Electronics World

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OCTOBER, 1971
60 CENTS

SPECIAL ISSUE

Hirsch-Houck Lab Report on HI-FI HEADPHONES

WHICH COMPUTER FOR THE ENGINEER/TECHNICIAN? PART 2

INTERSTELLAR COMMUNICATIONS—What Are The Prospects?

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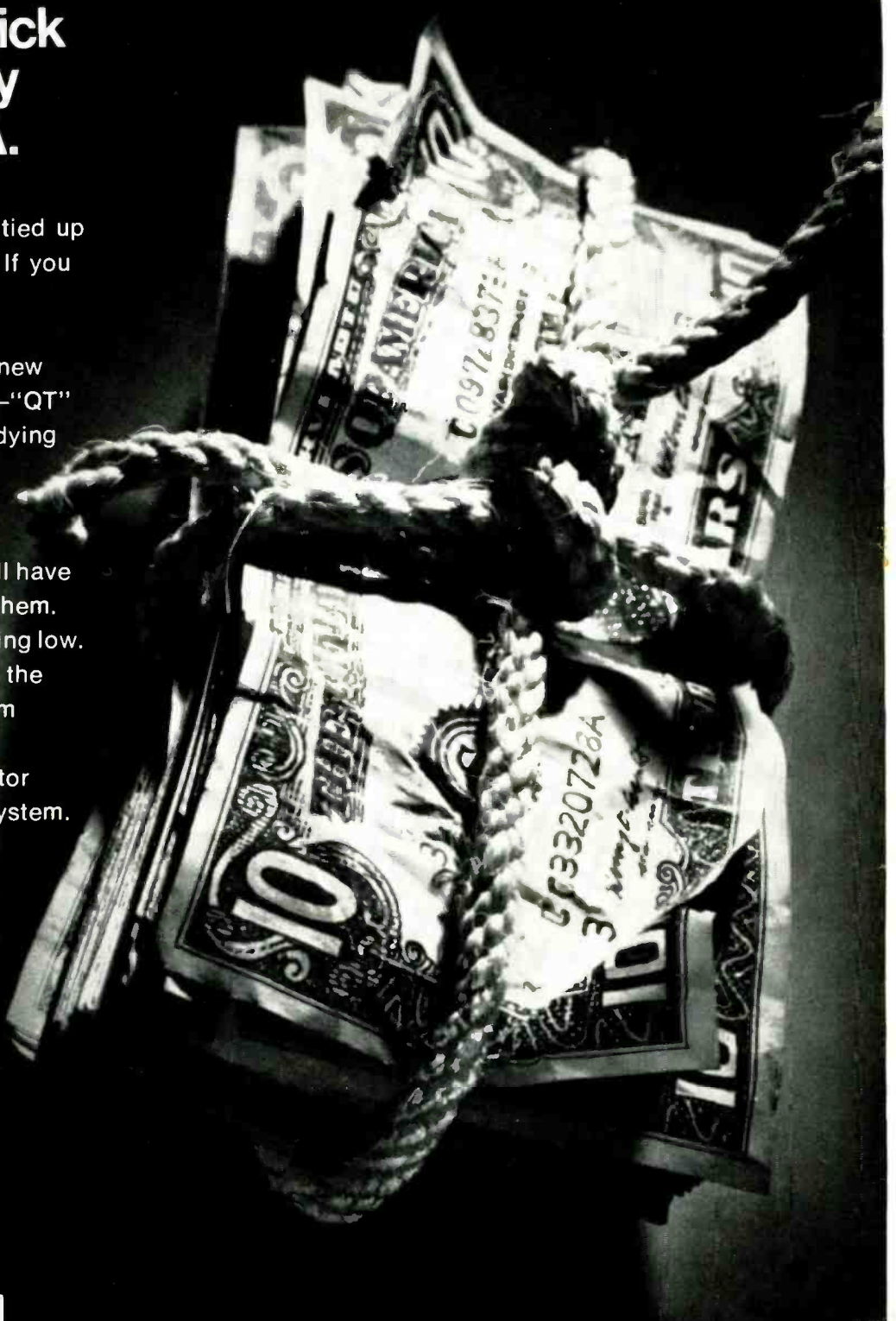

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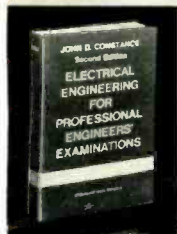

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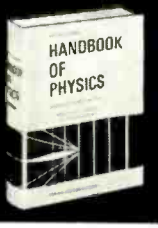

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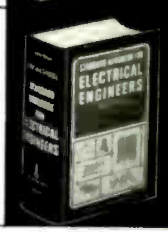

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Replaces 92 types

18VABP22
18VACP22
18VADP22
18VAHP22
18VAJP22
18VAQP22
18VARP22
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18VATP22
18VBAP22
18VBCP22
19EXP22
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19GVP22
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490MB22
490NB22
490RB22
490SB22
490TB22
490UB22
490VB22
490WB22
490XB22
490YB22
490ZB22

Replaces 22 types

19VABP22
19VACP22
21AXP22
21AXP22A
21AXP22A/
21AXP22
21CYP22
21CYP22A
21FBP22
21FBP22A
21FBP22A/
21GUP22
21FJP22
21FJP22A
21FJP22A/
21GVP22
21FKP22
21GUP22
21GUP22/
21FBP22A
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21GVP22/
21FJP22A
21GXP22
21GYP22
21GZP22
21HAP22

Replaces 71 types

23VACP22
23VADP22
23VAHP22
23VALP22
23VAMP22
23VANP22
23VAQP22
23VARP22
23VASP22
23VATP22
23VAUP22
23VAWP22
23VAXP22
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23VAZP22
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Electronics World

OCTOBER 1971 VOL. 86, No. 4

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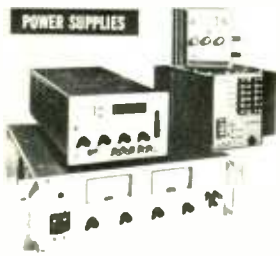
Electronics World



THIS MONTH'S COVER
Four examples of the "new breed" of power supplies. Clockwise: the Lambda LL-902 (0-20 V d.c., 0-.65 A) general-purpose bench supply; Trio ST631 (5 V d.c., 1-100 A) for inputs of 115 V a.c., 47-400 Hz; Hewlett-Packard 6428B high-power SCR type (1-20 V, 0-45 A); and Kepco precision voltage source for lab and systems applications. Photo: Dirone-Denner

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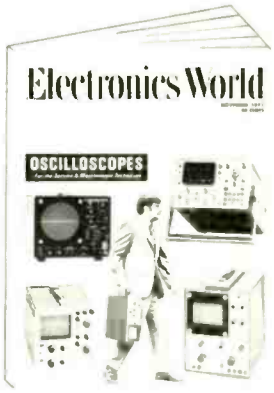
Special Feature Article



OSCILLOSCOPES FOR SERVICING

Stanton R. Prentiss provides a comprehensive look at the new scopes designed for general-purpose and portable applications. He outlines the features such instruments must have if you are servicing or maintaining various types of equipment—ranging from computers and radar to AM/FM/TV broadcast transmitters, hi-fi gear, and radio and TV receivers. Two handy quick-check directories are provided to help you make the right choice for your particular job.

Testing IC's in TV Receivers

Since linear IC's are making their appearance in many of the 1971-72 model color sets, the technician must know how to check them—rather than just replacing them if they are "suspect." Forest H. Belt contends that these components can be tested and provides step-by-step instructions on how it should be done.

Which Computer—Time-Sharing?

Concluding article on what the engineer/technician should look for in a computer for his job. Lee N. Beyer of General Electric explains the advantages of being able to call on a full-service computer by means of a time-sharing terminal—including costs, access, and limitations.

15 Years of Video Recording

Although one of the great developments of our times, will it really spawn a home recording/playback market as large as many presently anticipate? William Slatkin of Ampex gives his views on this subject.

All these and many more interesting and informative articles will be yours in the ***November*** *issue of ELECTRONICS WORLD . . . . . on sale* ***October 19th.***

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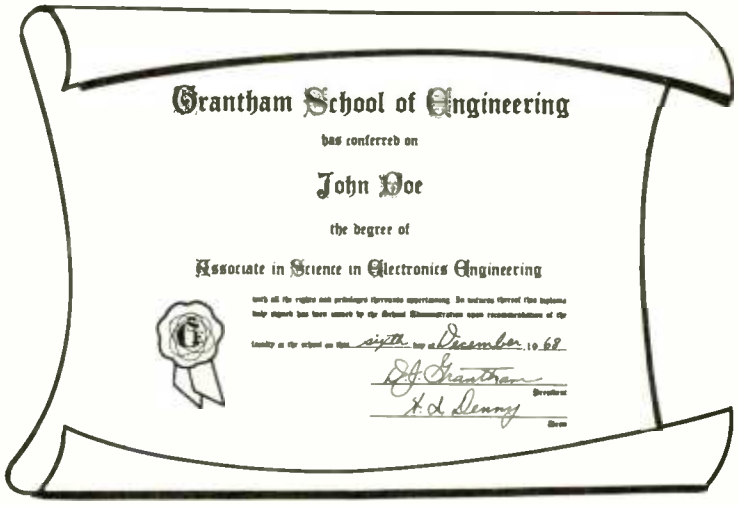

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The Grantham educational program in electronics engineering is *not for beginners*. Every point is explained just as carefully as if you were a beginner, but the important difference is that while the beginner would need extensive *laboratory* training, you (as an experienced technician working with modern equipment) do not require such training and should not waste your time doing the same laboratory experiments that beginners must perform. This program in engineering is designed, written, and taught for and to experienced technicians, and beginners are not accepted for enrollment.

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NEWS HIGHLIGHTS

Consumer Electronics Show

The fifth annual CES Show which was held in Chicago June 27-30 turned out to be a very exciting one with a record attendance of 36,160. In fact, it was so successful, that next year's show has already been planned for the same spot (McCormick Place, Chicago) June 11-14, 1972. The show has changed gradually over the years. In the early days it was more of an EIA membership participation exhibit with both black-and-white and color TV the outstanding features. Now only a few of the major domestic TV manufacturers were exhibiting; in fact, there were more foreign sets being shown than domestic. TV in general seems to have lost out and this year's show turned out to be predominantly a hi-fi show. With most of the major component hi-fi manufacturers exhibiting, it seemed to be more a component hi-fi show than an EIA show. The only difference between it and the Institute of High Fidelity's Hi-Fi Show was that the CES show, of course, was basically for dealers and representatives only; while the IHF Hi-Fi Show is directed to the consumer. Four-channel sound, the highlight of the show, was in evidence everywhere—and if what we have seen is any criterion then four-channel sound has developed such momentum that it will be impossible to hold back. There were matrixing, discrete four-channel, and multiplexing systems throughout the show. There were all different types of discrete four-channel systems, but the 8-track cartridge seems to be the most likely to succeed since there is a greater market for pre-recorded tapes. A discrete four-channel disc system has been designed by *JVC* and is in production in Japan, but whether or not it will be released to the U. S. market in the future will depend entirely on the availability of software. There are various four-channel FM multiplex designs, too, but since these would require FCC approval, it seems likely that any major development in this area would be at least 5-10 years away. Different matrixing system designs were displayed, as well, and *E-V* was prominent here, but surprisingly many receiver and/or amplifier manufacturers seem to have incorporated their own matrixing systems. Basically they are much alike, the only difference being the various combinations of phasing and amplitude. Great strides are being made in trying to standardize but it's hard to determine when and if such standardization will ever take place.

The Key to Security—Holograms

RCA has unveiled the world's first lock-and-key system based on a laser-made hologram. The system, called Hololock, enables employees to use a card with a laser-hologram to gain entrance to *RCA*'s new 40,000-square-foot technical center in Zurich, Switzerland. The hologram contains a coded number and other identification information. When inserted into a slot in a special box at the main entrance, the card's number is read by illumination with a standard light bulb and then compared with a number punched into an associated keyboard by the employee. If the two match, the door unlocks for 90 seconds. The system also keeps a record of the times each card is used. The hologram lock-and-key system affords a high degree of security because it cannot be altered and very sophisticated equipment is needed to produce it.

100°F to 700°F to 100°F in 10 Milliseconds

The *National Cash Register Company* just announced a new on-line Model 260 data terminal that will compete directly with Teletype machines but will be faster, cheaper, smaller, and quieter. It will print in dot patterns 30 characters per second through the use of thermal instead of impact printing. By its very nature, thermal printing is much faster. There are no keys, no inked ribbon, and no impact. Electrical energy converted to heat chemically alters the coating of the paper to form characters almost instantaneously. This is accomplished by a print head which barely touches the surface of the coated paper. The key to the design is a print head consisting of 35 tiny heat sources that can change their temperature from 100°F to 700°F and back down to 100°F in 10 milliseconds.

Women's Lib in the Lab

A new, nationwide club has been formed exclusively for women in professional electronic servicing. Ladies in Technical Electronic Servicing (called LITES) was founded by Mrs. Sandra Schaffner who works with her

husband Len Schaffner, a TV service technician, at his servicing firm in California. According to Mrs. Schaffner, the purpose of the club is to encourage women to enter the field of consumer electronics repair as well as to serve as a forum for the exchange of ideas and technical developments. There will be an annual national convention (not yet scheduled) as well as regional meetings in the course of the year and a newsletter. Mrs. Schaffner feels that "there is not only a tremendous shortage of qualified consumer electronic repair personnel today, but the field is highly compatible with women's capabilities . . . the natural feminine concern for small intricate detail makes electronic repair a natural vocation for women." Those wishing further information on LITES should contact Mrs. Schaffner at *Kings Magnavox*, 1209 Los Angeles Ave., Simi Valley, Cal.

Rechargeable Cardiac Pacemaker Weighs Only Two Ounces

Nickel-cadmium batteries (made by *GE*) in a rechargeable cardiac pacemaker (developed by Johns Hopkins University's Applied Physics Lab) can operate a human body for up to 20 years without removal or repair. It is only ½-inch thick and about one-third the size of conventional models. Heart pacers do have the disadvantage of having to be surgically removed about every two years because of depletion of the storage-battery power, but the new design can be recharged through the skin by a simple procedure that would take about one hour a week. The patient would wear a special vest in which an alternating-current field (generated by a small coil in the vest) passes through the intact skin and is picked up in the implanted cardiac pacemaker where it recharges the battery. No sensation is felt by the patient. The pacemaker also provides its own monitor of battery voltage. Since the pulse rate depends on battery voltage, a variation in the patient's pulse could indicate a change in charge level, warning that the battery needs to be recharged.

Balloon Interrogation Package Records Trans-Polar Flight

As a light plane flew over the North Pole last June, it was out of communication with the ground; yet NASA knew its exact location, its equipment voltages and temperature, and the physical condition of the pilot. In the cockpit was a miniaturized electronic data-collection and location system especially modified to record the trans-polar mission. Called BIP (Balloon Interrogation Package), it was designed for NASA by *General Instrument Corporation* to transmit information from the plane to a satellite which relayed it to ground control at the Goddard Space Center. Spotlighting the equipment's importance was its ability to pinpoint the plane's location in case of a malfunction or a forced landing. It also provided proof of a new aviation record—the first non-stop flight over the North Pole by a woman in a light plane. Sheila Scott flew the twin-engine *Piper* Aztec from Nord, Greenland to Point Barrow, Alaska in 12 hours. Although she was out of communication with the ground while crossing the Pole, the tracking system was able to plot the course of the mission by its fixes on the plane's position, insuring that the Pole was crossed.

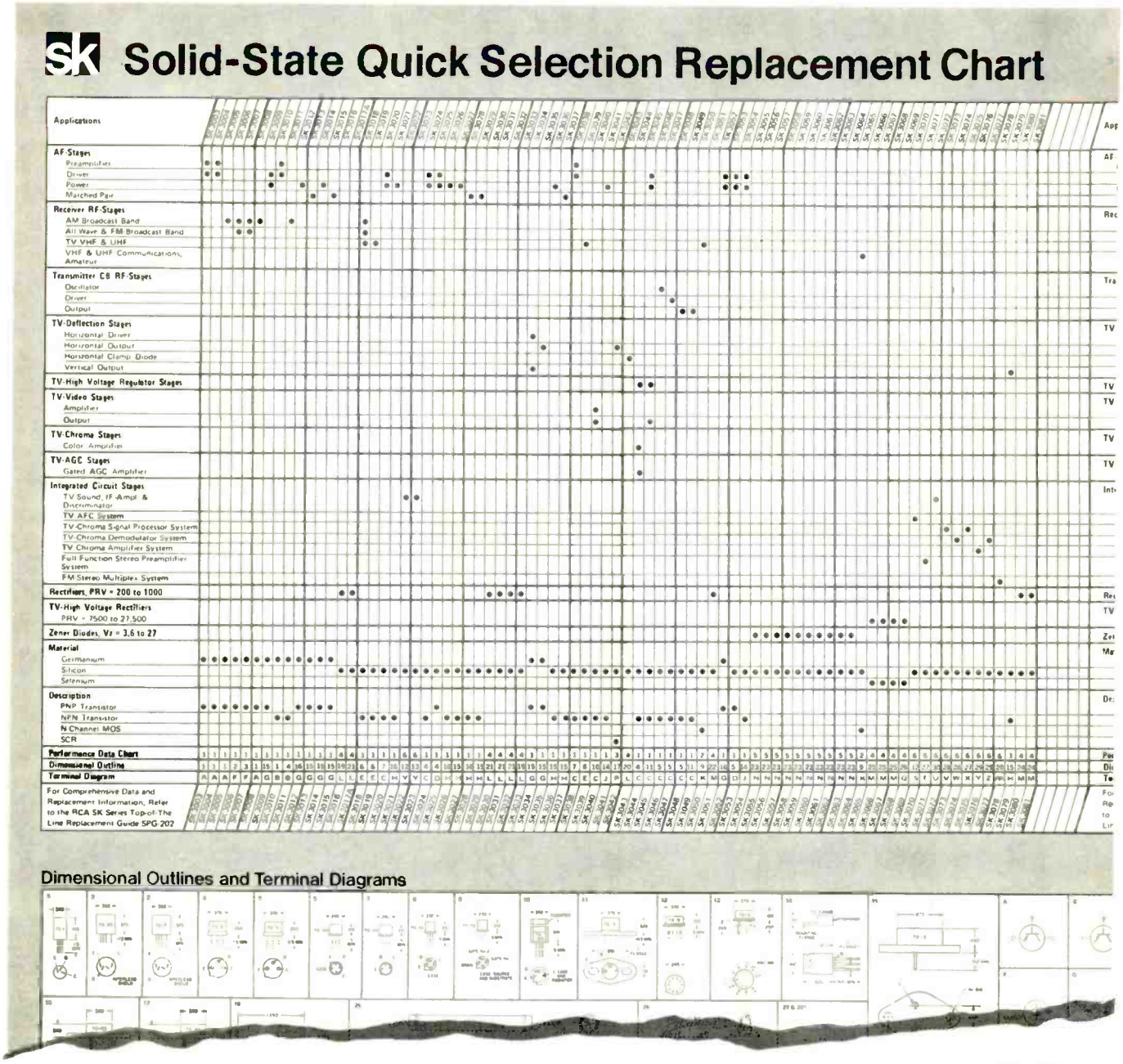
Congratulations!

