of 294 sodium-iodine crystals three-eighths of an inch in diameter and two inches long. These are packed in the mosaic in a six by nine inch array with a one-centimeter separation between centers. Each of the crystals making up the mosaic can sense 1000 different levels of photon radiation given off by a radioisotope in the body. Arranging this mosaic into a 13 by 21 array enables any one point within the array to be uniquely identified in location.

Levels of radiation are stored in two separate 14 by 21 array core memories (two are used for quantitative differential readings). For recording on the Ampex TM-7 tape memory, about five frames for each of the views taken of that particular procedure are sampled. A typical procedure for a brain or lung would have four views with five frames recorded on the TM-7 of each view. Dynamic studies of the kidney may need as many as a hundred or two hundred frames to study how adequately the kidney clears the radioactive substance. These longer studies will benefit

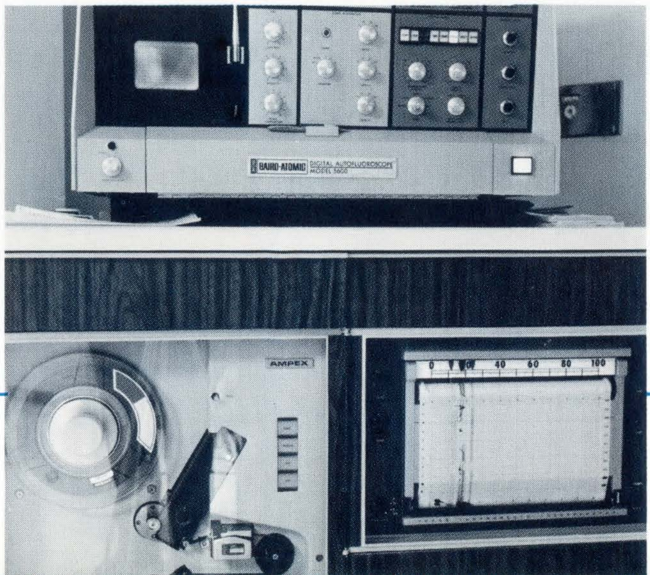


Baird-Atomic Autofluoroscope at Loma Linda University, California. At left is the yoke positioning assembly with scintillation counter and detector system. At right the computer console contains counting and display system, four-channel chart recorder, and an Ampex TM-7 digital tape drive which serves as a fast access memory to recreate procedures immediately afterwards or for later computer analysis without further radiation dosage to patient.



Control panel of the Autofluoroscope computer console. Section with Nixie tube readout at top is used to locate recorded frames for a particular patient from a three-digit code recorded on the Ampex TM-7 along with the data.

Playback of a procedure recorded on the Ampex TM-7 digital tape drive. CRT at top displays the output from the 294 element matrix contained in the detector system as recorded on the tape drive.



greatly from the shorter half life isotopes now coming into more common use.

The output of the core memory is continuously presented to two identical cathode ray tube display devices on the Autofluoroscope. The upper one is used for a Polaroid camera, the lower one for a visual display. During the procedure, the data is sampled on command and recorded on the Ampex TM-7 digital tape memory. This sampling takes about 33 milliseconds, which is not a significant loss of continuous visual data. Data is recorded on the tape in a standard computer format. Included in the Autofluoroscope is a four-channel strip chart recorder on which three selected channels can be displayed. These are either replayed from the TM-7 digital tape or can be displayed on-line during the procedure.

THE ADVANTAGES OF DIGITAL MAGNETIC TAPE: Recreate the Study Without Additional Dosage. The advantage of having a digital magnetic tape memory in the Autofluoroscope system is its ability to replay the study immediately afterward or at any later time for visual and quantitative reconstruction. Additional dosage to the patient is not required. It is quite common to repeat portions from each study immediately afterwards while the patient is still present so a physician can confirm the success of the procedure. A single reel of tape on the TM-7 can store about 7000 frames. Tapes are stored indefinitely to maintain records for individual patient history as well as departmental research.

According to Dr. Jansen, "Adding a fast access tape memory like the TM-7 to this type of system has given us a flexibility we have needed for some time. Not only can we replay the procedures at any time and as many times as we would like, we are able to do a detailed analysis with cross correlations and related studies by computer programs being developed now."