John W. Maxwell (*P. R. Mallory Co.*), winner of the Electronic Industries Association Outstanding Accomplishment Award, for contributions to EIA engineering committees over a period of more than 30 years. Part of the award cites his "outstanding technical expertise and leadership" resulting in a body of standards ranging from the original American war standards on all components to the current EIA and international standards on electrochemical capacitors . . . Dr. Herre Rinia, recipient of the IEEE Award in International Communication. Formerly director of research for *Philips Labs* (Netherlands), Dr. Rinia is now retired. His voluminous works touch many fields of endeavor—radio-TV, cryogenics, automotive engineering, digital computers—and have earned him well over 100 patents. The award, established jointly by *ITT* and the IEEE, consists of a plaque, a certificate, and $1000 contributed by *ITT*.

Did You Know That . . .

The Veterans Administration employs more architects and engineers for medical construction than any other Federal agency. It is the Government's largest independent agency, with 222 architects and engineers. Eighty-five percent of them have degrees and/or licenses; 20 percent are under 35 years old (including Vietnam veterans). . . . According to data compiled recently by the Electronic Industries Association's (EIA) Marketing Services Dept., U. S. factory sales of receiving tubes totaled 53.4 million units during the January-March, 1971 period. This represents a decline of only 0.9 percent compared with sales of 53.9 million units during the same period last year, and many had thought that the semiconductor era would signal the demise of the tube industry. ▲

Find SK replacements fast with the new RCA SK Wall Chart



Dimensional Outlines and Terminal Diagrams

A brand new expanded, king-size SK Quick Selection Wall Chart which shows you the correct SK replacement when the device to be replaced cannot be identified is now available from your local RCA distributor.

Keying all RCA SK types to applications, and showing terminal diagrams and performance data charts, this 23" x 35" chart is just what you need for fast SK replacement.

Also available is the new edition of RCA's SK Series Top-of-the-Line Replacement Guide which shows how only 79 RCA SK devices can replace more that 20,000 OEM solid state devices in radios, TV's, stereos, tape equipment and other home entertainment equipment.

The new Guide also features 17 industrial type SK's that replace devices used in power control and switching circuits and other industrial applications.

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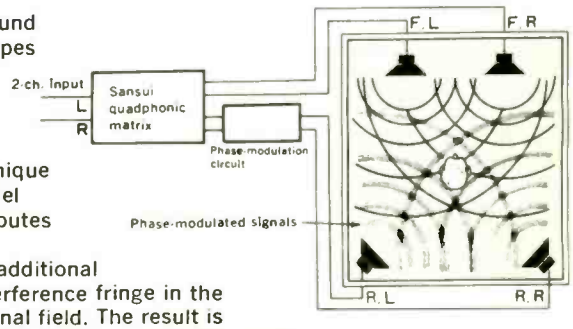
THE SANSUI QS-I QUADPHONIC SYNTHESIZER®

SANSUI QS-I

4-CHANNEL SOUND FROM ANY 2-CHANNEL SOURCE

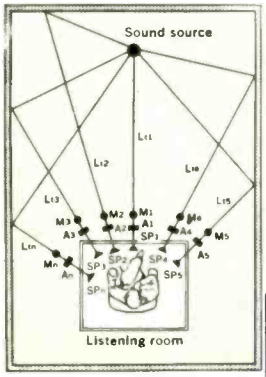
Senses and recovers the ambient information hidden in your stereo discs, tapes and broadcasts

After having discovered that the ambient components of the original total sound field are already contained in hidden form, in conventional stereo records, tapes and broadcasts, Sansui engineers developed a method for sensing and recovering them. These subtle shifts and modulations, if re-introduced, breathtakingly recreate the total of the original sound as it existed in the recording or broadcast studio.



The heart of the Sansui Quadphonic Synthesizer* is a combination of a unique reproducing matrix and a phase modulator. The matrix analyzes the 2-channel information to obtain separate direct and indirect components, then redistributes these signals into a sound field consisting of four distinct sources.

This type of phase modulation of the indirect components, applied to the additional speakers, adds another important element. It sets up a complex phase interference fringe in the listening room that duplicates the multiple indirect-wave effects of the original field. The result is parallel to what would be obtaind by using an infinite number of microphones in the studio (Ml through Mn in the accompanying illustration) and reproducing them through a corresponding number of channels and speakers.



The startling, multidimensional effect goes beyond the four discrete sources used in conventional 4-channel stereo, actually enhancing the sense of spatial distribution and dramatically expanding the dynamic range. Also, the effect is evident anywhere in the listening room, not just in a limited area at the center. And that is exactly the effect obtained with live music! This phenomenon is one of the true tests of the Quadphonic system.

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*Patents Pending

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Electronics World

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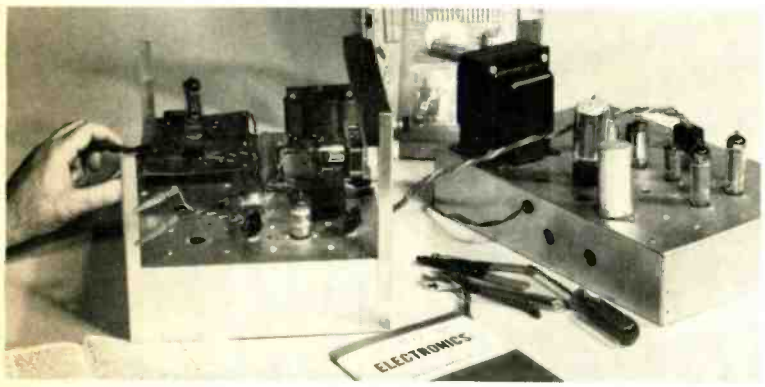

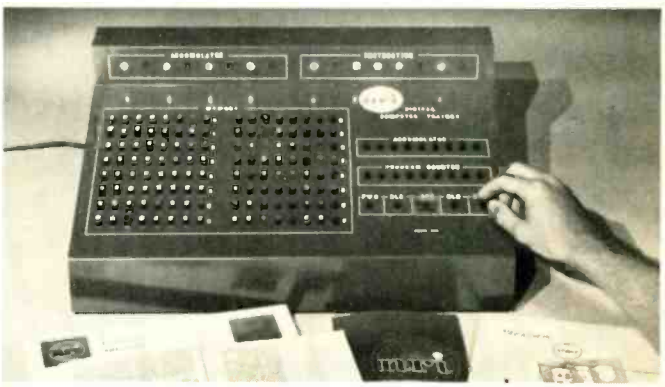

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LETTERS

PHASE-SHIFT OSCILLATOR

To the Editor:

All praise to Mr. Jon Turino for his article "Designing a Phase-Shift Oscillator" (July, 1971 issue). Contrary to his implication in paragraph 3, however, computer-aided design is not difficult with his procedure.

Using his equations, a desk-top computer (*Olivetti* Programma) was programmed to do all the calculations. A run was completed in 15 seconds entering only R_L and p-p volts, transistor *beta*, and desired frequency. I did one run of his specific example, which I wired up, and it hit right on the nose! In a second run, I changed R_L from 25k ohms to 10k ohms and the frequency from 5000 Hz to 1000 Hz—and the breadboarded version again worked.

Mr. Turino did not identify V_{BE} in the text (Step 9) so I left it out in the programming; evidently it is small enough not to affect the calculations.

Thanks for a fine article; it helps.

W. R. KENNEDY, Spectroscopist
American Cast Iron Pipe Co.
Birmingham, Ala.

* * *

TV RADIATION MEASUREMENT

To the Editor:

The article by J. G. Ello, "Measuring Color-TV Generated X-Rays" (appearing in the July, 1971 issue) is one with which I take some exceptions. In Fig. 1 the author shows a *Victoreen* 440 survey meter. This instrument is not acceptable for x-radiation measurements from TV receivers for the following reasons: (1) It is not radio-frequency shielded; (2) it does not average its detection over a 10-cm² area as required by the Bureau of Radiological Health; and (3) its most sensitive range—0-3 mR/hr—is not practical for x-radiation measurements from TV receivers which in all probability are, under worst conditions, approximately 0.1 mR/hr or less.

In all fairness to *Victoreen*, they do market the 440 RF/C survey meter which has been approved by both the TV industry and the Bureau of Radiological Health as an acceptable instrument for color-TV x-radiation measurement, and which reads directly in dose with very little correction necessary over the energy range concerned.

Also, Fig. 3 indicates a scanning speed of 2 in/s which is satisfactory for a scintillation detector or GM instrument but is far too fast for ionization-chamber-type survey meters which have time constants on the order of 8 seconds on their most sensitive ranges. For these instruments, 2-4 ft/min would be a more correct scan rate. Mr. Ello states that "at present there is no all-around survey meter for TV x-ray monitoring." I believe the instrument developed by the Bureau of Radiological Health, incorporating 6 GM (Geiger-Muller) tubes to an active length of 17", is very practical for detection—even though it is energy-dependent. An instrument of this type is being marketed by *Johnson Associates* as a TVX-1 x-ray monitor; it can survey an entire receiver in three to four minutes, compared to possibly 45 minutes for slower instruments.

CHARLES W. COMBS, JR.
Somerdale, N. J.

* * *

CALIBRATING D.V.M.'s

To the Editor:

In the June, 1971 issue of ELECTRONICS WORLD (page 36) an article by M/Sgt. David L. Kierstead describes a method of calibrating digital voltmeters. Obviously there are a few important words missing between the bottom of page 36 and the run-back at the top of page 62. (*A line was dropped; the "Calibration Procedure" should read as follows: "To start the calibration process, place switch S1 in position B, switch S2 to the standard cell, and close switch S3,* placing divider #2 in the circuit. Divider #1 is set to *10% of the standard cell voltage. . . ."—Editor*)

Also, it should be pointed out that with divider #2 having only five decades of resolution (settability), it will be impossible to adjust it for a null when S2 is connected to it. The last digit on divider #2 causes a change of slightly over 100 mV—which is far from a null! Nulling must be accomplished by changing divider #1. This prevents calibration of the d.v.m. at points chosen by the user; "fine-tuning" must be provided by divider #1 to obtain exact knowledge of the voltage. Furthermore, no digital voltmeter on the market has the linearity and accuracy of the best Kelvin Varley resistive dividers; the same applies to "absolute d.c. voltage standards." Thus, although the

described method is sound in theory, in practice one must resort to either a calibrated K-V divider or a set of transfer resistance boxes to establish accurate ratios of .1 and .01.

Lastly, a cushion of 10:1 in calibration support cannot be realized as one approaches one part per million; in most cases, one must settle for 1:1.

LLOYD W. ROOT
Dayton, Ohio

To the Editor:

In reference to Lloyd W. Root's letter regarding my article "Calibrating Digital Voltmeters," accuracy can be maintained within ±10 ppm, whereas I had said ±5 ppm. The article also states that divider #2 is a 5-decade unit and I would like to change this to state that it should have adequate resolution to accommodate the d.v.m. under test.

It should also be pointed out that, in order to maintain ±10 ppm accuracy, the first digit of the Kelvin-Varley divider (divider #1) should not be less than 0.1 in its setting.

Incidentally, the method I described does indeed use the calibrated K-V divider and transfer resistance boxes Mr. Root recommends; and, as the second sentence of my article acknowledges, accuracy that does not meet or exceed 10:1 ratio should be annotated to indicate the true ratio.

DAVID L. KIERSTEAD, M/Sgt., USAF
Aurora, Colo.

* * *

MORE ABOUT SOLDER

To the Editor:

Next time you publish an article like "Solder & Soldering Tools" (June, 1971), we would appreciate being included in the list of manufacturers. We have been in the solder business for 70 years now, and are the oldest and last surviving privately owned firm in the industry.

We manufacture bar and wire solder, both solid and cored, high- and low-temperature, as well as a soldering iron and some soldering tools. Perhaps you can also mention that we make the only new cored solder called "perforated solder."

Glad to see you're interested in solder, and hope we can be of some service to you.

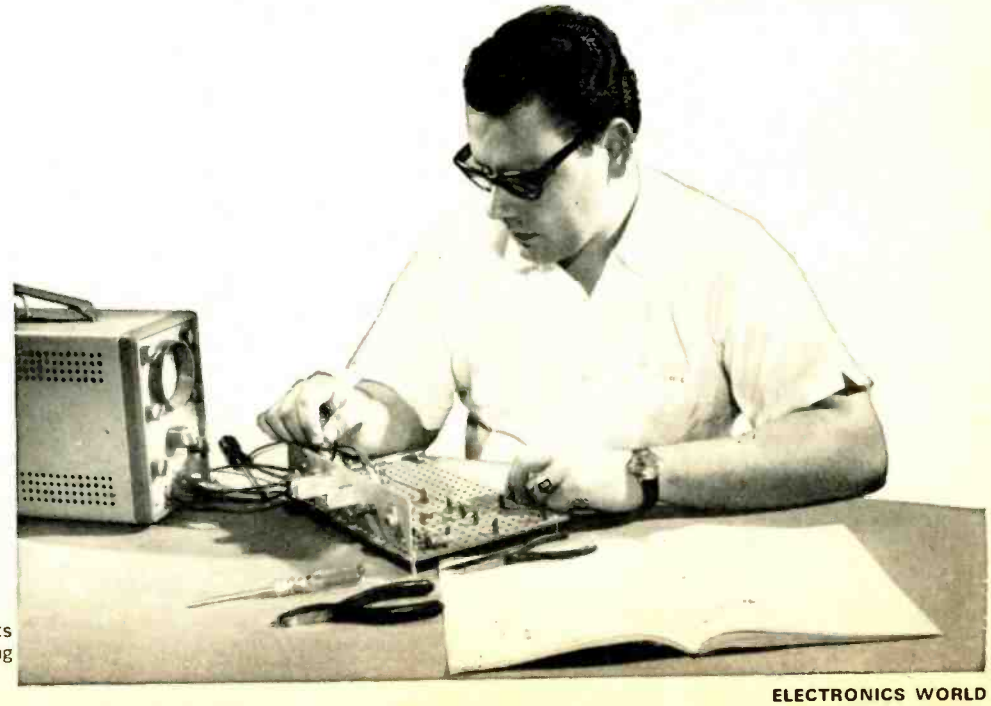
JOHN R. MAINS, Sales Mgr.
Gardiner Solder Co.
Div. of *Gardiner Metal Co.*
Chicago, Ill.

* * *

OSCILLOSCOPES

A number of our readers have expressed interest in oscilloscopes in recent months. So we have planned an extensive feature article on the subject for our November issue telling what's available on the market today. Watch for it.—Editor ▲

10 Reasons why RCA Home Training is your best investment for a rewarding career in electronics:



Performing transistor experiments on programmed breadboard — using oscilloscope.

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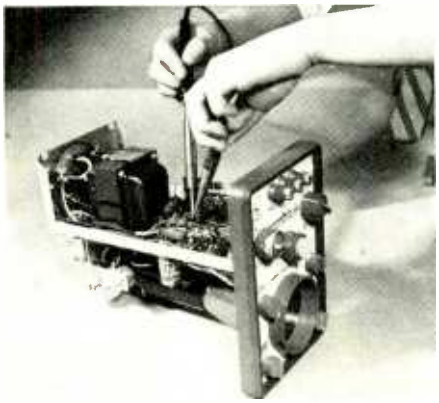
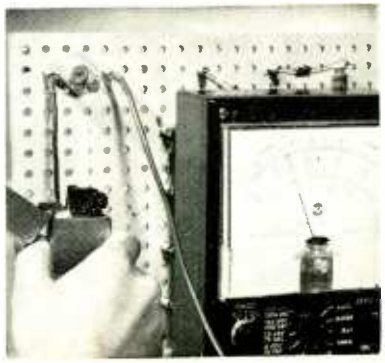
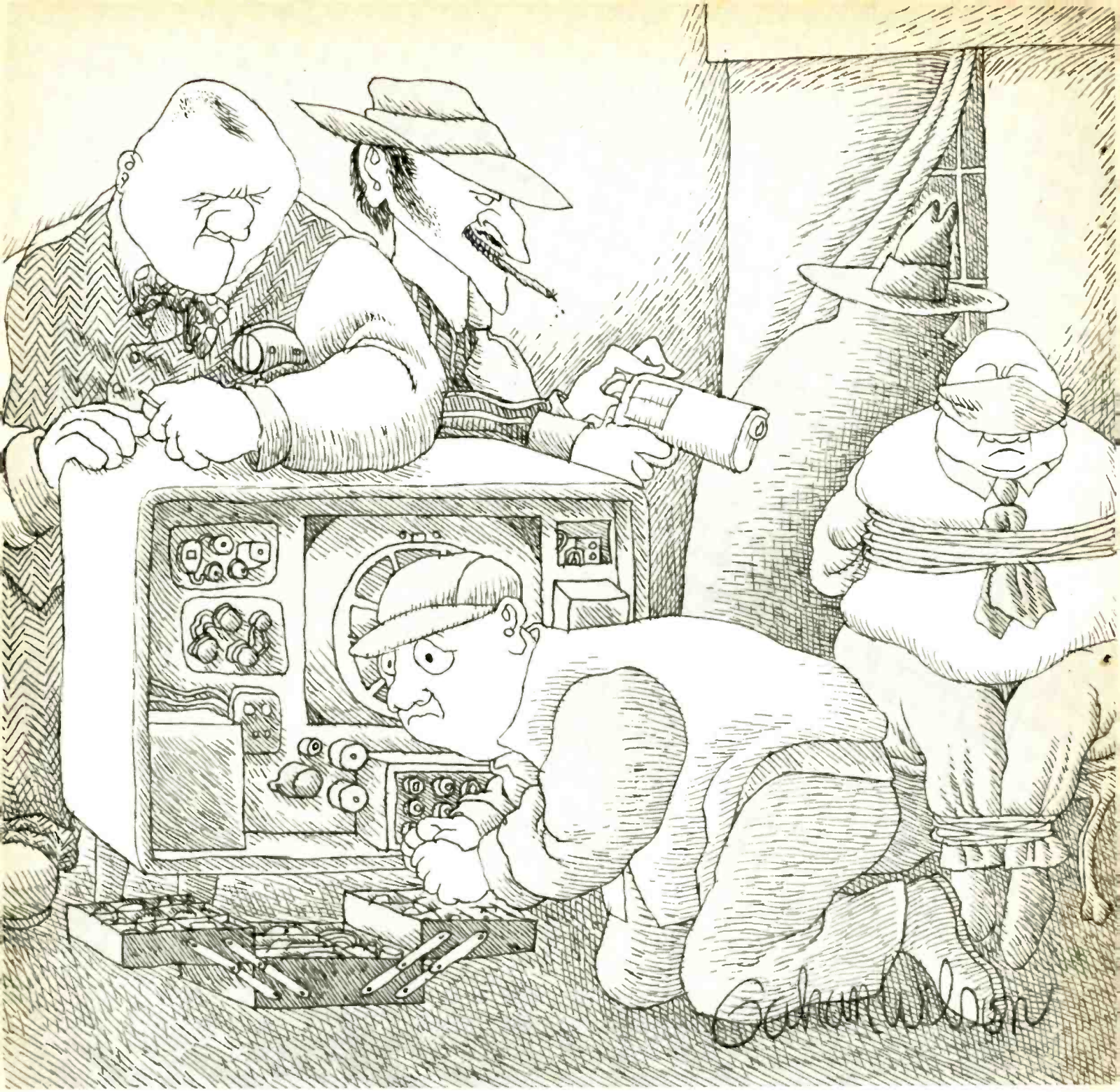


Construction of Oscilloscope.

Temperature experiment with transistors.





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And they save a lot of space in your tube caddy.