FUTURE TRENDS: More Computer Analysis. Detailed computer study is the next logical step in the nuclear medicine field, which Dr. Jansen points out, is really in its infancy even though it has made immense strides in its short history. Some of the other possible future procedures will be gas studies in the lungs (using Xenon gas) to measure ratios between blood supply (perfusion) and air supply ventilation (diffusion) in the lungs. Also, regional or localized studies of certain specific areas of the lung will be likely carried out in the very near future at Loma Linda. ■

Integrated Magnetic Logic Circuits

by C. H. Heckler, Jr., Ampex Corporation

INTRODUCTION

Interest in magnetic logic dates from the early days of the electronic digital computer, when a variety of logic devices and circuits were investigated in many of the university, government and industrial laboratories. This interest was sustained by the need for devices having greater reliability, lower power consumption, higher component-packing density and greater tolerance to severe environments than the vacuum tube circuits which were then in use. Because of the large numbers of devices needed to implement digital systems, cost reduction was an additional motivation for these investigations.

The first of the investigations involving magnetic logic elements to be reported in the literature was the work of the Harvard Computation Laboratory.[1] The logic circuits reported by Wang and Woo of that laboratory were of the core-diode type. In the early core-diode circuits, the magnetic cores (toroids) were made from up to 40 wraps of thin tapes (0.0010 inch thick) of a 50% iron—50% nickel magnetic alloy. This material exhibits a square hysteresis loop as shown in Fig. 1. The cores were wound with three windings, totaling up to 100 turns. The output and input windings of adjacent cores were coupled together through diodes as shown in Fig. 2. The diodes provided the necessary isolation between stages during information transfer. In magnetic logic circuits, information is stored without power consumption between clock pulses by the magnetic state of the cores. In core-diode circuits the states are $+B_r$ for a logic ONE and $-B_r$ for a logic ZERO. This class of circuit has been refined and highly developed to provide all necessary logic functions for the synthesis of general logic systems.

With the development of the transistor the diodes in the coupling loop have been replaced by transistors to produce the core-transistor class of circuits as shown in Fig. 3. This type of circuit has been modified to take several forms and has also been highly developed.

The development of the square loop ferrite memory core made feasible the random-access main-frame memory for digital computers which stimulated the development of a number of square-loop ferrite materials. Because these ferrite materials were able to be formed into a variety of shapes they have been used to produce magnetic logic elements of complex geometry known collectively as multiaperture or multipath devices. Some of the devices included in this group are the Transfluxer,[2] the MAD,[3] the BIAX[4], and the Laddic.[5] Along with the development of complex ferrite structures a new class of logic circuits was developed,* the core-wire or all-magnetic circuits shown in Fig. 4. The great attraction of this class of circuits lies in their inherent high reliability. In addition, their requirement for windings having only a small number of turns permits simplified circuit fabrication. For this class of circuits the only known failure mechanisms are fracturing of the magnetic element and opening of conductor connections.

*It should be noted that all-magnetic circuits are realizable using simple toroids; however, the greater effort has been concentrated on circuits utilizing the multipath structures.

INTEGRATED MAGNETIC CIRCUITS

The integrated magnetic circuits being developed by Ampex for the Langley Research Center of NASA are of the all-magnetic class of circuits and so are inherently highly reliable. The multipath structures being developed for these circuits differ from other multipath structures in several important ways. Two different magnetic materials are combined in each integrated structure, one material of low coercive force and one of high coercive force.[6] The low-coercive-force material is used for selected magnetic paths. The high-coercive-force material has been developed to have partial-set-state magnetic characteristics which are specially tailored to the requirements of all-magnetic logic circuits.

These characteristics are different from those of the materials developed for memory applications.

Partial-Set-State Characteristics. The thresholds of the magnetic material determine the operation of all-magnetic logic circuits. The special materials developed for all-magnetic circuits[7] and used in the bimaterial multipath structures have large partial-set-state thresholds. The threshold is that value of drive current which causes a magnetic element to start

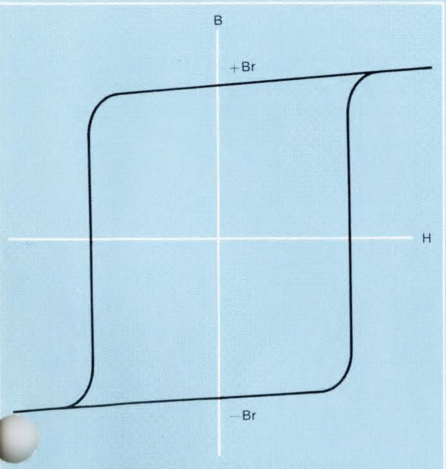


FIGURE 1: Square Hysteresis Loop

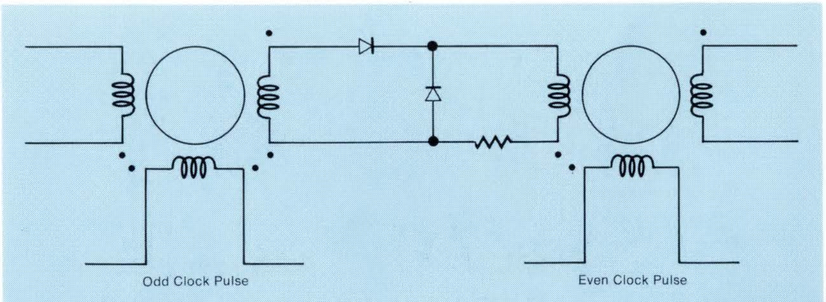


FIGURE 2: Basic Core—Diode Circuit

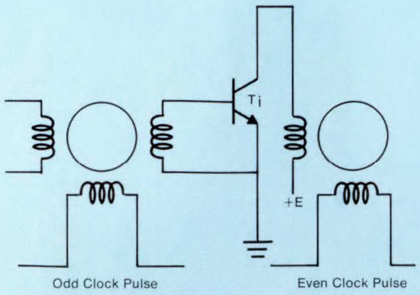


FIGURE 3: Basic Core—Transistor Circuit

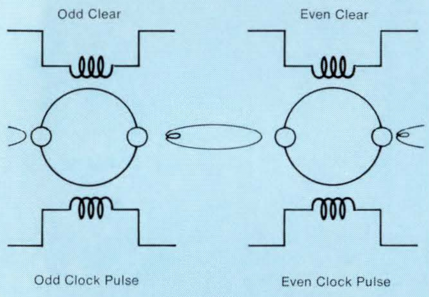


FIGURE 4: Basic All-Magnetic Circuit

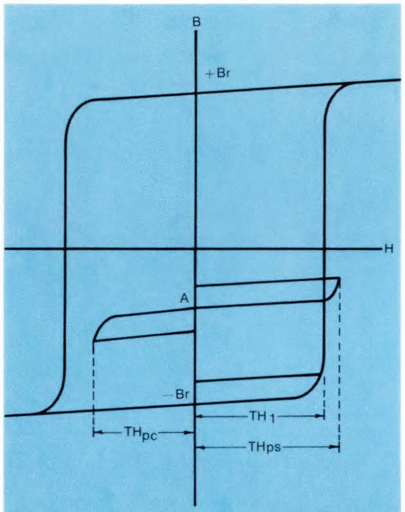


FIGURE 5: Partial Set State Characteristics

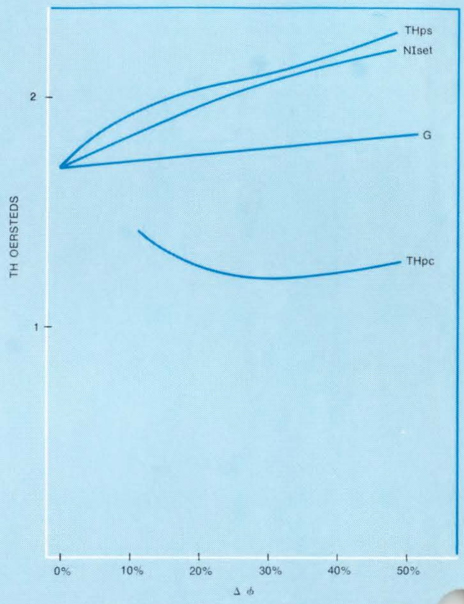


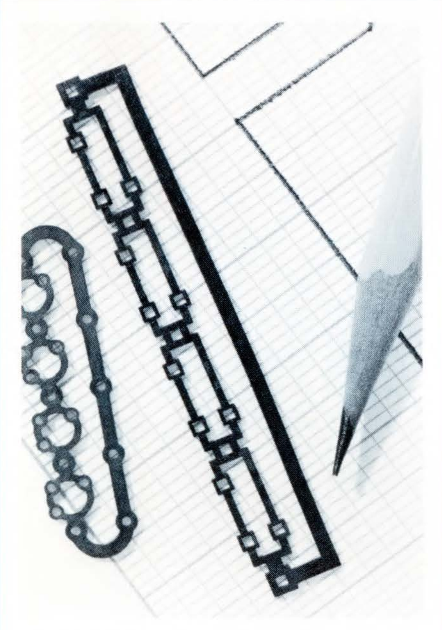
FIGURE 6: Profile of thresholds for different values of partially set flux.