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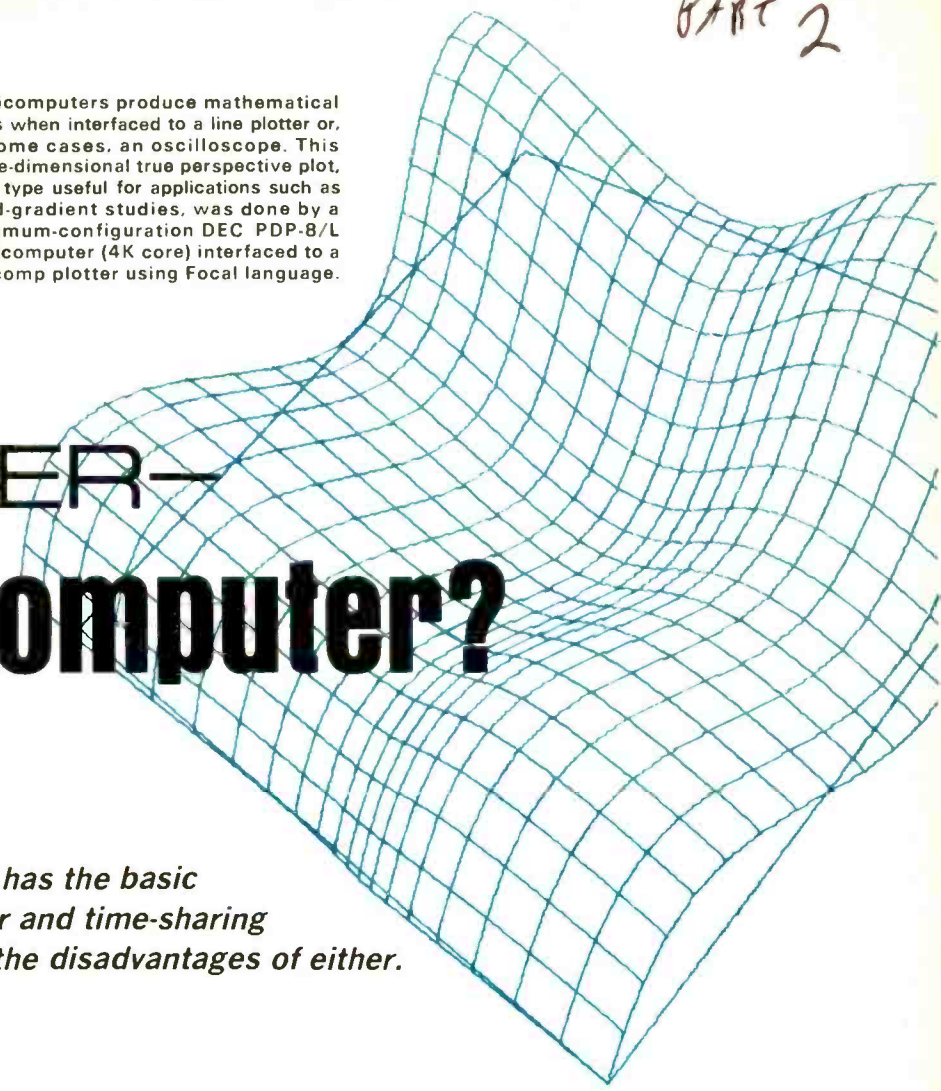
And that should help you make a fast getaway.

GTE SYLVANIA

PART 2



Minicomputers produce mathematical plots when interfaced to a line plotter or, in some cases, an oscilloscope. This three-dimensional true perspective plot, of a type useful for applications such as field-gradient studies, was done by a minimum-configuration DEC PDP-8/L minicomputer (4K core) interfaced to a Calcomp plotter using Focal language.

WHICH COMPUTER— The Minicomputer?

By ROB KATZ
Applications Engineer, Digital Equipment Corp.

It can be said that a minicomputer has the basic advantages of a desk-top calculator and time-sharing system but has remarkably few of the disadvantages of either.

Editor's Note: This is the second article on the subject of the computer best suited to the engineer. Last month, Paul Asmus of Hewlett-Packard *covered the "programmable calculator." Next month Lee N. Beyer of* General Electric *will discuss the pros and cons of time-sharing systems.*

THE image of the electronic computer is changing. Along with the huge, monolithic pieces of machinery usually found in computation centers (and wildly parodied in movies), a new breed of machine has made its appearance. This newcomer is considerably smaller (sometimes small enough to fit on a desk top), is usually more rugged, and has been adapted to a number of unusual uses. Variously called "small general-purpose computers," "little computers," and "baby computers" by some manufacturers and users, these devices are almost universally dubbed "minicomputers" by the electronics industry. However, since they come in various shapes and sizes, there is some confusion as to just what constitutes a minicomputer.

A minicomputer is a complete computer, capable of performing normal computer functions independently (as opposed to, say, an exotic terminal that has to be connected to a large computer in order to work); and it is general purpose, meaning that whatever functions it may do are determined by the program that is read into it—and that its functions can change merely by reading another program into it. By contrast, a special-purpose computer, whose functions cannot be reprogrammed directly, is not considered a minicomputer.

Another aspect that identifies a minicomputer is its word length. Although all digital computers use binary information units (bits) for their computation these are grouped into larger units of bits called "words." The typical word length of a large computer is 32-36 bits, the minicomputer from 8 to 18 bits. The minicomputer memory has a capacity of at least 4096 words (4K words in computer parlance).

A final parameter defining a minicomputer is that it generally costs less than $25,000 in its basic configuration. Admittedly, this last parameter is somewhat arbitrary, but it draws a line in the rather extensive gray area where a minicomputer leaves off and the larger "medi-

Some models of minicomputers come in "desk-top" versions. This PDP-8/E can be used as an independent terminal for engineering calculations in this configuration. With the modern programming languages available, such as Focal, the computer can be programmed by engineer for use by untrained personnel.

um-scale" or "midi" computer starts. It is important to emphasize "basic configuration" since quite frequently the minicomputer uses supplemental devices to help it do its job—known in the industry as "peripheral devices" or "peripherals."

Peripherals are used to store data or programs or to input and output information to the computer. For storage, the basic method is magnetic recording. Magnetic tapes, disks, and drums are all used to record and play back information from and to the computer. With such storage media, it is possible to keep available for rapid recall program elements or data that may be used only from time to time, thus keeping the computer's internal memory free for more immediate program needs. In order of recording and playback data rates, drums are the fastest, followed by disks and tape in that order.

Tapes and some disks can be used to transfer data from one computer to another in the same way that it is possible to play back an audio tape recording on a machine other than the one on which it was recorded. Thus, in addition to being storage devices, some disks and tapes are used for data transfer. Sometimes when a small computer system is logging data from a process, it will prepare tapes so larger computers located elsewhere can make a more detailed analysis at a later time.

The fundamental peripheral device by which one communicates with the computer is a Teletype or its equivalent. Although almost all minicomputers come equipped with some such device, it is considered a peripheral because it is tied to the computer in the same way as all other peripherals—that is, through appropriate interfacing.

Besides the basic teletypewriter, other more specialized and sophisticated devices are used. High-speed line printers are used to output large quantities of printed data in a short time. Graphical plotters are used to output information in graphic form, which can be in Cartesian or polar coordinates—or even isometrics or perspective drawings. All these peripherals put out printed or "hard-copy" outputs.

Another form of peripheral is the display. In a display, a CRT presents imaged information—"soft copy" in computer parlance. Some displays merely present data; others act like teletypewriters, providing alphanumeric images and accepting data from a keyboard input. Others permit the user to act directly upon the image being presented.

Quite frequently, minicomputers are required to gather data from a device or sensor that outputs an analog signal or must sometimes send analog signals to a process or device. Converters are used to interface a computer to such a process or device. As its name implies, an analog-to-digital (A/D) converter transforms analog signals into digital form for computer manipulation; digital-to-analog (D/A) converters do the reverse.

The key to all peripheral operation is information transfer. The storage units transfer internal to and from the computer. The teletypewriter or its equivalent (often called the input/output or I/O device) transfers instructions or finished data between user and computer. Converters transfer information between the computer and the "real world"—the outside activities the computer is involved in, other than direct communication with the user.

When we speak of a computer and a number of peripherals configured together to do a particular job, the result is usually referred to as a "computer system" to differentiate it from its central component. Since the teletypewriter is a peripheral device, a purist often refers to a computer that only has a teletypewriter connected to it as a computer system, although many people consider this particular combination a computer, saving the "system" designation for something a little more elaborate. This has led to some confusion. In this discussion, the author takes the latter approach.

An engineer can view a minicomputer in two ways: as a "free-standing" unit to help him with his calculations, designs, and so forth, or as a component to be used in a system to do a particular job. In this latter category, the engineer can consider the minicomputer "component" as something to help in engineering work (such as testing systems), or as something to solve a particular engineering problem (directing a machine to manufacture a consumer product, for example). Although using a minicomputer as a component to solve a particular problem is important to the minicomputer industry, it is only marginally important to the engineer; consequently, emphasis here will be on how the engineer can be helped by a minicomputer—either by itself or in a system—rather than the different ways it can be incorporated.

Programming

Most engineers who have only a nodding acquaintance with computers consider them simply and solely as devices on which to perform calculations—"supercalculators," in other words. In order to comment upon the "calculating" capabilities of a minicomputer it will be necessary to touch briefly upon the different types of computer programs. "Programming," to many people, means writing certain formulas and statements to enable a computer to solve explicit problems. Actually, it is a little more complex than that. A computer cannot function without some sort of program, but there are all types. The circuits within a computer can recognize an "on-off" relationship (that is, whether a circuit is active or not); "on" and "off" are assigned the numbers 1 and 0 respectively, and thus computer operations are binary, forming the basis of "machine language."

A less cumbersome form of programming is an "assembly language" or "assembler." Instructions are read into the computer which enables it to recognize symbolic notation (for example, in a PDP-8 family computer, if you wanted to clear the accumulator, you could type "CLA"; this would be translated by the instructions—program already in the computer—to machine-language binary number 111110000000). Assembler programs are organized the same way machine-language programs are—the way the computer's components operate rather than the way people normally handle mathematics.

A form of programming more nearly paralleling the way human language and mathematics operate is known as a "compiler program" or a "compiler." Fortran, to take a well-known example, is a compiler. Because of the organization of a compiler, it is far easier to learn to work with.

But you don't get something for nothing. The necessary instructions to convert the compiler's statements into machine language take up considerably more of the computer's memory than an assembler, leaving less of the memory available for the programmer's instructions.

Another high-level program is an "interpreter." Such a program is almost English-like in nature and very easy to learn. But, like the compiler, an interpreter takes up quite a bit of the computer's memory.

Viewed from the programming context, the minicomputer is a versatile calculating tool. A large number of minicomputers can handle compilers like Fortran or interpreters like Basic or Focal.

When a high-level program has been entered in the machine, it is possible to formulate programs in the language that will permit detailed calculations to be performed by an assistant, freeing an engineer for other tasks. In this mode, the program is written by the engineer in such a way that it asks questions of the person. The computer does most of the talking so a relatively unskilled person can work with the computer (*i.e.*, if the computer types out "Please enter the resistance of the load in ohms," the operator only has to enter a figure and, from the question, he knows which figure to enter).

In addition to printing out single calculations and programs involving single calculations, minicomputers can perform matrix calculations and solve simultaneous equations (precisely how many depends on the computer in question, how much memory is being used, and what type of program is involved; a 4K PDP-8 minicomputer can handle a 6 × 6 matrix or solve ten simultaneous equations with 10 terms using Focal, for example).

Output Devices

Minicomputers can be coupled to graphical output devices, permitting them to plot representations of solutions. These can be the form of conventional Cartesian or polar coordinates, and—depending on the computer and program used—can be two- or three-dimensional representations (some minicomputers are capable of generating real three-dimensional plots by plotting a stereoscopic pair of images).

A further extension, which actually goes beyond the realm of mere "calculation" for the more complex minicomputer systems, is the use of a visual display and a "light pen" for design work. The "light pen" is a probe with a photosensor built into its tip. The operator holds the pen directly against the face of the CRT; the pen detects the glow of an image on the CRT and sends the information back to the computer *via* a connecting lead. Since the computer is generating the image, it "knows" what image element of the total scene is being presented. This lets a designer manipulate elements within a design (such as parts layout) and permits the computer to optimize a design (such as circuit routing). Many "display-" configured minicomputers can also be connected to plotters to permit a finished "hard-copy" drawing of the design.

As in the case of a high-level language, interactive graphical design is fairly easy to work with. Most systems are designed to be used by someone who is not a sophisticated programmer since the instructions flashed upon the screen are in English.

The key to the calculation and design uses of minicomputers is interaction. Many of the programs are set up to permit the user to interact with his minicomputer for maximum effectiveness. Unlike "after the fact" operations such as data-center batch processing (which a minicomputer can also do), the operator can alter his program (or design) while he is working, thus permitting him to operate more creatively.

In addition to its calculating abilities, the minicomputer is useful as an engineering instrument for measurement, data logging, and evaluation. Historically, a large number of minicomputers have either been built into measuring systems or interfaced with instruments to extend the scope, precision, or both of such instruments.

Interactive graphical design is possible with both large and small computers by using a "graphical terminal" equipped with a light pen. In this arrangement, the photosensor-equipped light pen is held over an element of the image to be worked with. Since the photosensor picks up the image and determines its timing, it acts as a feedback mechanism to the computer, permitting the computer to "know" where pen is being held. This particular configuration is the Graphic 15, used with PDP-15 computer. Graphic 15 is often used for circuit-design work and testing prototypes.

Engineering Applications

Evaluating the performance of engineering prototypes of mechanical and electronic equipment is a normal minicomputer function. The reason a minicomputer is used for this purpose is simple: its operations can be altered by reprogramming; to do the same with a specially constructed instrument would generally require a redesign plus the rebuilding that would be necessary. Thus, while initial costs are similar, the readjustment or modification costs of a minicomputer-based system are lower (with the added advantage that if you wish to return to your original application, you have merely to read in the initial program).

In this respect, minicomputers offer an additional dividend. They are general-purpose machines, which means they are able to perform a wide variety of different functions merely by reading in different programs, although the majority of minicomputers are able to do only one of them at a time. Thus, a minicomputer can be put to several different uses by the same facility. For instance, at one facility, the minicomputer could be used to perform engineering calculations in the morning, system calibration in the early afternoon, and run accounting, payroll, or inventory calculations at night. All it would require is the proper program (and in a few cases, some additional peripheral devices).

How Do Minicomputers Compare?

Quite frequently individuals who are associated with minicomputers being used for calculations are asked how the machines compare with desk calculators and with large computers used on a time-sharing basis. In one sense, it can be said that a minicomputer has the basic advantages of both with few of the disadvantages of either. In its basic configuration, that is, 4K of core memory and a teletypewriter, the average minicomputer is roughly comparable to a programmable desk calculator with regards to speed and accuracy. It can be used with slightly greater ease, but it is

(Continued on page 63)

Recent Developments in Electronics

A compact magnet that operates without power consumption, the new Intermagnetics General Corp. Minibrute 100 is being examined by IGC staff. When operated at low temperature the Minibrute produces 100,000 gauss or five times the magnetic strength of iron. A conventional magnet or solenoid with the same characteristics weighs several tons and consumes millions of watts of electrical power. The Minibrute will attract a one-pound block of iron with a force of 1000 pounds. The magnet shown, mounted on its support structure, is of split configuration, allowing radial and axial access to the central high field region. This miniature superconducting magnet is made from patented IGC niobium-tin which becomes superconducting at comparatively warm temperatures (−427°F) and will carry steady electric currents many times those carried in copper or aluminum—without any power losses whatsoever. Niobium-tin tape is wound into pancake-like modules (discs) which are then stacked and electrically connected to produce the actual magnet. Just one of many potential applications for the superstrength magnet might be the levitation of high-speed trains on magnetic air cushions.

New proton accelerator will be world's largest. Three Phelps Dodge Industries, Inc. operating units are fabricating over 2,141,000 pounds of copper into conductor for the beam-bending magnet field coils in the world's largest and most powerful proton accelerator. The accelerator, now being rushed to completion this summer at the National Accelerator Laboratory near Batavia, Ill., has a main ring 3.9 miles in circumference (shown) and will accelerate protons to an energy of about 500 GeV to send them traveling at 99.9999 percent the speed of light before they are directed at experimental targets. At left, the beam tube enters a steering magnet between the out-turned ends of the copper coils that were fabricated from Phelps Dodge Copper Products Company hollow conductor. These coils are hollow to permit the passage of cooling water. Both the water and the electrical current are fed to the coils through the copper tubing lines coming down from the left.

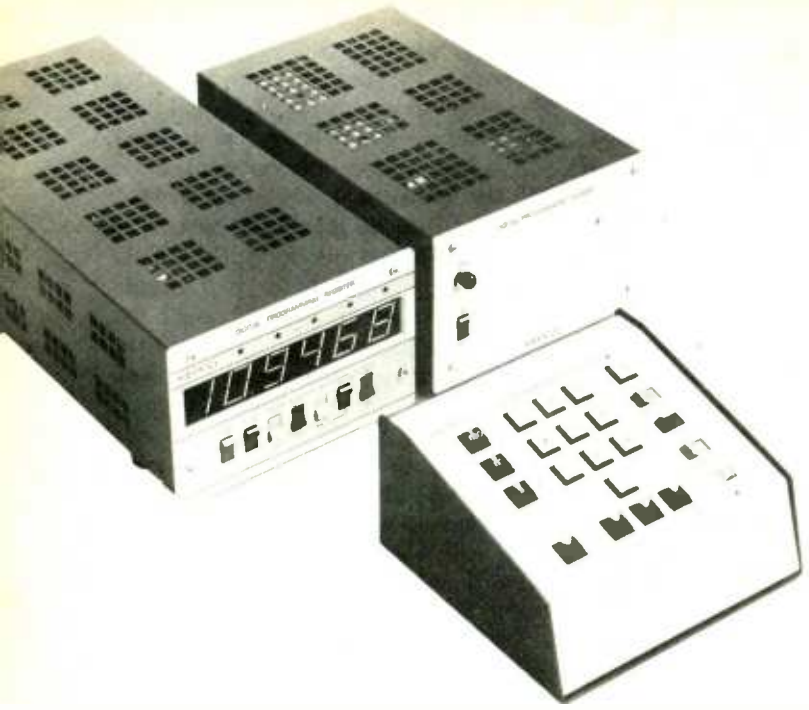
New "dry box" welding unit provides vacuum environment controllable to 10^{-3} torr. Tantalum crucible designed for use in an Atomic Energy Commission project is shown in new production unit developed by Norton Company. Controlled environment, gas flow, welding cycle, and weld thickness are all provided by the new welding unit. After the chamber is evacuated of most environmental gases, argon is pumped in, and the controlled environment enables effective welding of tantalum which would otherwise oxidize. Tantalum, used in electronic, nuclear, aerospace, and other fields, has the third highest melting point of all metals (5400°F), the acid resistance of glass, and is one of the easiest refractory metals to fabricate. Welding unconventional shapes such as elipses and parabola is possible with the new system.