to change its magnetic state. When an element is in the clear or reference state ($-B_r$) the threshold measured is the well-cleared threshold. When an element is not in either the reference or the fully switched ($+B_r$) state, the thresholds measured are the partial-set-state thresholds. These thresholds are shown in Fig. 5. The partial-set-state thresholds vary with both the amount of flux preset and the direction of the applied current. When a structure is partially set to some flux level, for example, to the level indicated by "A" in the figure, the threshold measured by applying current in the direction to increase flux (TH_{ps}) is larger than the well-cleared threshold. The threshold measured by applying current in the direction to decrease flux (TH_{pc}) is always significantly less than the well-cleared threshold, a behavior which is not understood. When the thresholds for different values of partially set flux are plotted they form a graph called a profile as shown in Fig. 6. Such graphs are useful in evaluating magnetic materials for logic elements. It is important for integrated logic circuit operation that the average value of the set and clear-direction thresholds is greater than the well-cleared threshold. In typical memory materials, both of the partial-set-state thresholds are lower than those in Fig. 6. The set-direction threshold of the memory materials drops below the well-cleared threshold and the clear-direction threshold approaches a value of half the well-cleared threshold.

Bimaterial Multipath Structures. The present integrated structures under development are for a ring counter, which is a specialized form of a shift register. Two types of structures are shown in Figures 7 and 8. Two structures of the same type are interconnected to form an 8-stage ring counter.

As shown in Figures 7 and 8 the output aperture of each stage of an integrated structure contains the low-coercive-force material. The structure is continuous across the interface between the two materials, the bond being formed during the sintering process. The method by which the bimaterial structures are formed is best explained using the test structure shown in Figure 9. The preparation of the powder follows standard ceramic processing up to the point of binder addition. A thermoplastic binder solution is added to and then mixed with the ferrite powder to form a slurry. This material is then dried, broken up and passed through a screen to form a powder with particles of the desired size. The powder is placed in a heated die and pressed into small rectangles of uniform thickness. Square holes are punched in these rectangles. The squares punched from the low-coercive-force material are inserted into the square holes in the high-coercive-force material. The rectangles with inserts in place are returned to the heated die and with the application of pressure bonded together. The bimaterial punching blank is then inserted into a second die set and the test structure as outlined by the dashed line in Figure 9 is punched out. The structures are sintered at a temperature of approximately 1300 degrees Celsius to form rigid continuous structures having the desired magnetic properties in each magnetic path. Several critical processing problems that had to be solved in order to obtain useful bimaterial structures were: formation of a good bond between the two different materials, differential shrinkage, warping of the structures and excessive diffusion of the atoms of one material into the other.

Integrated Circuit Operation. The magnetic states used in the integrated multipath s[illegible]ture to represent a logic ONE and ZERO [illegible]fer from those used in the core-diode and



FIGURES 7 and 8: Integrated Structures

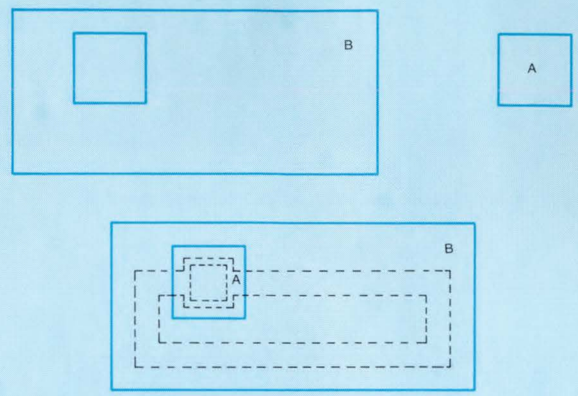


FIGURE 9: Forming the Bi-material Test Structure

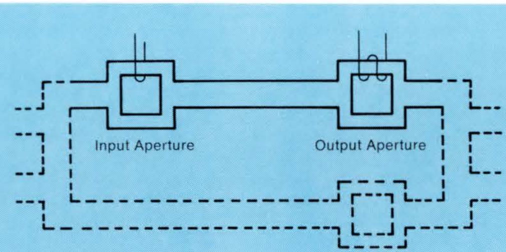


FIGURE 10: Signal Path of Integrated Structure

core-transistor circuits since the magnetic state of the several paths in a stage will necessarily be different. The state of the magnetic path shown in Figure 10, however, is of central importance. In the ZERO state this signal path remains in the clear state, i.e., at $-B_r$. For a ONE this path is set to a demagnetized state, which corresponds to the flux in Leg A being half switched from the clear state. When this signal path is in the ZERO state the output aperture is "blocked" and flux cannot be switched around the output aperture to induce a transfer current in the coupling loop. When the signal path is in the ONE state, the output aperture is "unblocked" and flux is switched around the output aperture upon application of a clock pulse, inducing a transfer current in the coupling loop. This coupling loop current then sets the signal path of the next stage to a ONE state.

For ring counter operation the last stage is coupled to the first stage. All stages except one are in the ZERO state, the remaining stage is in a ONE state. The single ONE flux pattern is progressively transferred from stage to stage under control of the clock pulses. …er logic functions are accomplished by …ing the transfer of a ONE pattern conditional on the presence of additional signal transfer currents at the input to a stage. Additional logic circuits are being developed so that an integrated structure may be designed to form a small arithmetic unit. Methods of forming the required conductor patterns as part of the processing of the structure are also under investigation so that complete integrated circuits may be fabricated by a batch type process.

CONCLUSIONS

Integrated magnetic logic circuits have evolved from the magnetic logic circuits conceived and investigated in the early days of the electronic digital computer. Because these circuits are of the all-magnetic class they require no semiconductor elements and require simple windings containing only a few turns each. Through the combining of different and especially tailored materials in the various magnetic paths improved circuit performance is provided. The further development of integrated magnetic circuits is expected to produce a new standard of high reliability logic circuits. Such high reliability circuits will find application in systems where failures cannot be tolerated either from financial or humanitarian considerations. With man's accelerating reliance on automated systems, it is to be expected that the cost of system failure will increasingly be measured by the extent of human jeopardy.

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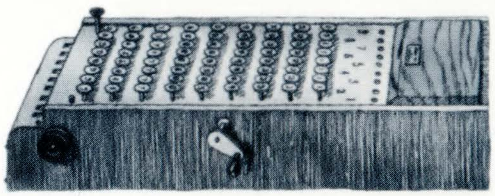
Felt's "Comptometer" (1886)



Technical Information: STAYING AHEAD OF THE GAME... CORE MEMORY TRENDS

by Roy H. Norman

Ampex Corporation, Culver City, California

The trend in ferrite-core memories over the years has been toward greater speeds at lower costs per bit. These memories have from time to time been threatened by other storage techniques that promised to be cheaper and faster, but they have always managed to hold their place.

Cores are again being challenged, and the threat this time is, in some ways, more serious than ever before. It's therefore wise to take a look at what's been done and what may be done in the future.

The increases in core memories' operating speed have been due primarily to decreases in the size of the individual cores. The earliest memories used cores more than 100 mils in outside diameter —"nearly the size of Cheerios," as one expert has put it. Then came a series of reductions in standard core sizes to 80 mils, to 50 and 30 mils, and finally to the 22 and 18 mils widely used today, as shown below. It's perhaps worth noting that each new standard core could almost pass through the hole in its predecessor.

This process has been accompanied by a corresponding decrease in switching time—from the several microseconds of the old 100-mil cores to as little as 140 nanoseconds today. This, in turn, has been followed by a decrease in memory cycle time—always greater than switching time because of noise problems, current rise times, and delays in peripheral circuits.

Advances in speed have been paralleled by cuts in prices facilitated by the declining costs of semiconductors and other components. And advances in component design have permitted refinements in the design of circuits and whole systems, again reducing costs. Development of automatic wiring equipment for threading a maze of wires through thousands of cores and utilization of low-cost labor in such places as Hong Kong and Taiwan have also helped drop prices.

Economy vs. speed. For moderate storage capacities, the most economical system configuration is coincident-current or three-dimensional organization. This arrangement, now used in the great majority of core memories, is inexpensive because it requires the minimum number of drivers and decoders. Other configurations can provide more speed than 3-D, but they're always more expensive.

Of the two basic types of 3-D memory in common use, one has four wires through each core, and the other has three. In both designs, the core's magnetic hysteresis loop must be so nearly square that the core is fully switched by currents carried in the same direction by two selection wires passing through it, but is undisturbed by either one of the currents alone. With this coincident-current scheme, the core array itself performs part of the address decoding, thus minimizing circuit costs. Instead of locating a specific core in a plane, external decoders locate two lines of cores that intersect at the address. A single set of driver circuits steers current through all cores in the data word, which are strung on a single selection wire.

A typical design stores 4,096 words of 32 bits each. It uses 32 planes each of 4,096 cores in a 64-by-64 array threaded with 128 selection wires — 64 in each direction. Corresponding selection wires in all the planes are connected to each other and are driven by a single driver circuit.

In the four-wire design, two other wires are threaded through all cores in each plane, as in Fig. 2, but are not interconnected between planes. The switching of any core in the plane from a 1 to a 0 generates a pulse that one of these wires carries out to the sense amplifier serving that plane. The other wire carries a current equal but opposite to one of the two half-select currents. This current can thus inhibit the action of the selection wires on a core and keep it in the 0 state.