Digital musical computer replaces organ pipes and bellows, with the aid of aerospace microelectronics. Occupying 1/8 cubic foot and fabricated from 22 MOS/LSI circuits containing 48,000 transistors, the computer has literally billions of tone variations. Developed jointly by North American Rockwell and the Allen Organ Company, the digital organ computer concept was based on its ability to convert sound waveshapes into digital signals (binary numbers) which can be stored in the memory and recalled by a touch of the organ keys. The brain of the organ is a digital computer which adds, subtracts, and multiplies musical sounds expressed as numbers. Its function is so precise that to produce the breathiness of organ pipes it was necessary to intentionally introduce error into the system. The keys are connected to a microelectronic digital computer consisting of 22 tiny circuits on an 11 × 17-inch board in the console. By inserting a computer program card into a slot, an infinite variety of sounds, including those other than pipe organ, can be automatically introduced into the memory and be available as the organist wants them. The changing of the many voice combinations is automatic; the organist merely presses a button to select any of the voice combinations and tones he has pre-selected for an entire recital. Standard models will range from $5000 to $14,000.

Improved vehicle communications are possible with new vehicle location systems developed by GTE Sylvania and RCA. GTE's "digimap" (shown in photo) enables a driver to report the location and status of his vehicle in less than one second. The new system is designed for use with existing GTE Sylvania communications equipment that reduces radio channel congestion by sending messages in quick tone bursts rather than by voice. Each vehicle terminal has a pressure-sensitive map mounted on a grid-coordinate board which the driver merely touches to indicate his position. The vehicle also has a keyboard and small video screen for sending and receiving messages. The system also permits cars to send pre-selected messages such as "send ambulance" simply by pressing a button. RCA's Voice-PLUS system (not shown), presently being used by a New York taxi group, flashes a silent alarm to headquarters in case of robbery or other emergency. By pressing a hidden switch, a driver can signal the radio dispatcher, without the passenger's knowledge. After consulting a log of the cab's earlier assignments to determine its general location, the dispatcher can then summon help by calling the police or radioing other cabs near the one in distress. The alarm is part of an RCA two-way radio system which relays messages in number code as well as by voice. The system also automatically transmits a return signal from the dispatcher that lights an "ackowledge" lamp on the cab's dashboard to indicate the driver's message was received. The new equipment was demonstrated originally for police communications and is also expected to find applications in trucking and related industries, as well as in taxis.

New international Videovoice system, by RCA Global Communications, Inc., links New York and Tokyo. The new system enables businessmen to exchange black-and-white TV still pictures over conventional voice channels. Once two locations are equipped with Videovoice units, operation is simple. A subscriber wishing to transmit visual information (products, charts, etc.) places a call in the usual manner over his private network. If the subject is fixed, such as a chart, the subscriber merely pushes the transmit button. If the subject is live, the sender pushes a freeze button and then transmits it. The receiving unit at the distant terminal displays the picture on a TV screen until a new frame is transmitted. A two-way discussion can proceed while the pictures are being exchanged, if a full duplex system (consisting of two circuits) is being used. If only one circuit is used, voice communications must cease during the transmission period; two-way conversation can resume after the picture is transmitted. Heart of the Videovoice frame-freeze unit is the novel RCA silicon target storage tube which stores the picture electronically and allows it to be read off at the required speed for transmission. This permits the service to employ a normal voice circuit having a bandwidth of 3000 Hz. The domestic visual telephone service recently developed by AT&T requires a bandwidth of 1 MHz.

October, 1971



Digitally

by PAUL BIRMAN
Manager, Applications Engineering, Kepco, Inc

◀ A digitally programmed system that will function with any operational power supply to produce a digitally controlled output of 0-1000 V. Units (left) the DPR-5-5½-digit readout; (right) the DPD-1 digital programming decade; and (front) the DPK-1 digital programming keyboard are by Kepco, Inc.

POWER supplies belong securely to the world of analog things, a world where electrical quantities flow smoothly in a (hopefully) infinite continuum. Your bench supply is like that; its output is probably adjusted by a knob whose possible settings, or resolution, is limited primarily by the steadiness of your hand. It is also limited by the quality of the control used to make the adjustment.

In the digital world of computers, bits and pulses, and such, resolution is not so haphazardly determined. A given quantity is composed of just so many "bits of information" and the resolution of the thing is set by the number of bits used.

When power supplies are used in automatic systems, the knob-method of control (Fig. 1A)—so handy on the bench—gives way to a more machine-compatible way of control, in other words—programming.

It is a fact of life that most machine controls today employ digital language to communicate instructions to the various elements of an equipment system. To fit into such systems, then, it is necessary to teach the basically analog power supply how to understand digital language.

There are units available which can perform a digital-to-analog conversion (called DAC's). Placed between the incoming digital instruction and a programmable power supply, they will provide the needed interface (Fig. 1B). Alternatively, you can feed the digital signals into decoding circuits which operate directly into a power supply's reference and feedback control circuits.

You can't do these things to an ordinary power supply, of course. It must be one "smart enough" to understand digital instructions—it must be a power supply with sufficient suppression of spurious responses that it *only* answers to legitimate digital signals. It must be the kind of supply known as "operational," because its response can be mathematically figured from the relationship of "operators" or controls (Figs. 1A and 1B).

An operational power supply, like an operational amplifier, responds linearly to the combination of input and feedback conditions to produce an accurate output reproduction of its instructions. If the instructions are to remain fixed at a specific voltage, the operational power supply becomes a constant-voltage stabilizer. If the instructions say remain fixed at a certain current, it is called a current stabilizer. If the instructions call for the output to be varied in accordance with this pre-planned program, the operational power supply can do that too.

A critical characteristic of the operational power supply is its ability to "go to zero" when commanded to do so—or in the absence of any contrary instruction, it must not go to −0.1 volt or +0.01 volt; it must be trimmable so that zero is really zero. It this were not so, its response to the digital instruction would always have an error.

A second important characteristic is the power supply's ability to change output quickly. This will govern how far behind the digital instructions the actual output will lag and determine the minimum time between successive instructions.

Assuming you have a "smart" operational power supply and have chosen to use it either as a linear amplifier, reproducing the analog output of the DAC, or are going to decode directly into the supply's control loop (Fig. 2), you now must worry about isolation. If the supply's d.c. output is electrically common to the digital "ground" (and is of the right polarity), there is no problem. More likely, though, there will be a need for electrical isolation so that the d.c. output of the power supply floats relative to the digital lines.

The popular ways of isolating the digital from the analog involve: (a) relay coupling; (b) r.f. coupling; (c) optical coupling; and (d) inductive coupling. In most cases, the isolation is provided at the digital end of the interface because it is easier to put an "on-off" digital bit through the selected coupler than it is to get a linear analog signal through.

Relays, often encapsulated reed-types, are the most widely used method of insuring electrical isolation. The digital signal goes to the relay's coil and comes out, isolated at the contacts, ready for the digital-to-analog conversion. Inductive and r.f. coupling have also been used with success. Modern semiconductor technology with light-emitting diodes (LED's) has greatly enhanced the attraction of optical coupling, and the newer digital programmers for operational power supplies use this method for their isolation.

In today's highly developed equipment systems, "smart" operational power supplies can be found on-line with their output under digital control responding quickly and accurately to the demands of a high-resolution control computer. Such power supplies may seem remote from the ordinary unit on the bench—but chances are it is quite similar, since the operational technique for controlling output is widely used for most precision equipment.

If it has (or you can add) provision for proper zeroing and it is a "programmable" supply, you might have the basis for a digitally controlled power supply right at hand.

There are a number of digital/analog interfaces available

Controlled Power Supplies

There are many occasions when you must use a power supply which is "smart enough" to understand digital instructions. Here's how it is done.

commercially including the *Kepco* DPD series which are relay-isolated and work directly in any selected operational power supply's feedback loop. These include: Model DPD-1 (4½ digit, 0-1000.0 V control), DPD-2 (4½ digit, 0-100.00 V control), DPD-3 (5½ digit, 0-1000.00 V control), DPD-4 (3½ digit, 0-1000 V control, DPD-5 (3½ digit, 0-100.0 V control), DPD-6 (3½ digit, 0-10.00 V control, and DPD-7 (3½ digit, current control).

These units couple to any operational power supply to form a digitally programmable power-supply system, a bipolar (two-directional) digital system if a bipolar supply is used.

Also available are 3½, 4½, and 5½ digit serial to parallel information-storage and display registers (DPR-3, DPR-4, and DPR-5) as well as a manual keyboard, Model DPK-1.

The *Kepco* Model PVS 100-1M is a switch-selected or relay isolated D/A with built-in 0-100 volt, 0-1 ampere precision voltage source.

The company's SN series are optically isolated digital-to-analog converters which produce analog output which the power supply can amplify linearly. The SN-2 is a 2-digit BCD, 8-bit binary, parallel storage unit with 0-1 volt output which can be amplified to any desired level. SN-3 is a 3-digit BCD, 12-bit binary, parallel storage type with 0-10 volt output which can also be amplified to any desired level. These units couple to any operational power supply to form a digitally programmable power supply, unipolar or bipolar.

Hewlett-Packard's Models 6130B, 6131B, r.f.-isolated combination of digital-to-analog converter has parallel storage with built-in bipolar power supply. The 6130B is rated –50-0-+50 volts at 0-1 ampere while the 6131B is rated –100-0-+100 volts at 0.5 ampere.

John Fluke offers a combination of digital-to-analog converter, parallel storage with built-in supply in its Models 4210A (0-10 volts at 0-100 mA), 4216A (0-16 volts at 0-100 mA), and 4250A/4265A (0-65 volts at 0-1 A). ▲

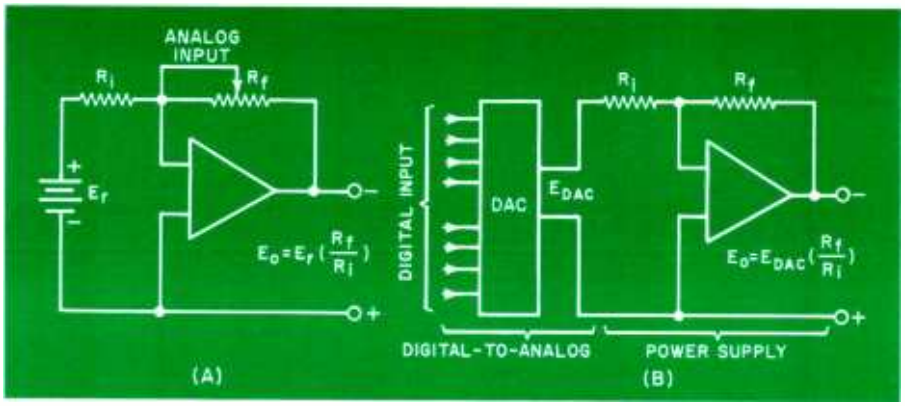
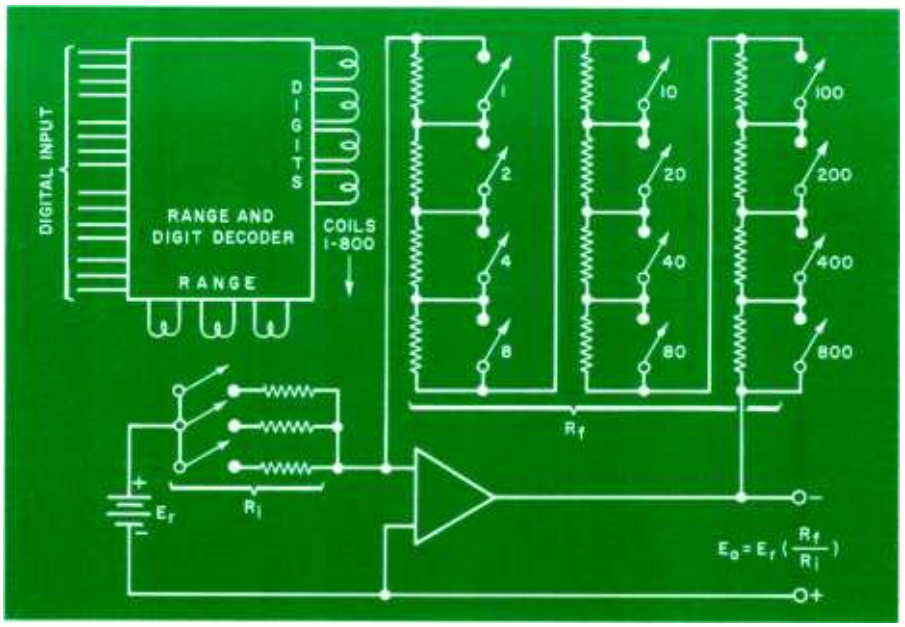


Fig. 1. (A) An operational power supply connected as voltage stabilizer. R_f is voltage control and adjusts output; and (B) with a DAC driver.

Fig. 2. An operational power supply with the digital operators controlling both R_f and R_i directly. Refer to article for details on operation.



General Purpose POWER SUPPLIES

By ED BRENNER / Director of Engineering
Lambda Electronics Corp.

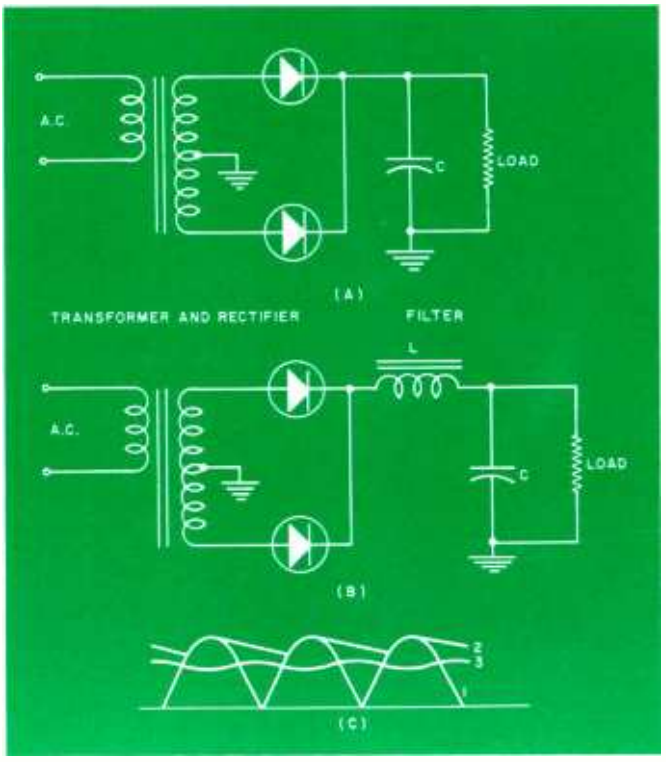
Lambda Model LL-902 bench-type IC regulated laboratory power supply which provides an adjustable d.c. voltage range of 0-20 volts at currents from 0 to 0.65 ampere.

The capacitor-filtered, series-regulated supply is the most common. Final decision as to characteristics is usually trade-off between performance and price.

POWER supplies and power regulators are represented by a wide assortment of devices ranging from batteries and generators to dynamic electronic units using feedback circuits.

The specific function of the a.c.-to-d.c. power supply is to provide d.c. voltage and current from a primary a.c. source. The electrical characteristics of the power supply and the physical form it takes must be a function of the circuitry being powered and the physical requirements of the system in which the circuitry is used.

Fig. 1. Rectifier and filter configurations showing (A) capacitor and (B) LC filters. (C) D.c. output voltage waveforms for single-phase, full-wave rectifier with (1) no filter, (2) capacitive filter, and (3) an LC filter.



Circuits and Characteristics

Power conversion generally starts with rectification, *i.e.*, converting a.c. input voltage to a d.c. voltage. Because the output of a rectifier contains a relatively large a.c. ripple component in addition to its d.c. value, a filter must be used to attenuate the ripple component before this d.c. voltage is applied to a d.c. load. Figs. 1A and 1B show two types of unregulated power supplies while Fig. 1C shows the output ripple.

The amount of ripple present after filtering the rectified output is a function of the circuit components and the load current. In actual practice, at full-rated load, the capacitor-input filter supply is limited to approximately 5% r.m.s. ripple voltage while the *LC* input filter supply attains 1% r.m.s. ripple voltage. Of course, better filtering can be had by using components larger than those dictated by economics or package volume when compared to the size of the transformer. However, such filtering can better be accomplished using other means.

With the unregulated power supply, no matter how efficiently ripple is reduced, the rectified-filtered d.c. output can change substantially with load current and/or power-line variations. Typical regulation characteristics include: For capacitor-input filter supply: line regulation of 1.2% per % line change at full load, and load regulation of 20% from ½ load to full load. For *LC*-input filter supply: line regulation is 1% per % line change at full load, and load regulation is 10% from ½ load to full load.

Because of these relatively poor performance specifications, unregulated supplies find limited application and are generally only used to power lamps and electromechanical devices where poor regulation is acceptable. They find greater use as front-ends for regulated power supplies or as d.c. power distribution sources in systems where d.c.-to-d.c. point-of-load regulators are employed.

It is only recently that the unregulated supply has been readily available as an off-the-shelf item. *Lambda* has made available, as stock items, a line of power kits containing

components selected for a predesigned power-supply circuit so that a purchaser could build his own d.c. power supply. The kit components vary depending on circuits selected as well as the d.c. voltage and d.c. current required. Major components supplied are transformers, filter chokes, computer-grade electrolytics, silicon rectifiers, and a power hybrid voltage regulator when a regulated output is required.

The Ferroresonant Transformer

The ferroresonant transformer is an effective means of compensating for poor line regulation. The capacitor-input filter supply can be transformed into an improved regulated supply by replacing the linear input transformer with a ferroresonant transformer which provides regulated a.c. to the rectifier-filter section and improves ripple attenuation by squaring the sine wave. Line regulation and ripple waveform change are caused by the resonance set up between a transformer winding and an external a.c. capacitor. See Fig. 2.

The ferroresonant transformer, inherently a current-limiting device, provides automatic protection against overload. Because its major drawback is sensitivity to line frequency changes, it is used only where line-frequency stability is assured. A typical ferroresonant power-supply specification includes: line regulation of 2% for line changes from 105 to 132 volts a.c. or 132 volts a.c. to 105 volts a.c. for any load between 25% and 100% of full load; load regulation of 5% from ½ load to full load; frequency regulation of 2.4% for each cycle change in line frequency; and ripple of 1% r.m.s.

The simple ferroresonant power supply is the most reliable regulated power supply in use today. Prerequisites for its use are: fixed input frequency, small load variations, and a tolerance for slow response to transients. A ferroresonant supply requires many cycles of input frequency to recover from any line transient.

Feedback-Controlled Regulation

The demand for better regulation imposed by today's sophisticated circuits and complex electronics systems is best met by the feedback-controlled power supply. This type of regulated power supply is capable of maintaining a substantially constant output voltage at a selected value, even though changes occur in the a.c. input voltage (within specified limits) and/or in the rated d.c. load current. In addition, these power sources can be made short-circuit-proof, preventing damage to the supply caused by load fault and can be made load-protecting by using overvoltage protectors to prevent load damage caused by internal supply failure. Fig. 3 is a general block diagram of the feedback-controlled regulated power supply.

There are many circuits which can be used to meet the requirements of the feedback-controlled power supply. The approach selected is determined by economics, performance requirements, power output needs, efficiency, and specified input/output voltage levels.

The circuit with the widest application is the linear or series-regulated power supply, which is used most often where output voltages are below 100 volts and power output is below 500 watts. Refer to Fig. 4.

In this example, a.c.-to-d.c. conversion is accomplished by using a full-wave rectifier and a capacitor-input filter circuit. The control element is one power transistor or many transistors in parallel, as required, which absorbs the difference between the desired output voltage and the unregulated d.c. input. Because the series-pass element must handle the full-load current while maintaining relatively high voltage between input and output, it is basically a low-efficiency circuit. But since it is a linear circuit it has the potential for the best general specifications. No other practical circuit has as fast a response, possesses the regulation specifications, as low a ripple, or is as versatile in application as the series-regulated power circuit.