The sense and inhibit functions are combined in a single wire in the three-wire design because the two operations need never be performed at the same time. However, this setup requires more complex circuits and is therefore somewhat more expensive than the four-wire system. This cost, though, is at least partially offset by the savings involved in threading only three wires.

With each reduction in core size have come predictions that threading four wires through every core in an array will be impractical. With 18-mil cores now coming into use, this prediction seems more realistic than ever. If the prophets are right for once, the faster, smaller cores will make the three-wire design the only practical 3-D form.

The simplest core-memory organization is the two-dimensional or linear select form, in which the cores are arranged in a single plane array with word wires and bit wires at right angles to one another, as in Fig. 3. In data storage, currents on any one word wire and on the bit wires combine at the intersections to switch cores that are to store 1's or to prevent switching at cores that are to store 0's. For readout, a single, larger current on a word line — rather than the coincidence of two currents—switches all the cores on the wire. Thus currents greater than the normal full switching current can be used. The overdrive makes for very fast switching, but at a high cost because all the address decoding must be external.

A compromise between the economy of 3-D and the speed of 2-D is found in an arrangement that has come to be known as 2½-D (see Fig. 4). Originated in 1951, it remained dormant until rather recently, when 3-D core memories began to reach what may be their ultimate limitations.

This approach has a level of address decoding in the bit dimension. Like the 2-D memory, one wire threads the cores in a particular word, and a bit wire passes through each of these cores at right angles to the word wire. But in a typical arrangement, the same word wire threads the cores for two words, and each bit wire loops around in a U shape to thread corresponding cores in both words. Coincident currents in the word and bit lines, as in a 3-D memory, switch one or the other of these cores, the bit current's direction determining the core that switches. In the other core, the two currents oppose one another. When storing a 0, the bit current is simply not turned on. A sense wire threads all the bits common to one doubled bit line.

Since the bit current drivers control whether or not a particular core switches, the 3-D memory's inhibit drivers and windings aren't needed. Their absence reduces noise and pulse overlap, and these are the prime factors contributing to the 2½-D organization's speed.

Bulk core memories contain perhaps 10 times as much data as computer main memories and run typically at one-third the speed. In these memories, the cost of the core array predominates over the cost of the electronics; therefore, they are usually built in the 2½-D configuration but with only two wires. The bit and sense wires are common.

The drive circuits in a 2½-D memory require lower voltages than do those in a 3-D memory, so that large-scale integration will be easier to apply to 2½-D. On the other hand, if the cost of electronic circuits continues to decrease as it in the past, the cost differential between the two arrangements should diminish.

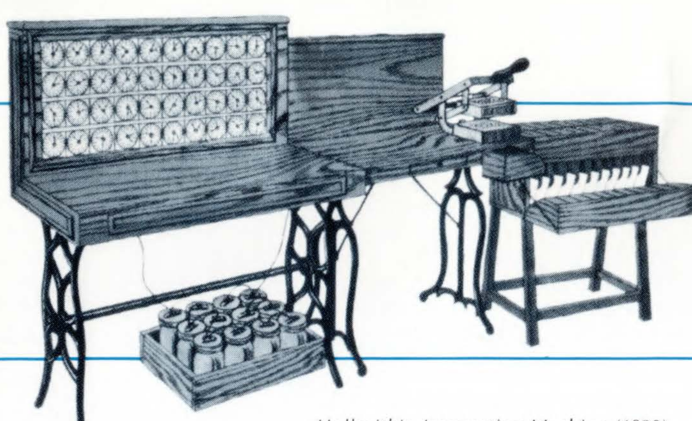
Although no competing technology has yet displaced ferrite-core memories as the primary storage element in high-speed memories, thin magnetic films pose a definite threat with their speed, and monolithic integrated circuits are being heralded as future challengers.

Thin films are very fast because they switch by magnetic domain rotation instead of by domain wall motion as in solid cores. A single planar thin-film element has an open flux path in most designs, which tends to make the film demagnetize itself, although this is not true in at least two proposed designs. Coupled film structures have flux paths that are closed except for two very small air gaps at the ends of the element. And plated wires usually have completely closed flux paths.

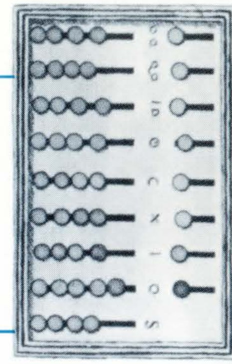
But most of these designs depend on the film's magnetic anisotropy—its higher reluctance in one direction in the plane of the film that at right angles to that direction. In the "hard" axis, the film has no magnetic threshold — its hysteresis loop isn't square — so that coincident-current organization isn't possible. The cost savings of a 3-D organization in ferrite cores are therefore not realizable in thin films. But films may be faster.