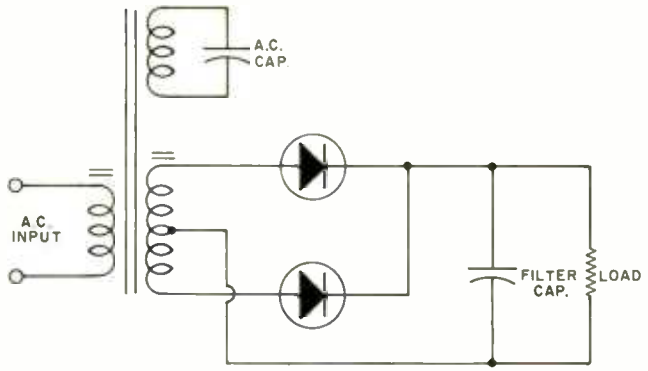


Fig. 2. Ferroresonant transformer power supply.

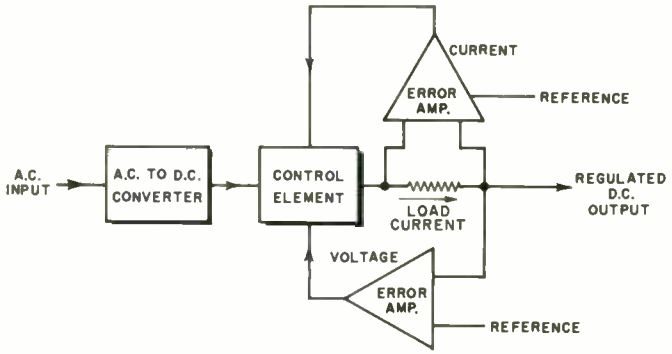


Fig. 3. Regulated power supply using feedback control.

Circuits with higher efficiency are usually obtained by switching techniques (see page 43), a circuit that produces pulses of current when the control element is in a saturated state or when the control element is at cut-off and absorbing maximum voltage and no current flows. The pulse width or repetition rate determines the output voltage and a filter section is required to transform the pulses of energy to d.c. The control element in this type of circuit is usually an SCR (for low-frequency switching, high-power applications) or transistor (medium-power, high-frequency switching). The resultant circuit is a high-efficiency package with poorer regulation, ripple, and transient response than a series regulator but more watts per unit volume and lower cost per watt.

As seen from the preceding categories, the selection of a power supply is a study in economics and specification trade-offs with no single approach having an advantage for all applications. By studying some typical application requirements, a better understanding of power-supply technology and selection can be obtained.

Power-Supply Applications

Laboratory Supplies: The use of supplies for a laboratory can be broken down into two categories, 1. standards and calibration, and 2. experimentation and breadboarding.

When a d.c. power supply is used as a voltage standard or a transfer standard for calibration purposes, its specs must be an order of magnitude better than average laboratory measuring equipment and include a means of setting up output conditions accurately. Almost all lab supplies are series-regulator types because of their superior performance characteristics. By using aged reference elements and high-quality resistors, voltages with accuracies of better than 0.01% can be obtained. By housing temperature-sensitive circuitry in a proportional-control oven within the supply, temperature coefficients better than 0.001%/°C are obtained which virtually eliminate output changes caused by changes in ambient temperature. Circuit design and shielding techniques allow ripple to be below 100 μV peak-to-

peak thereby approaching an almost perfect d.c. signal. The aged components and the oven insure a stability an order of magnitude better than the accuracy. Decade switches can be used to set up output conditions so that resolution down to the microvolt range is obtained. If the calibrator is to be part of an automatic test rack, its output voltage must be capable of being programmed from an external source, such as a resistor network or a digitally coded signal. In the latter case, an accurate digital-to-analog converter is required to transform the digital command into either a programming resistor or analog voltage, depending on the accuracy required. In most applications, this type of supply is programmed by either a resistor or a programming voltage. In all cases, of course, the dynamic voltage standard must not be affected by load conditions or overloads, hence current limiting is a necessity and a line/load regulation specification of 0.0005% is required.

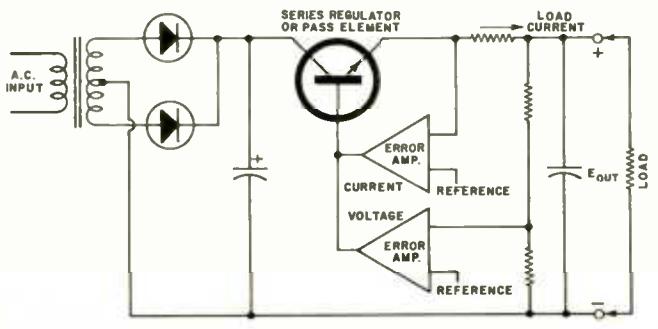
As a general lab tool, the power supply must be versatile, reliable, and rugged. Most lab supplies are capable of constant-voltage operation, constant-current operation, of being remotely programmed by either resistance or voltage, or series or parallel operation with similar supplies for expanded capabilities, and are completely protected against load fault. Voltage regulation for line or load is usually around 0.01% with ripple and noise approximately 1 mV peak-to-peak.

Meters are a "must" on lab supplies so that conditions of experiments can be monitored. Because these supplies are constantly handled, heat sinks should be inaccessible or, if exposed, electrically isolated and thermally cool to the touch. Power supplies, dissipative by nature, must have reliable cooling. For this reason fans should be eliminated in favor of convection cooling because fans and their associated filters represent a weak-link maintenance problem.

System Supplies: The power-supply user, faced with the problem of putting together a complicated electronic system, has a difficult job selecting not only the regulation technique to be used but also the method of power distribution. An electronic system normally needs a number of voltages to power a variety of circuits. Irrespective of the types of power supplies used, power can be distributed using various methods, *e.g.*, 1. individual power modules for each voltage required; 2. a multi-output power supply where all power required for a system is derived from a single package; 3. unregulated d.c. voltage or coarsely regulated voltage distributed to point-of-load regulators where power is regulated at the point of final usage; and 4. a combination of all or some of the above.

Selecting the individual module is an attractive approach because almost any rating is available as a standard product from the power-supply manufacturer. This insures reliability because standard products from a reliable vendor usually have a performance record that can be verified and can be counted on for mechanical stability and production reproducibility. Moreover, the individual module requires simpler maintenance and fewer spare parts provisioning. Most power-supply manufacturers will assemble standard individual modules into a complete system power supply.

Fig. 4. Simplified schematic of the series-regulated power supply.



Multiple-output power supplies, usually less expensive than individual modules when volume production quantities are involved, normally lead to custom design, which has drawbacks. In addition to the initial circuit design phase, power-supply design also includes mechanical packaging design, thermal performance evaluation, and printed-circuit board layout design. Consequently custom design, where quick delivery is required, usually yields poor mechanical and thermal design, with resultant poor reliability. If, however, series regulators are used, power hybrid regulators, with known electrical and thermal properties, can be used to reduce design time. By using a number of hybrid regulators in a standard mechanical package with known thermal properties, packaging design is greatly simplified, the printed-circuit board is eliminated, and more time can be spent on testing to assure greater reliability of the multi-output power supply. Although this approach does not guarantee instant availability, it eliminates many of the disadvantages inherent in the custom-design approach.

When system noise and power-line degeneration results in power distribution problems, the point-of-load regulator is used. In this application a highly efficient power source such as an unregulated supply, a ferroresonant regulator, or a coarsely regulated SCR supply delivers d.c. power to remote sites within the system. Regulation and fine filtering is accomplished at various circuit locations, eliminating crosstalk and noise injection between different sections of the system. The d.c.-to-d.c. type point-of-load regulators can be hybrid, monolithic, or discrete circuits mounted on printed-circuit boards or some other local assemblies where the regulated power is required. Here, again, the hybrid approach has the advantage because it provides the greatest amount of power (up to 5 amps) with a minimum of design time. Present monolithic regulators are not practicable above 200 mA. In most very large electronic systems, it is not uncommon to find combinations of approaches used to satisfy the power distribution needs of the system.

It becomes evident, then, without even raising the question of regulation techniques, that the formidable problems confronting the system designer in the areas of power distribution are staggering. Factors involving economics, availability, maintenance, reliability, and signal conditioning must all be considered and a decision made.

Another factor not previously mentioned is: 3-phase *vs* single-phase power input to reduce copper requirements and power-supply skin temperature and their effects on associated circuitry. Because system power supplies are not accessible from exterior positions, they are normally designed with surface temperatures exceeding 100°C. Judgment must be used in power-supply placement to ensure proper cooling and prevent system circuitry temperature rise.

Data-Processing Equipment: All foregoing problems related to system power supplies are equally applicable to data-processing equipment. Because this type of equipment is commonplace in non-industrial environments, it is increasingly coming under the jurisdiction of *Underwriters' Laboratories.* Thus, it can be assumed that any power supply used in data processing must have or be capable of obtaining *UL* approval.

Modern data-processing equipment, because of its increased use of LSI (Large-Scale Integration), requires large concentrations of power in relation to equipment size. Because digital circuits do not require very finely regulated power sources, high-efficiency regulation techniques can be used. Generally, power supplies in these applications should have a combined performance bandwidth (line, load, ripple, and temperature) of better than 1 or 2%. In some applications, however, ferroresonant power supplies are acceptable, where combined performance bandwidths of better than 10% are compatible with requirements.

Memory Systems: Memory systems are a particular prob-

lem because the preservation of data is of prime importance and a specific requirement. In order to ensure that no data is lost, power supplies must be sequenced "on" and "off" in a prescribed order. In the event of a.c. input power-line failure, d.c. power must be kept available for anywhere from 1 to 20 ms so that the system can permanently store the data before d.c. power is lost. Some means of detecting the loss of prime power must be provided. The same requirement also results in the need for undervoltage and overvoltage sensing circuits so that power-supply malfunction can be detected and the data stored before the power supplies fault to an out-of-limit condition.

In core-memory systems, the power-supply voltage must be varied with ambient temperature to assure proper functioning of the magnetic memory material. This is accomplished by programming the power supply with a thermistor network located at the core memory site.

Analog Circuits: The most widely used analog circuit is the operational amplifier. Its power requirements are normally a plus and a minus voltage of equal magnitude (±12 to 15 volts being the most popular range). In analog circuits the accuracy of the signal being processed is of the utmost importance. In order to keep power-supply fluctuations from affecting signal processing, the plus and minus supplies are made to track each other so that changes caused by one supply are offset by changes caused by the other. Feedback-controlled regulators can easily track each other within 0.2% for all conditions of line, load, and temperature variations. This is satisfactory for most applications.

Since signal-processing accuracy is of primary importance, most analog circuits use power supplies with line and load regulation of no worse than 0.1% and ripple specifications of no more than 5 mA peak-to-peak. To prevent power-supply errors due to distribution wire drops, remote sensing is used. This allows regulations of the d.c. power at some point other than the output terminals of the supply.

Battery Chargers and Back-Up Power: To prevent shutdown of electronic equipment when a.c. prime power is lost, batteries are used as back-up power for a.c.-to-d.c. power supplies. When a.c. power is available, the power supplies charge the batteries and supply load current. When a.c. power is lost, the batteries supply full load current. The power supplies must be electronically current-limited to ensure that proper charging rates are used. With no a.c. power, the supply must be capable of withstanding a voltage at its output terminals without causing internal circuit damage.

If loss of a.c. power is not a prime consideration, a redundant power supply can be used to permit continuing equipment operation in the event of power-supply failure. Power supplies can be made to share the load, each operating at approximately half-load, or if desired, one supply can handle the full load while the other is set to a slightly lower voltage idling at no load. Redundant operation is normally handled by isolating each power supply from the load through a diode. When redundant operation is required, it is best to consult the applications department of the power-supply manufacturer to assure proper power-supply connections.

Protection of Power Supply and Load

Protection devices are used for two main reasons; 1. to protect the power supply from load faults, and 2. to protect the load from power-supply malfunctions. A discussion of commonly used fault protectors follows.

Current Limiting: Power-supply overload beyond current rating limits must always be considered. Overloads caused by either operator error or load failure can result in catastrophic damage to the power supply. Unregulated power supplies can be protected by a fuse or circuit breaker in series with the output. Circuit breakers can be reliably selected to trip at selected current levels. Fuses, on the other hand, must be selected to blow at levels well above the maximum operating current to prevent random fuse failure due to electrical or mechanical fatigue of the element. A 50% to 100% safety factor is normally required of fuses. Conversely, a fuse may last indefinitely at its maximum rating so that a protection level cannot be accurately set or relied upon using this method.

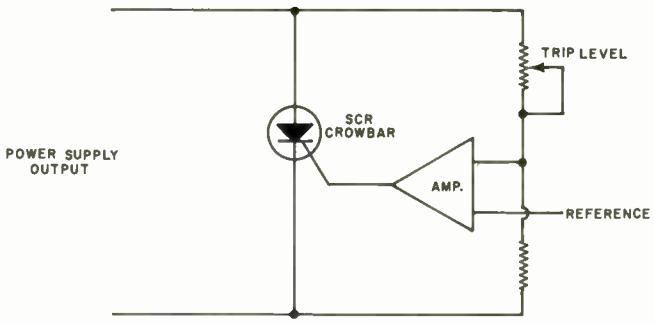


Fig. 5. Functional diagram of an overvoltage protection system.

As mentioned previously, the ferroresonant power supply is inherently current-limiting. Irrespective of load conditions, the output will never develop more than 200% of maximum current rating (maximum fault current will occur at short-circuit).

The feedback-controlled regulated power supply is designed with electronic current limiting which holds the output current to a preset value, thereby providing protection for the load as well as the power supply. Removal of the load fault should result in normal power-supply operation without having to manually reset the supply.

Thermal Protection: Many power supplies are provided with a thermostat which automatically cuts off power when an overtemperature condition is sensed. This type of protection is primarily intended to prevent operation of the supply at load currents or ambient temperatures which exceed the manufacturer's ratings. Thermostats normally take several minutes to reset themselves once the cause of overtemperature is removed.

Overvoltage Protection: Excessive power-supply voltage output can be caused by power-supply malfunction or operator error. In either event, with today's delicate integrated circuits, excessive voltage can cause catastrophic failure. Because the cost of protection is minimal when compared to the cost of the circuitry being powered, overvoltage protection has been adopted as a standard requirement by most power-supply users. The overvoltage-protection circuit should be an independent system, not having to depend on the power supply for anything other than as a source to be monitored. In the event of an overvoltage condition, the protection circuit will "crowbar" (short) the output by means of an SCR before the circuit limit is exceeded. Refer to Fig. 5 for diagram of a simple overvoltage protector.

Undervoltage Detection: As explained previously, an undervoltage condition can cause loss of information in memory systems. Circuits are available which give an alarm should a power supply voltage output drop below the prescribed limit.

A Check List

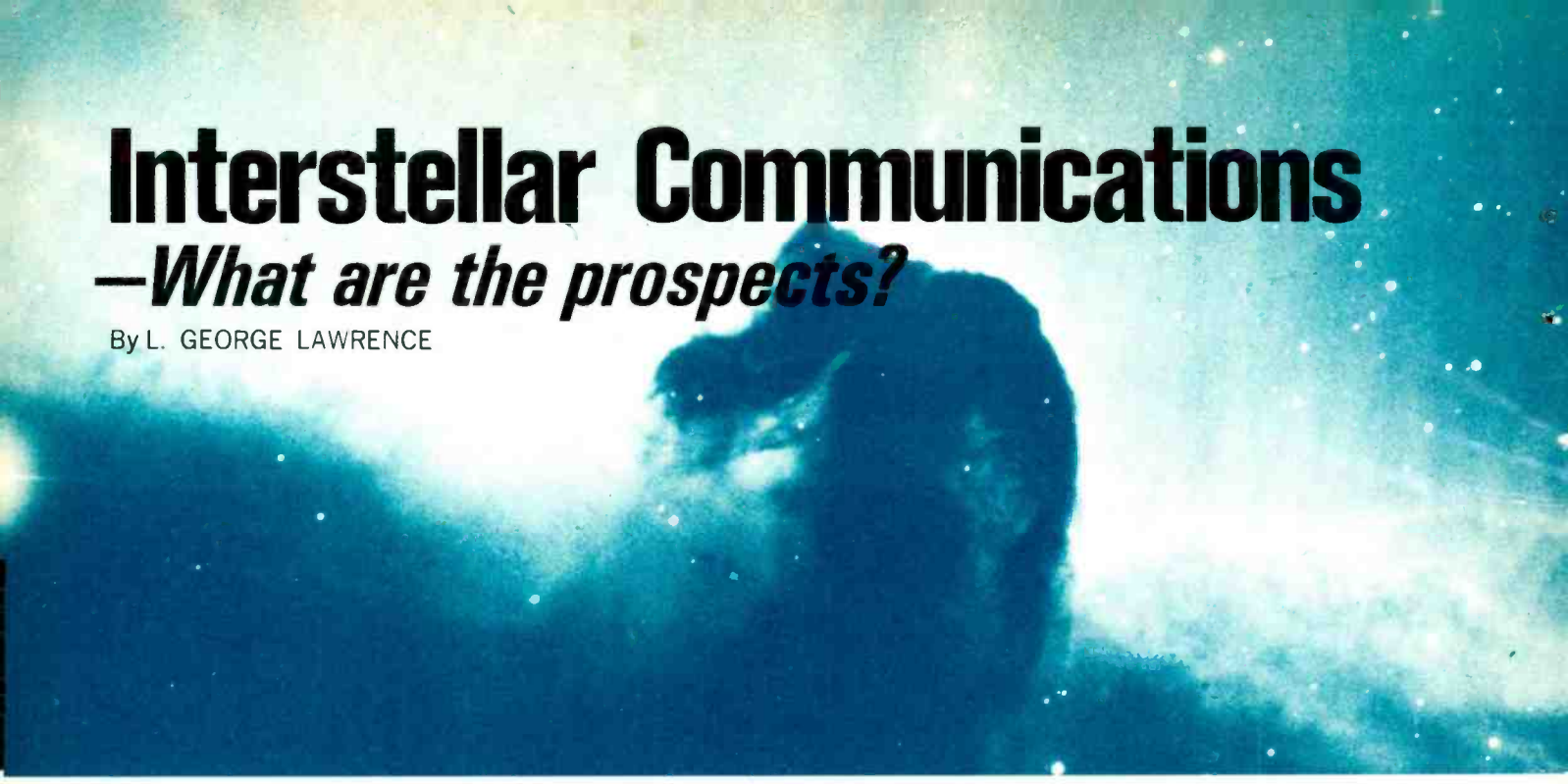
Before selecting a power supply, a careful check-list should be made, which should include the following points:

1. Performance based on minimum circuit requirements
2. Power supply cost *versus* performance
3. Power supply cost *versus* application
4. Requirements for system circuit protection
5. Requirements for power-supply protection

Such an evaluation can only be made if all the inter-related characteristics associated with the product are completely understood by the potential user. ▲

Interstellar Communications —What are the prospects?

By L. GEORGE LAWRENCE



Clouds of interstellar dust and gas in Horseshoe Nebula.

All attempts to pick up intelligent communications from the stars have failed so far. But some scientists are still wondering about intelligent beings on other worlds and our ability to contact them.