Advocates of semiconductor technology claim that prices on both bipolar and metal oxide semiconductor circuits will soon reach a point competitive with core prices. Maybe so, but monolithic arrays are still selling for about a dollar a bit, compared with a nickel a bit for million-bit ferrite-core arrays. For another thing, cores are being made today with yields of 60% or 70%, and core-stacks can be reworked if necessary, whereas monolithic arrays are unreworkable and still have yields of only a few percent.

All this suggests that IC's must undergo order-of-magnitude improvement in this area before they can compete seriously with cores.



Hollerith's Accounting Machine (1890)



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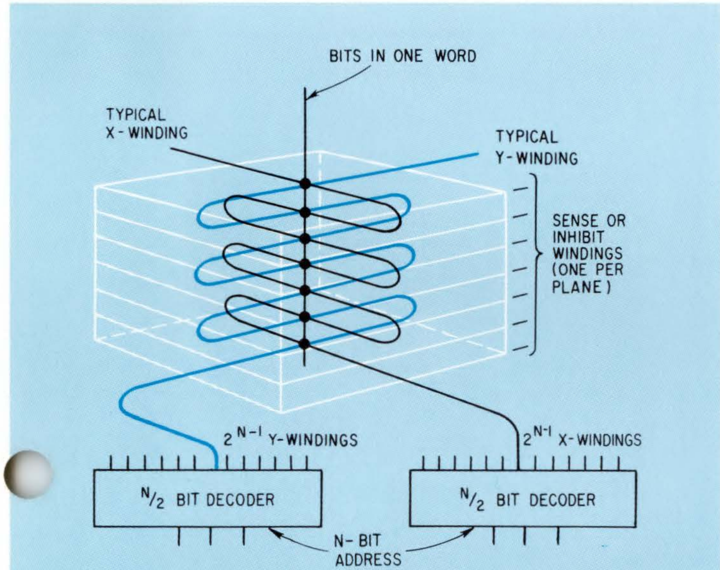

FIGURE 1. In depth. In the most common memory organization, 3-D, two sides of a stack are addressed to locate a vertical column of cores containing the stored data.

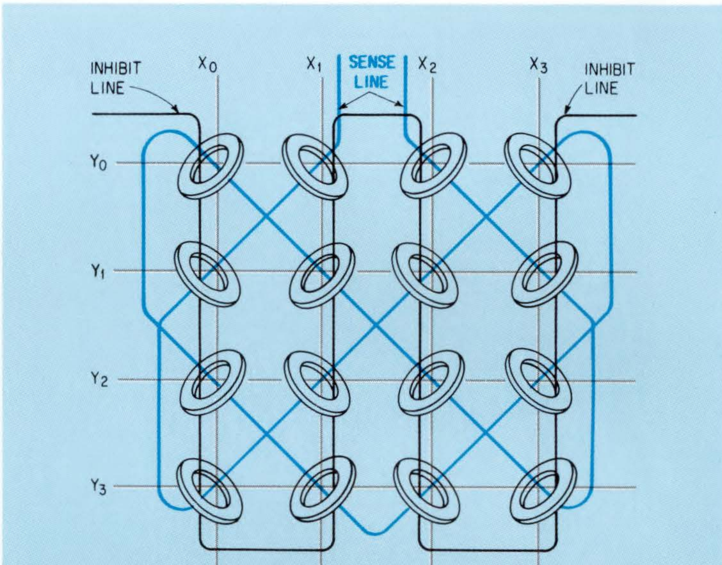

FIGURE 2. Sense and inhibit. Two additional wires in a 3-D stack sense a core's switching when reading a 1 and inhibit its switching when writing a 0.