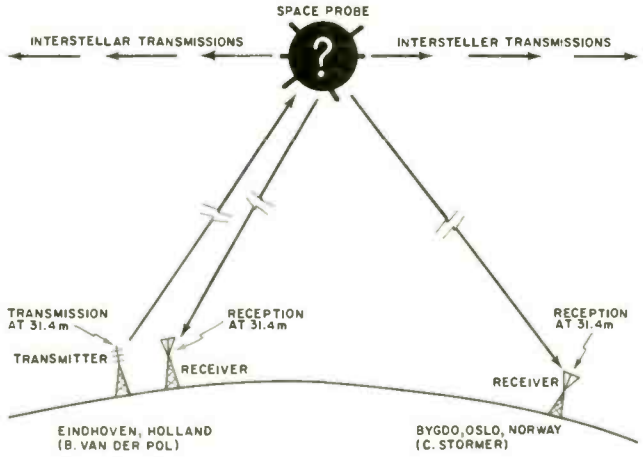
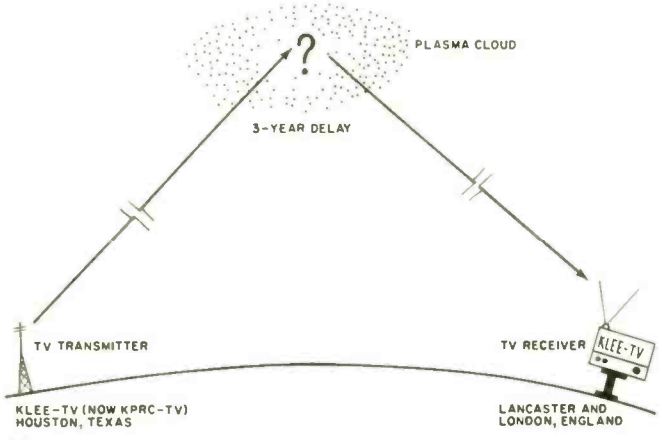


Fig. 1. Mysterious radio echoes were heard as early as 1928. Some though that a space probe may have been responsible.

Fig. 2. Some said that a plasma cloud stored TV signals.



LESS than two decades ago, we still insisted that our small planet was unique in the universe. Today, on the basis of careful celestial observations and other scientific inferences, we admit that we may not be alone in the cosmic immensity and concede the possible existence of extra-terrestrial folk whose scientific development could very well be superior to our own. Some feel that good and direct benefits could be obtained by getting in touch with them.

These speculations have rekindled an interest in interstellar communications technology. Principal attention is directed toward electronic aids because of the limitations of optical devices.

However, we have massive problems here and approaches are not uniform. Some scientists, for example, like to look for any non-Gaussian characteristic in signals received by radio telescopes. Others think that the natural calibration frequency of the universe, the 21-cm hydrogen line which radiates at 1.420 GHz, should be looked at more intensely. Still other investigators have suggested different approaches altogether.

Thoughts on interstellar communications have a long and continuous history. It was the modern world's first philosopher, the Greek scholar Thales of Miletus (636-546 B.C.), who proposed that the stars may be other worlds. But it was his student, Anaximander, who apparently was the first to hint that the number of worlds is infinite, some in the process of birth, some dying.

Later, in our own time, thoughts turned to means of communicating with non-terrestrials. The German mathematician Karl F. Gauss proposed that wide lanes of forest be planted in Siberia, forming a huge right-angled triangle. An Austrian astronomer, J.J. von Littrow, suggested that geometric canals be dug in the Sahara and be lit with kerosene at night. Charles Gros, a Frenchman, conceived the idea of a vast mirror to reflect sunlight toward Mars.

More realistic approaches were suggested following the discovery of radio waves. One of the early pioneers in this

eld, Nikola Tesla, claimed to have received signals of interstellar origin shortly after setting up his electrostatic laboratory in Colorado Springs, Colorado and equipping it with a 200-foot transmission tower.

Edison reported a somewhat similar experience. However, a massive attack, in the form of ridicule and skepticism, was made against both Edison and Tesla which reduced them to silence.

At the same time, some radio observations were made which seemed to imply (as interpreted today) that the Earth is visited by transponding communications satellites of extraterrestrial origin. These so-called "radio mysteries" were first noted in 1927 and expressed themselves as signal delays. The principal investigators attributed the phenomenon to odd behavior of the Aurora Borealis and filed it as a scientific curiosity. We will present the facts, since they form a strong argument for various hypotheses.

The Radio Mysteries

During the summer of 1927, the Norwegian radio engineer Jorgen Hals of Bygdo, Oslo was listening to the Dutch shortwave transmitting station, PCJJ at Eindhoven. At the time he heard the telegraph signals he also heard strange echoes. One was the usual echo which goes around the world with an interval of about 1/7 second, as well as a weaker echo emerging about 3 seconds after the principal echo had disappeared.

This matter was brought to the attention of Prof. Carl Stormer who, in turn, observed the phenomenon himself and then contacted Dr. van der Pol at the *Philips* laboratories in Eindhoven.

On October 11, 1928, van der Pol and his assistant arranged to have the transmitter staff send a series of three short dots in rapid succession, sent every 30 seconds between 8:00 and 9:00 p.m. local time and comprising a total of 120 signals.

Thirteen echoes were observed, the delay times between the echoes and signals being 8, 11, 15, 8, 13, 3, 8, 8, 8, 12, 15, 13, 8, and 8 seconds. The transmissions were conducted at a wavelength of 31.4 meters; the echoes being weak, slightly blurred but plainly audible and, most important, of the same frequency.

This odd phenomenon came and went, rather than existing continuously. The echoes were again observed in 1934 during a series of tests organized by the World Radio Relay League and inaugurated by Sir Edward Appleton. This time the observers were British radio amateurs who worked the frequencies of 9.5 and 6.7 MHz. Similar echoes have also been reported by Drs. Galle, Talon, and Ferrie.

To make a scientific detective story short, it was in the early 1950's when the fact of these echoes was re-examined and that the theory of extraterrestrial-type interference was advanced. Here, as illustrated in Fig. 1, reviewers assumed the intermittent existence of an interstellar communications probe whose job it was to (a) monitor solar systems for intelligent life, and (b) re-transmit radio-frequency emanations from such life (us!) to a distant "home world." Again, the monitoring probe seemed to come and go. In 1947, 1948, and 1949, Drs. Budden and Yates attempted to observe long-delayed echoes at Cambridge, England but without success.

Critics of the interstellar transponder hypothesis became less vocal when another observation was made. This time it involved a television signal that had been delayed for over three years.

At 3:30 p.m. on September 4, 1953, C. W. Bradley of London, England, picked up on his TV set the American call letters KLEE-TV. Later that month, and various times thereafter, the same letters were observed on TV screens at *Atlantic Electronics Ltd.* of Lancaster, England. There is, of course, nothing unique about freakish long-distance TV reception. The strange fact is that this signal had been sent from Houston, Texas three years earlier and had never been transmitted again prior to the time it was received in England. In July, 1950 KLEE-TV became KPRC-TV and no other TV station on this planet has broadcast the call letters KLEE-TV since. (*Of course, there is the possibility that some illegal or amateur broadcaster could have transmitted these call letters.—Editor*)

As shown in Fig. 2, some insisted that the signal was stored, together with scanning information and correct video signals, in a "plasma cloud" which, somehow and for reasons unknown, released this data in a broadcasting mode for all to see, or perhaps it was due to the interstellar transponder postulated above.

Later Experiments

In 1959, the prospect of instellar communications *via* radio was supported by Drs. Cocconi and Morrison, both then at Cornell University. However, because of absorption and scattering of waves by interstellar gas clouds and nebula, plus similar attenuations by atmospheres of planets of interest, the effective range of radio-wavelengths one could use was very limited.

(Continued on page 56)

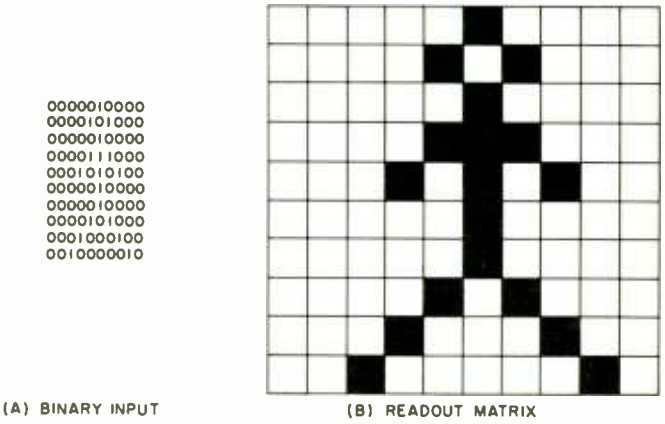


Fig. 3. One guess of possible format of interstellar signals.

The 85-ft radio telescope at the National Radio Observatory, West Virginia, used unsuccessfully for interstellar listening.

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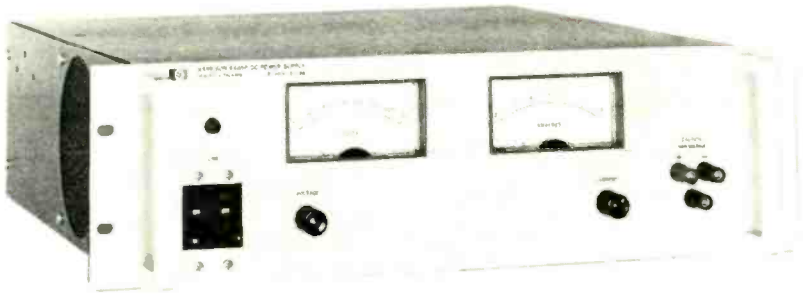


Typical rack-mounted SCR type power supply. The output is 0 to 600 volts and 0 to 1.5 amps.

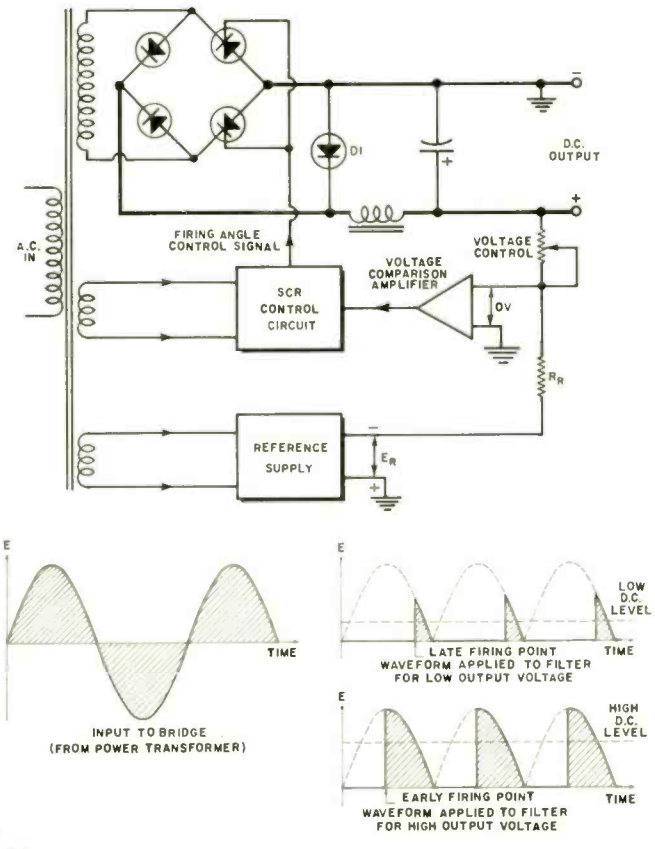
SCR Power Supplies

By GEOFFREY F. WALKER/Hewlett-Packard Co.

SCR supplies are designed for applications requiring large amounts of fixed or slowly varying, moderately well-regulated and moderately ripple-free d.c. power.

THE SCR power supply was developed to supply loads requiring substantial amounts of fixed or slowly varying d.c. power with moderate regulation and ripple. Covering (and dominating) the d.c. output power range between 1 kW and 30 kW, SCR power supplies use silicon controlled rectifiers (thyristors) as their regulating element. SCR's, the semiconductor equivalent of thyratrons, are rectifiers which remain in a non-conductive state, even when forward voltage is provided from anode to cathode, until a positive trigger pulse is applied to a third terminal (the gate). Then the SCR "fires," conducting current with a very low effective resistance; it remains in conduction after the trigger pulse has been removed until the forward anode voltage is removed or reversed.

Fig. 1. A secondary-regulated, constant-voltage SCR power-supply in which the SCR's are included in two arms of the bridge rectifier.



Regulator Operation

There are two basic SCR power-supply circuit configurations: primary regulation and secondary regulation. Fig.1 shows a secondary-regulated, constant-voltage SCR power supply in which the SCR's are included in two arms of the bridge rectifier. By controlling the firing time of the SCR's during each half cycle of input line frequency, the duration of conduction of the bridge rectifier is varied and the d.c. output is controlled in accordance with the setting of the output voltage control.

Diode *D*1 across the bridge output is a "recirculating" or "freewheeling" diode. It discharges the energy stored in the filter choke at the moment the bridge stops conducting by providing an alternate path for the current flowing in the choke. If the diode were not present, the sudden current change in the inductor would produce a large voltage spike in the output.

The voltage-control circuitry shown in Fig. 1 is common to almost all regulated power supplies, irrespective of the regulating method employed. The heart of the circuit is a voltage-comparison amplifier that continuously compares the supply output voltage with the drop across the front-panel voltage control. If these two voltages are not equal, the comparison amplifier produces an error signal that, when applied to the SCR control circuit, adjusts the SCR firing time (and thus changes the current through the load) until the output voltage equals the voltage across the voltage control.

Fig. 2 is a diagram of a primary-regulated, constant-voltage/constant-current SCR power supply. Here the SCR's are connected in shunt opposition and placed in series with

the primary of the power transformer. It is apparent that in this arrangement the SCR's play no role in rectification; instead, the SCR's control the average a.c. level applied to the power transformer. Notice that the transformer primary is not required to sustain the full power-line voltage; with a 115-V, single-phase a.c. input, the highest voltage typically measured across the primary is equivalent to an 80-V r.m.s. sine wave. This results in a substantial saving in size and weight of the power transformer and consequently of the entire power supply.

The constant-current circuitry shown in Fig. 2 operates in much the same manner as the constant-voltage circuitry; a comparison amplifier continuously compares the drop across the front-panel current control with the *IR* drop developed by the load current flowing through the current sampling resistor. If the two voltages are momentarily unequal, the comparison amplifier produces an error signal that, when applied to the SCR control circuit, varies the SCR firing time until the two voltages are again equal. Although constant-current circuitry is shown only in the primary-regulated supply, it can be (and usually is) used in all types of SCR supplies.

Fig. 3 illustrates another type of power supply utilizing SCR's: the series-regulated/SCR-preregulated supply. This circuit uses a series regulator to reduce ripple, absorb transients, and handle rapid, low-magnitude regulation of the output; and an SCR preregulator to handle large, relatively slow regulation demands. The preregulator also minimizes power dissipation in the series regulator by maintaining the voltage drop across it at a low and constant level. Note that in Fig. 3 the primary SCR's have been replaced by a triac (a bi-directional device that can conduct current in either direction, and fires whenever it receives a gating pulse, irrespective of the polarity of the input a.c. applied to it); the use of this device is very common in modern SCR preregulated supplies.

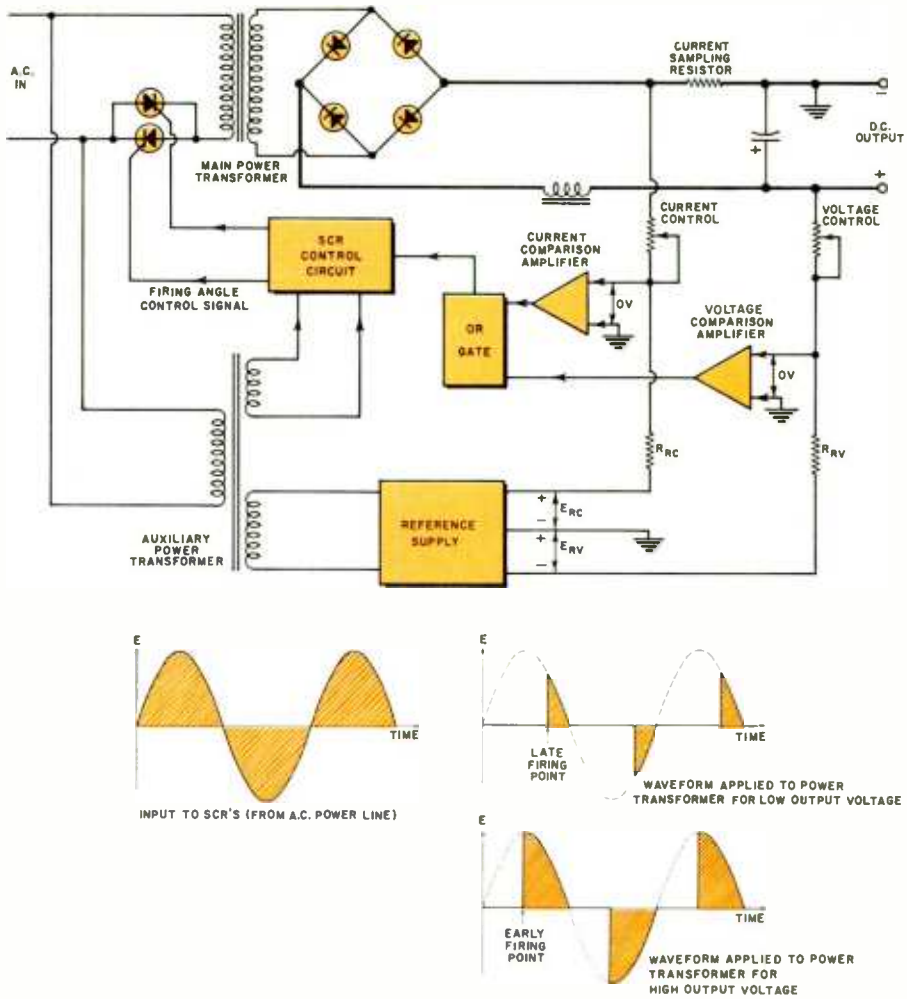
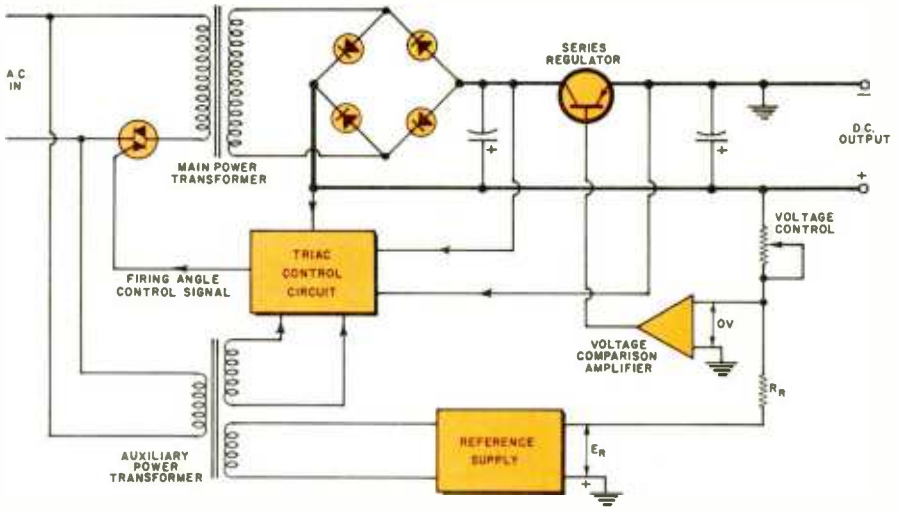


Fig.2. Circuit of a primary-regulated, constant-voltage/constant-current SCR power supply. SCR's are not used for rectification but control a.c. applied to power transformer.

Fig.3. Another type of power supply using SCR's—series-regulated/SCR preregulated.



Performance Specifications

After output voltage and current ratings, the main criteria by which a power supply is selected for a given application are its performance specifications: line and load regulation, ripple and noise, stability, temperature coefficient, and transient response. Specifications for a typical constant-voltage SCR power supply are as follows:

Line and load regulation: 0.05% for a load current change equal to the rating of the supply.

Ripple and noise: 0.5% r.m.s. for a supply without a "ripple reducer" circuit, 0.05% r.m.s. for a supply with a "ripple reducer" circuit, and 3.0% p-p (d.c.-20 MHz) for both supplies.

Stability: 0.2% under constant load, line, and temperature conditions.

Temperature coefficient: 0.05% per degree centigrade change in ambient following a 30-minute warm-up period.

Transient response: 100 ms for recovery to within 0.5 V after a half-to-full or full-to-half load current change.

These are typical values only; manufacturer's specifications for different supplies vary over a moderately wide range. For example, SCR supply load and line regulation is nearly always in the range of 0.01% to 0.5%. (Actually, regulation is usually specified as a percentage term plus a fixed term, because the percentage term alone does not accurately describe the regulation at low outputs. The com-

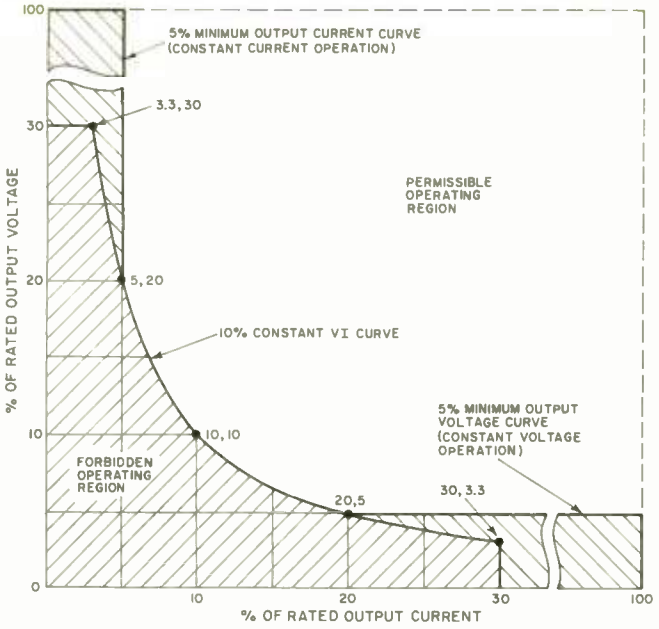


Fig.4. All SCR supplies have output restrictions. Unfortunately, some manufacturers erroneously specify or completely neglect to specify forbidden output operating regions.

bined expression can, of course, be converted to a single percentage term at any given output voltage.)

It is important to realize that the "all in the same ball park" principle applies to power-supply specifications—if load regulation for a given supply is 0.05%, a stability specification of 0.0001% for the same supply is pointless. Thus, while it is possible to greatly improve *some* of the specifications of an SCR supply (such as stability and temperature coefficient), the nature of the basic design limits the overall performance. For example, the transient response is limited because regulation corrections can be made only once every half cycle of the a.c. input; this means that if there is a sudden load change immediately after the SCR has fired, no correction can be made (for a 60-Hz, single-phase supply) until at least 8.3 ms later. Another limiting factor also affecting the response to load transients is the amplifier bandwidth—it must be significantly less than the a.c. line frequency to avoid oscillation (gain crossover, the frequency at which the amplifier gain is unity, is typically 10-15 Hz in SCR supplies).

Ripple and noise is another specification that is limited by the basic nature of the SCR power-supply design. High-frequency ripple (spikes) is a natural by-product of the switching technique employed in an SCR supply; although considerable effort is made to counteract this problem in modern power supplies, the magnitude of the remaining peak-to-peak ripple is sufficient to bar the use of SCR supplies in many applications. The r.m.s. ripple, however, is a different story. It is quite possible to reduce r.m.s. ripple to very low levels either through the use of massive *LC* filters, or through "ripple reducer" circuits. In operation, the latter senses ripple at the output of the supply, amplifies it, and applies it to a control circuit. The control circuit in turn applies an auxiliary a.c. potential to the supply output; this a.c. potential is 180° out-of-phase with the normal ripple voltage, effectively filling in the valleys of the output voltage. However, in applications where moderate load regulation and moderate peak-to-peak ripple is acceptable, very low r.m.s. ripple is usually not required (this is the "all in the same ball park" principle again).

Other Characteristics

Other notable characteristics of SCR supplies include efficiency, reliability, size (watts per cubic inch), value (cost per watt), and functional features.

The switching technique used in SCR supplies results in an efficiency of 80 to 90% at the supply's maximum output rating; as the supply is turned down, the efficiency remains above 50 to 60%. By comparison, series-regulated supplies rarely reach 60% efficiency even at full output, and at lower outputs (where the series regulator must dissipate the unused power), their efficiency drops to 10% or less. Compared with other types of supplies in the same power range (ferroresonant, mag amp, and Variac-preregulated), SCR supplies are still more efficient, although not by as great a margin.

In general, there is an inverse relationship between the number of electronic components in a power supply and its reliability (as the former rises, the latter falls). SCR supplies use more components than ferroresonant or mag amp supplies and fewer components than series-regulated supplies; thus the reliability of SCR supplies falls somewhere between the two.

Present SCR supplies exhibit an increasing power/volume relationship—as the power output goes up, the watts/cubic inch (W/in^3) goes up. Typically, a 1 kW-5 kW SCR supply may offer 0.55 to 0.70 W/in^3, while a 10-kW supply may offer between 0.9 and 1.5 W/in^3. (This is significantly different from the typical 0.08-0.15 W/in^3 figure for series-regulated supplies.) The relationship between power output and price is less distinct; SCR-type power supplies in the 1-10 kW range generally cost between $0.25 and $0.65 per watt.

Modern SCR supplies are very similar to other types of supplies in their functional (operating) features; most supplies include remote-programming and remote-sensing capability, CV/CC operation, front-panel meters and output controls, parallel and series operation, optional over-voltage crowbar, and adjustable loop response. This last feature is particularly necessary due to the unusually wide range of load impedances that may be connected to an SCR supply (storage batteries present from 1 to 10 farads of capacitive load, while cryogenic magnets present from 1 to 10 henrys of inductive load).

Distinctive Operating Characteristics

SCR power supplies exhibit a unique set of "operating peculiarities," again due to the nature of the basic design. These include a minimum output restriction, a sensitivity to line transients and line-to-line voltage imbalance (in three-phase supplies), and large short-circuit energy surges.

All SCR supplies have a minimum output restriction that is determined by the characteristics of the SCR and the particular firing circuit used. At very low outputs, the SCR may skip one or more half-cycles of the a.c. input, degrading the regulation, transient response, stability, and linear programming characteristic. As a result, some manufacturers specify a forbidden-output operating region, such as that shown in Fig. 4. For the particular case shown, the supply will not meet published performance specifications as a constant-voltage source at less than 5% of its rated output voltage, or as a constant-current source at less than 5% of its rated output current. In addition, when the supply is operated at low voltage *and* low current levels, the output power is further restricted to at least 10% of its maximum value.

Line-transient sensitivity, another peculiarity, occurs because an SCR supply has no active element in its power mesh (the SCR is either "on" or "off"—it has no linear mode of operation as does a series transistor). When the SCR is on, any momentary change in the a.c. line voltage is passed through to the output.

In higher-power SCR supplies where three-phase input is used (with three SCR's), a voltage imbalance of only a few percent between input phases can cause a low d.c. level to appear across the power transformer primary; this d.c. volt-

(Continued on page 62)

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Hirsch-Houck Lab Tests

Stereo Headphones

By JULIAN D. HIRSCH

"Noise pollution" is driving many audiophiles to phones in order to get the most from their favorite recordings.

THE growing use of stereo headphones reflects, in a way, one of our major contemporary social problems—"noise pollution." With more people living and working in close proximity, the ordinary sounds of living tend to become obtrusive.

Playing a high-fidelity music system at reasonably high volume is frequently impossible without disturbing the neighbors or one's own family. On the other side of the coin, we have the problem of hearing *pianissimo* musical levels through the *fortissimo* interference of dishwashers, lawnmowers, jet airplanes, and the TV set in the next room.

Stereo headphones provide an attractive solution to both problems, at very reasonable cost, which probably explains why many music lovers are switching to phones—at least for those times when ordinary loudspeaker reproduction is not possible.

Headphones—as we know them in high-fidelity applications—are actually miniature loudspeaker systems, coupled tightly to the ears and usually designed to exclude outside sounds. Headphones have been used since the early days of electrical communications, for many of the same reasons that have been described—to provide efficient transduction of low-power electrical signals to sound, even in the presence of high ambient acoustic noise levels. However, communications headphones (particularly the lower priced types) often resemble telephone receivers in which a flat metal diaphragm is flexed by a varying magnetic field to produce sound. The poor dynamic range, frequency response, and distortion characteristics of such headphones rule them out for high-fidelity applications.

Most stereo headphones are moving-coil dynamic speakers, with cone diameters up to about 3½". The close coupling to the eardrum, through a well-sealed air volume, results in very efficient operation and extremely high sound-pressure levels can be generated with a small fraction of a watt of electrical power. The low-frequency response is controlled to a great degree by the tightness of the acoustic seal around the ear and many headphones are capable of reproducing the lowest audible frequencies just as well as many of the best loudspeakers in an ideal listening room. However, no headphone produces the sense of physical pressure on the skin that can be generated by a speaker system with true low bass response.

The over-all frequency-response smoothness of any electro-acoustic transducer is strongly influenced by its acoustic environment. In the case of loudspeakers, this is principally the listening room and its furnishings; with headphones it is the ear cavity which loads the moving cone. Standing waves are set up in the ear cavity at various frequencies, much as they occur in a room with loudspeakers, except that they affect the higher frequencies rather than the low end of the spectrum. Since there is little that one can do to modify his ear dimensions (unlike the choice of acoustic treatment possible in a room), the headphone manufacturer must either design his product for optimum performance with a hypothetical "average" ear or to be relatively unaffected by individual variations (or both).

Problems in Testing Headphones

Objective frequency-response measurements of headphones are both easy and difficult to make. Easy, because simply clamping the earpiece to a standard coupler, or "artificial ear," provides a controlled acoustic environment independent of the surrounding room, and difficult because the results obtained from such measurements often bear little relationship to how the headphones sound.

The standard coupler for headphone measurements is specified by the American Standards Association, together with other test conditions for making measurements of various types of headphones. Most headphone manufacturers are understandably reluctant to use data from such measurements in their specifications, since above a few kHz the response smoothness is highly erratic. The ASA acknowledges this deficiency (the coupler was originally designed for testing communications headsets with a limited frequency range), and there the matter stands. One manufacturer (*Koss*) has developed a modified coupler which it claims yields results more consistent with subjective performance, but others apparently remain skeptical.

Other parameters of headphone performance include the maximum sound-pressure level (SPL) that can be developed without exceeding a specified distortion, the sensitivity (amount of electrical power for a given SPL), the electrical impedance as a function of frequency, and the acoustic isolation of the ear seal (how effectively it attenuates outside noises).

Our aim in this survey was to evaluate and compare a representative group of some 30 stereo headphones, from

(Left) David Clark stereo headphones, one of the three models tested. (Right) Fisher's new HP-70, a moderately priced headphone with a frequency range of 30 to 18,000 Hz.

12 manufacturers, using both subjective and objective criteria. In view of the unsatisfactory situation with respect to test standards (insofar as high-fidelity phones are concerned), we created our own highly unofficial standards. Our evaluation was mostly comparative and we gave considerable weight to listening tests. In the absence of a criterion for "ideal" headphone sound (such as the "live *vs* recorded" comparison we use for loudspeakers), we had to depend on our personal judgment in many cases. When considering such factors as smoothness of frequency response and transient response with tone-burst signals, we applied the same standards which we would have used for loudspeakers, making due allowance for the effects of our coupler where these could be identified.

How We Tested

Our coupler was simply a piece of ¾" plywood drilled to hold our calibrated microphone flush with its surface. The earpiece was pressed firmly against the coupler, centered over the microphone. Each phone was driven from a power amplifier at a constant level of 300 millivolts (except for a couple of relatively insensitive units which were tested with 3 volts of drive). Our *General Radio* 1304 frequency-response plotter supplied the sweeping test signal from 20 Hz to 20 kHz, and recorded the output of the microphone on a synchronously moving chart.

Each phone was also tested at 400 Hz, where we measured the level and distortion of the microphone output and adjusted the drive until we obtained 1% distortion. The absolute calibration of our microphone gave us a rough idea of the actual SPL that would exist at a listener's ear. The sensitivity of the phone was determined by subtracting from this SPL the electrical drive in dBm (0 dBm = 1 milliwatt). The result was the SPL in dB that would be developed by a 1-milliwatt drive level. The driving power was computed from the relationship $P = E^2/R$, where R was the measured impedance of the earphone at 400 Hz (and for our purposes was assumed to be resistive).

Impedance was measured by driving each phone through a series resistance from our sweep oscillator and recording the voltage drop across the phone on the chart recorder. By substituting an accurately known resistance for the headphones, we calibrated our chart.

Acoustic isolation was measured by placing a small loudspeaker about 8 inches from the microphone in our coupler and driving it with white noise. The change in output level when the earpiece was pressed firmly over the microphone was an indication of the effectiveness of its ear seal.

We also tested each headphone with tone-burst signals, as we would with a loudspeaker. The frequencies at which ringing became serious, and the degree of such ringing, were carefully noted in each case.

Interpreting Test Data

Our test results are presented in tabular form. Since our numerical measurements of SPL and sensitivity would be difficult to interpret in a meaningful way, we have translated them into letter ratings. For most headphone users, this is merely background information, since even a "D" output-level rating corresponds to a more-than-comfortably loud listening level. Most of the phones, carrying a "B" rating, developed about 115 dB SPL at 1% distortion, which is *very* loud. The one rated "A+" (*Fisher* HP-70) was the only headphone that exceeded the threshold of pain, developing a deafening 136-dB volume without exceeding 1% distortion (our ears gave up well below that point). This might be of interest to hard-of-hearing listeners, but hardly to most headphone users.

Similarly, with sensitivity the rating is primarily for general information. Any of the phones could be driven beyond their limits of distortion from virtually any amplifier output, so that this is not comparable in importance to loudspeaker efficiency. However, if you want to use one of these phones with a low-power source such as a transistor radio or a preamplifier with low-impedance voltage outputs, it would probably be advisable to avoid a "C" rated phone.

The impedance of a headphone can be an important consideration if you plan to use it for monitoring with a tape recorder. Many recorders have outputs for 600-ohm phones and will not develop sufficient volume with low-impedance types. Any of the headphones with impedances of 250 ohms or higher should be suitable for this application. If the phones are to be driven from an amplifier or receiver, the impedance is not a significant factor. It could be anywhere from 8 to 600 ohms or even higher.

Acoustic isolation may or may not be important to you. If the ambient noise level is high, it should be considered seriously. From a subjective standpoint, the headphones with more than 18 dB of measured isolation (in our tests) were much more effective in eliminating room noises than the lower rated types. The three top *Sharpe* models were especially noteworthy in this respect. On the other hand, the *Fisher* HP-100 and *Sennheiser* HD-414 had virtually no isolation.

Many phones showed a severely degraded tone-burst response above 2 or 3 kHz. We classified them as "P" (poor), since a loudspeaker with this characteristic would indeed be a poor one. However, it must be admitted that every one of the "P" phones sounded much better than one would expect from their tone-burst responses. In other words, a "P" rating means poor tone-burst response under our test conditions, and not necessarily a poor headphone.

At the other end of the rating scale, the *Koss* electrostatic headphones had essentially perfect tone-burst response (better than any speaker we have ever tested), and the *Fisher* HP-100, *Sennheiser* HD-414, and *AKG* K-180 were very nearly as good. All of them sounded excellent, and the "E" rating unequivocally applies to the headphone as well as to its tone-burst response.

One of the more arbitrary decisions we had to make was the rating of frequency-response smoothness. As we pointed out, even the standard ASA coupler can be expected to give a very irregular response curve, and we could hardly expect better from our home-made coupler. However, some of the headphones had truly excellent frequency response in our coupler, even when judged by the standards

we would apply to loudspeakers. The *Koss* electrostatic phones produced curves which were, over most of their range, within 3 dB of the individually run curve supplied with the headphones. The *Fisher* HP-100 and *Sennheiser* HD-414 also had exceptionally smooth frequency response. All of these phones ranked very high in subjective listening tests and gave us renewed confidence in our test set-up.

However, most of the others exhibited the expected irregularities, and we rated them from "Poor" to "Good" in relation to their standing within the test group. In this case, too, a "P" rating means a response which is more irregular in our coupler than other phones in the group, rather than

DIRECTORY OF STEREO HEADPHONES

Make & Model	Output Level at 1% THD	Sensitivity	Z (ohms at 1 kHz)	Tone Burst	Isolation (dB)	Response Smoothness	Wt. (oz)	Cord [1] (ft)	Price ($)
AKG K-60	B	A–	700	P	15	P	9	6S	39.50
K-180	B	B	700	GE	19	G	19	7C	69.00
Clark 300	B	B+	10	P	16	P	13	9C	21.00
200	B	A–	9	P	21.5	P	15	9C	29.00
100A	C	C+	20	F	16	FG	16	9C	50.00
Fisher HP-70	A	A+	12	P	14	P	12	10C	29.95
HP-100	C	C	65	GE	2.5	E	9	8S	39.95
Foster RDF-224	B	B	19	P	11.5	F	11.5	8C	24.95
Koss SP3XC	B	A	4.8	P	16	P	16	10C	19.95
K-6	B	B	4.8	P	17	F	16	10C	26.50
K-6LC	B	B	90	P	20.5	F	17	10C	29.95
KRD-711	B	C	280	F	16	G	14	10C	29.95
KO-727B	B	B+	4.7	P	12	P	17	10C	34.95
Pro-4AA	C	C+	18	FG	16.5	G	20	10C	60.00
ESP-6	C	C	70	E	15.5	E	32	10C	95.00
ESP-9	D	C	40	E	16	E	21.5	5S*	150.00
Pioneer SE-30	B	B+	11	F	18	F	15	8.2S	29.95
SE-50	B	C+	11	P	15	F	21.5	16C	49.95
PML D-42	B	A	250	F	12.5	FG	7.5	6.5S#	29.95
Sennheiser HD-414	C+	A	2200	GE	0.5	E	6.5	10S	33.95
Sharpe 7	C	C+	19	P	13	F	12	12C	19.95
9B	B	A	9	P	17	P	16	12C	25.95
10A	C	C+	10	FG	23	G	17	6S	35.95
MK II	C	C+	15	FG	22	FG	18	12C	45.00
660	D	C	450	G	25.5	G	19	12C	65.00
Superex SW-2	C	B+	9	FG	13	G	15.5	10C	24.95
SST	D+	B	15	F	16	F	20	15C	39.95
ST-Pro-BV	D	B+	20	FG	20	F	17.5	10C	59.95
Sylvania SP20	C	C+	22	P	13	F	11	12C	19.95
Telex Studio 2	D	C	28	P	14	F	24	25C	84.95

RATINGS: Output Level—A=high, B=average, C=below average, D=low; Sensitivity—A=high, B=average, C=low; Tone Burst/Smoothness—E=excellent, G=good, F=fair, P=poor

*Notes: Listed weight does not include the cord. *Separate power unit has a 6-foot cable. # No plug supplied. (1) C=coiled, S=straight. Phones are listed in alphabetical order by manufacturer, within each company's line, the listing is in order of increasing price.*

(Left) Sylvania's SP20 lightweight phones. (Right) Telex "Studio 1", which was not tested, is similar to the "Studio 2" but features tone/level controls at each earpiece.

a "poor" phone (although at some point which we do not feel able to define, it must also correspond to a really poor quality headphone).