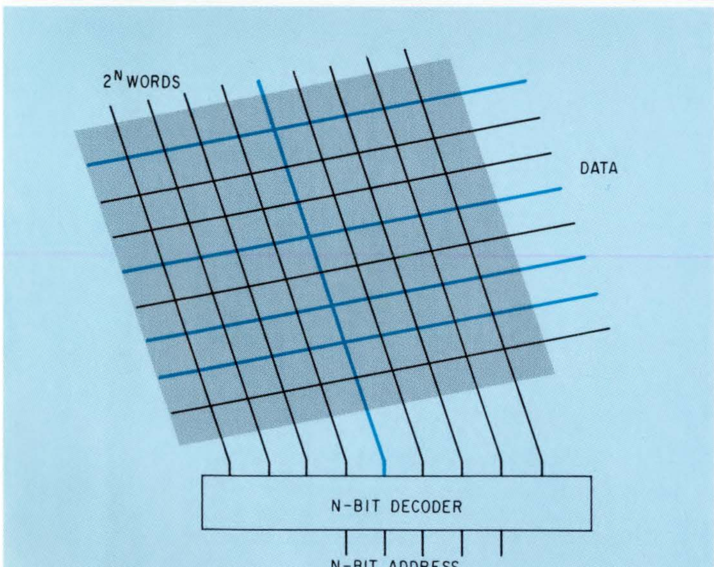

FIGURE 3. Fast plane. The simplest memory organization addresses one side of an array and brings data out at right angles to the addressing. The scheme is fast but expensive.

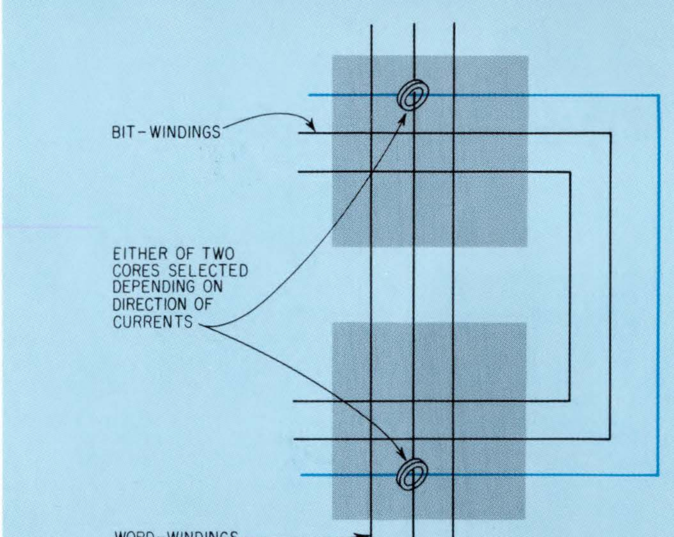

FIGURE 4. Compromise. The so-called 2½-D arrangement combines the speed of 2-D with the economy of 3-D.

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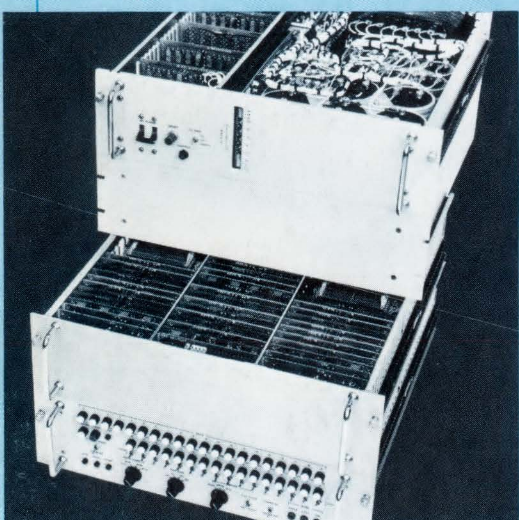
3DM-2000 Memory: 800 nsec access; 2 μsec full cycle; 32,768 cap., expandable to 131,072 wds. to 76 bits; 5.25"H x 19"W x 21"D.



Unmatchable Reliability—Ampex memory systems are subjected to a consistently high level of quality control from raw core materials through final systems check-out. Core compositions, stack design parameters, and systems worst-case circuit design characteristics are all arrived at through computer-aided analysis. Ampex memories are manufactured in accordance with quality standards based on years of experience with thousands of memories. This complete capability has enabled Ampex to utilize the more reliable 3D memory organization in a 650-nanosecond memory.

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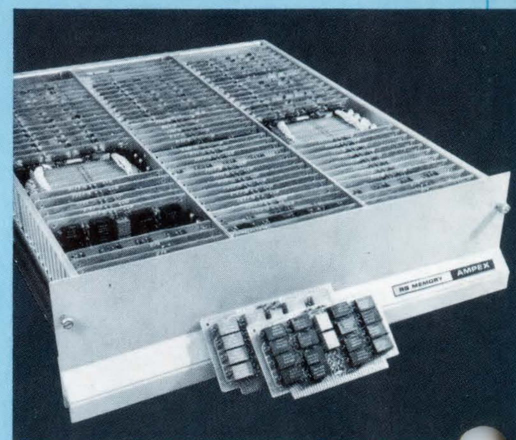

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