Comments on Listening Tests

All the headphones were judged able to deliver a more-than-adequate sound level, with acceptable distortion, when used with any amplifier or receiver of moderate quality.

Those ranking "FG" or "G" in smoothness generally had an "easier," more open sound, with noticeably better high-frequency content. The clarity of these phones with a tone-burst rating of "F" or better was also in general noticeably superior to that of the "P" rated models.

As with loudspeakers, individual preference must play a large role in the selection of headphones. The sonic differences may not be easy to detect without a direct side-by-side comparison. Much easier to evaluate (and probably more important for most people in the long run) are the weight and general comfort of the phones and the effectiveness of the ear seals. It is obvious that a light phone will be more comfortable to wear for extended periods. The major sacrifice one must make for light weight is reduced acoustic isolation. The *Fisher* HP-100 and *Sennheiser* HD-414, two of the lightest and best sounding dynamic phones, have almost no isolation, but (to us) were exceptionally comfortable to wear.

Frankly, we usually would find little positive correlation between price and performance in any one manufacturer's line. The top-priced phone was always better than the least expensive one, but between these limits the units seemed to vary more in features (individual volume and/or tone controls in each earpiece, different headband designs, etc.) than in sound. Buying headphones is much like buying clothing—they should be "tried on" to avoid disappointment.

Special mention should be made of the two electrostatic phones we tested—the *Koss* ESP-6 and ESP-9. They are expensive, and (in the case of the ESP-6) almost inordinately heavy. They must be driven from the amplifier's speaker outputs (not the usual headphone-output jack). They require more drive voltage and will not play as loud as many of the dynamic phones. The ESP-9, besides its $150 price tag, uses an auxiliary power supply, with only a 5-foot cable between the phones and the supply.

For all of this inconvenience and cost, one gets what is unquestionably the best sound in the group. Indeed, the electrostatic phones are in a class by themselves, surpassing speakers as well as other headphones in transparency and smoothness. We heard an occasional rather disconcerting "pop" in our ears when seating the phones and sometimes when listening at rather high levels, which may have been related to the construction of the phones, but apparently did no permanent harm.

In the following section, some of the differences between the various products of each manufacturer will be described. The listing is in alphabetical order by manufacturer.

AKG: The K-60 is a lightweight phone with a 700-ohm impedance and an unusually short cord (6 feet, straight). The K-180 is totally different in appearance and has a unique in-out adjustment of the drivers relative to the ear. This modifies the upper mid-range response, shifting the listener's apparent position from the front to the rear of the auditorium (it seemed to work quite well, although we found the "front" setting more satisfactory).

David Clark: The 300, 200, and 100A have the same general sound character, with the top-priced 100A showing notably improved frequency response.

Fisher: The HP-70 is distinguished by its extraordinarily high sensitivity and undistorted output capability. The HP-100 is completely different in design, very light, and fitted with comfortable foam cushions. It has no acoustic isolation, but delivers exceptional sound quality.

Foster RDF-224: These lightweight phones, imported from Japan by *Ercona*, have good sound for their price.

Koss: The various models differ widely in external appearance and headband design. The K-6 and K-6LC are similar, except that the latter has individual level controls in the earpieces (and a much higher electrical impedance). The KRD-711 ("Red Devil") is a bright red phone with a molded plastic headband, lighter than the others, and had very good sound quality in its price range. The Pro-4AA is the top of the line in dynamic phones, apparently different internally as well as externally from the other *Koss* phones, and was one of the better phones in the tested group. The electrostatic ESP-6 and ESP-9 have been described.

Pioneer: The SE-30 and SE-50 are quite similar in appearance. The most obvious difference is in the better acoustic isolation of the SE-50, and its 16-foot coil cord which allows the wearer considerable movement.

PML D-42: This Swedish import is marketed by *Ercona*. It is a very light-weight phone with above-average sound quality and somewhat less acoustic isolation than most. It is supplied without a plug on its 6½-foot cord.

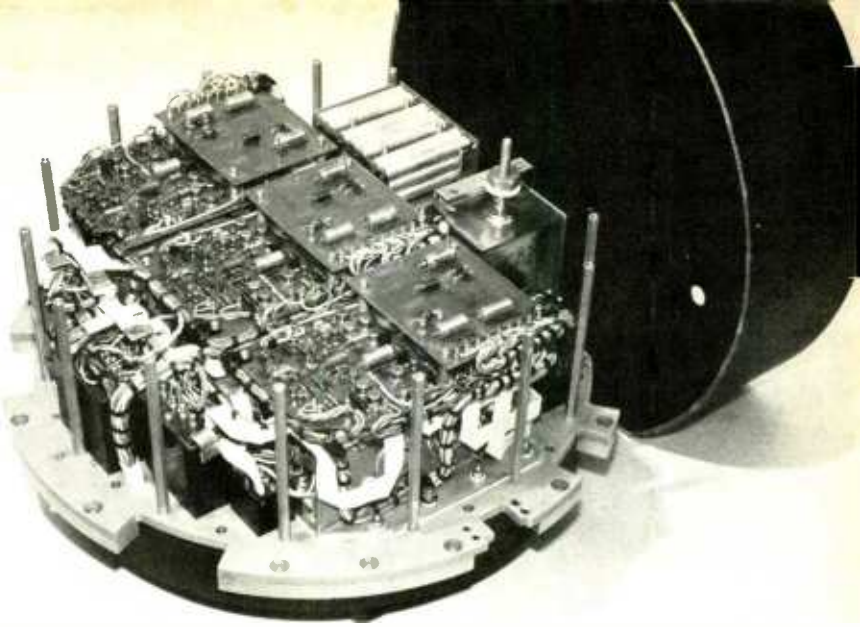
Sennheiser HD-414: These were the lightest phones in the group, with acoustically transparent ear pads. Their 2200-ohm impedance is unusually high, but high sensitivity makes them easy to drive from any low-impedance source. Together with the *Fisher* HP-100 (which is similar in design), they provided the best sound of any dynamic phones.

Sharpe: The 7 is a lightweight headset. The 9B, 10A, MkII, and 660 are successively heavier, have better isolation and listening quality, and cost more. The latter three, in particular, have considerably better isolation than any of the other phones tested. In the case of the top-priced 660, this is combined with better-than-average audio quality.

Superex: The SW-2 delivers better-than-average sound quality for its price. The SST has a separate ceramic tweeter in each earpiece, as well as individual volume and high-frequency adjustments for each ear. The ST-Pro-BV also has a "two-way" design, but lacks the level adjustments.

Sylvania SP-20: Appeared to be identical to *Sharpe* 7.

Telex Studio 2: This was one of the heaviest as well as the most expensive of the dynamic phones. Its 25-foot coil cord is the longest of the group. The Studio 1, not tested, is similar but has tone and level controls at each earpiece. ▲



Bottom view of multi-output torpedo-borne power supply for MK27 Torpedo Target Vehicle. Output power is 1.6 kW pulsed to 3.5 kW. Efficiency is 80% and input power is 33 to 70 volts d.c. The temperature range for this underseas unit is 28 to 160 degrees F. Switching regulators are used for high-efficiency regulation on this unit with five d.c. outputs and one 115-V a.c., 400-Hz output.

The Switching Regulator POWER SUPPLY

Although more costly, the switching regulator power supply is lighter in weight and dissipates less heat than a conventional series-pass type of supply. Frequency range is 7-25 kHz.

By FRED HEATH
Applications Engineer, Trio Laboratories

BECAUSE of new advances in high-speed and high-power transistors, the switching regulator power supply has come of age and is now starting to become competitive in many areas where it was unheard of previously.

Generally, the term "switching regulator" is applied to any type of power-control device which regulates by alternately opening and closing some sort of switch. This switch is usually a transistor or an SCR, and control can sometimes be augmented by using a magnetic amplifier (mag amp). For the purpose of this discussion, only the transistor switching regulator will be considered, although mention will be made of both the SCR and the mag amp when pertinent.

The Switching Regulator

Basically, there are just two types of switching regulators: the series or buck regulator and the shunt or boost regulator. Fig. 1 shows both schemes. The series regulator allows current to flow to the *LC* filter when the switching transistor is "on" When the transistor is "off," the inductor keeps current flowing, with the flyback diode providing a return path. The output voltage is $E_o = E_{in}(T_{on}/T_{off} + T_{on})$; thus the output voltage is always less than the input voltage.

The shunt or boost regulator, on the other hand, has an output voltage which is higher than the input voltage. When the shunt transistor turns "on," the inductor prevents a step current load on the capacitor and the current through the transistor becomes a ramp function. When the transistor turns "off," the inductor prevents current from changing instantaneously and thus the current will flow into the capacitor and the load.

Switching feedback is accomplished by one of three methods. The first consists of keeping the frequency constant and varying the pulse width as a function of the output voltage. The second involves keeping the pulse width constant while varying the frequency (such as with a monostable multivibrator or one-shot). With the third method both frequency and pulse width are allowed to vary as a function of output by using a Schmitt-trigger-type device. When using the third method the driver of Fig. 1 will be a Schmitt trigger controlled by the feedback circuit.

The Inverter

Because of the need for input-output isolation, an inverter is usually used in a switching regulator-type supply. An inverter is a device which changes d.c. to a.c. In most pieces of equipment the inverter does this by alternately connecting the input d.c. to one side of a transformer primary and then to the other (as shown in Fig. 2). The switches, *S1* and *S2*, can either be transistors or SCR's. The output is a square wave which can either be rectified and filtered to provide a d.c. output or simply filtered to provide an a.c. output. A device which adds rectification and filtering on the output of an inverter to make the output d.c. is called a converter.

Mag amps are sometimes used in series with the inverter switches to regulate current to the inverter transformer. The control winding of the mag amp provides the feedback

from the output. Using this scheme, a switching regulator, as such, is not necessary. A few years ago this technique was quite popular. Today, however, the cost of building a complex magnetic amplifier *vs* buying switching transistors makes the former choice uneconomical unless the ultimate purpose of the inverter is to provide a low-frequency a.c. output.

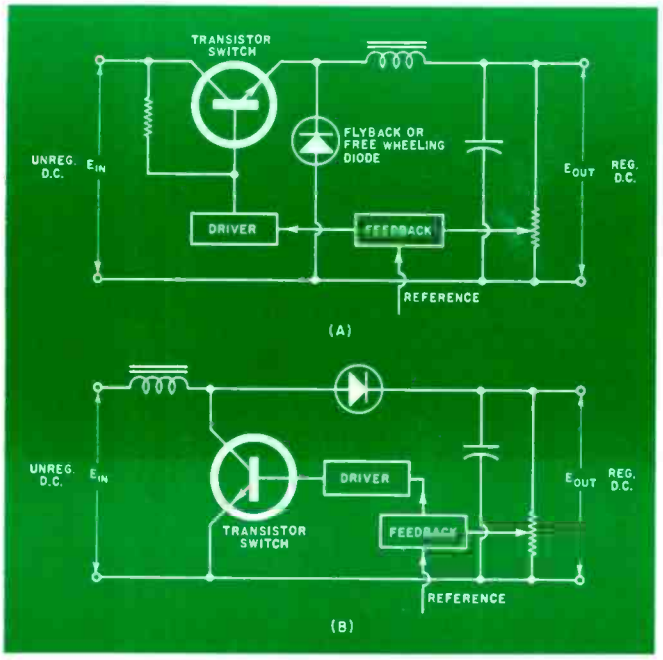


Fig. 1. There are two types of switching regulators (A) series or buck regulator, and (B) the shunt or boost regulator.

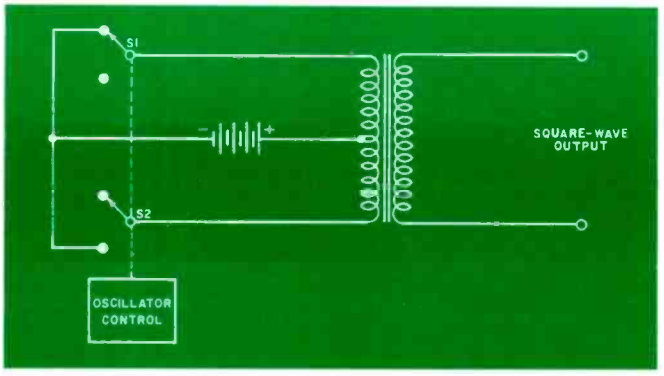
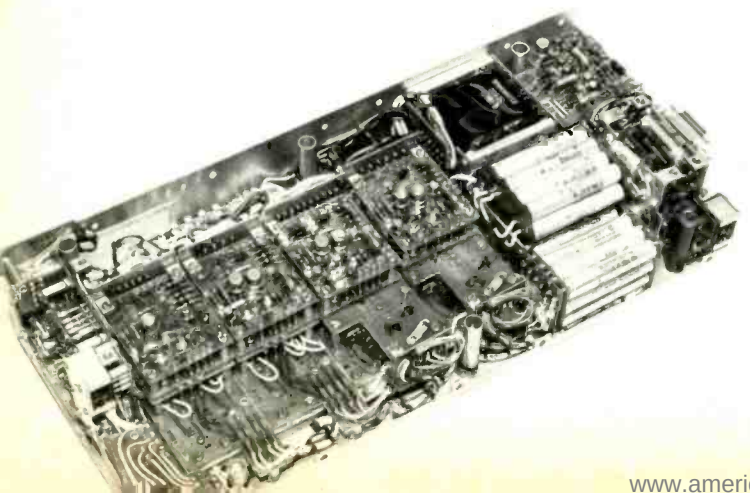


Fig. 2. Basic configuration of inverter circuit which changes d.c. to a.c. by alternately connecting d.c. to one side of a transformer primary and then connects it to the other side.

This supply designed for the F-111 has eight outputs with 150 watts delivered power in the temperature range of −54 to +95 degrees C. Built using many connectors, this supply has no board-to-board hand wiring and can be completely disassembled at PC card level in less than 20 min with screwdriver.



Oscillation control for the inverter can be supplied by one of a number of approaches. The simplest method is to have a separate oscillator which provides base drive for the inverter transistors. Another approach is to have a winding from the inverter transformer itself provide the base drive for the transistors. However, using this approach necessitates having some sort of start-up circuit to get the inverter cycling upon application of input power. Recently various schemes have been used in which the inverter transistors themselves are part of a built-in oscillator. Capacitance bridges or small timing transformers (or both) are designed to form a self-oscillating astable-multivibrator-type circuit with the inverter transistors.

If an inverter is being used with a switching regulator, the frequency at which the inverter is working is generally the same frequency at which the switching regulator will operate. This improves over-all power-supply stability and eases filtering for both the input and output lines. Using a common frequency, of course, implies that the switching regulator can provide regulation only *via* a pulse-width control approach.

The Power Supply

Many combinations of switching regulators and inverters can be and are used in the design of the complete power supply. A few of the possible combinations are shown in the block diagrams of Fig. 3. Fig. 3A is of a switching regulator power supply which regulates for line variation directly and for load changes *via* a feedback loop from the main (or only, as the case may be) output. Feedback is generally transmitted using some sort of chopper amplifier to maintain isolation. A series-pass regulator can be used (as shown) for low-power outputs and, because line regulation has already been taken care of, the efficiency is better than it would normally be for a pass regulator.

Fig. 3B shows the raw d.c. going directly into the inverter with regulation finally achieved just before the output by a switching regulator. This scheme allows quicker response to load steps. A series-pass regulator can, of course, be used at the output of the inverter, but since there is no line regulation, efficiency of this regulator will typically be low.

Fig. 3C shows separate switching regulators for line and load regulation. This allows faster response to load steps, with better over-all regulation, but with decreased efficiency. A series regulator hung off of the inverter in this approach will work very efficiently because it will see an input that has been regulated only for line variations.

Frequency

One of the principal advantages of a switching regulator supply is light weight and small size for a given delivered output. Much of the benefit is derived from the frequency at which the inverter operates. Most switching supplies work with frequencies in the 7-25 kHz range. Since a transformer's size is highly dependent on the frequency at which it operates, a 60 or 400 Hz transformer used for isolation in a series-pass supply will be much larger and heavier than a high-frequency inverter transformer.

Lower limits on the inverter frequency are determined by two criteria: (1) the size and weight—obviously, if the frequency is too low the main reasons for using a switching regulator are negated; (2) audible noise—below about 12 kHz a switching regulator power supply can produce a high-pitched noise which is objectionable in many applications. For this reason many switching regulator manufacturers prefer to use switching frequencies above the audible range. However, with proper design of magnetic cores and sound packaging techniques, many high-power switching regulator supplies which use frequencies in the audible range are not, in fact, audible at all.

The upper limits on switching frequencies are determined by core losses. At frequencies above 20 kHz, effi-

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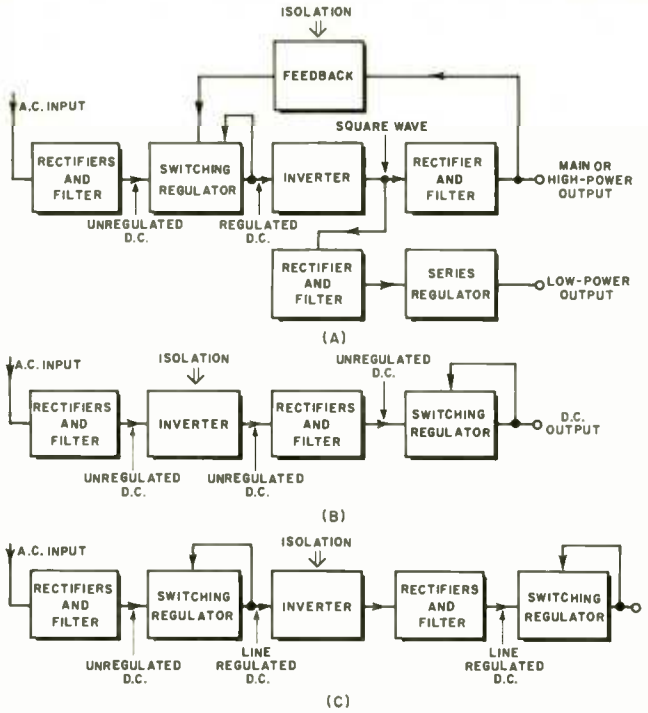


Fig. 3. Several combinations of switching regulators and inverters. (A) Regulator for line variations and for load changes; (B) Raw d.c. goes directly to inverter with regulation achieved near the output; (C) Separate switching regulators for regulation of line and load.

ciencies start to drop drastically and cooling becomes a problem if thermal runaway or the eventual degradation of the magnetic components is to be prevented.

Efficiency

Because in the basic buck (series) switching regulator scheme the transistor is used as a switch which is either full "on" or full "off," very little power is dissipated in the circuit. In the boost (shunt) switching regulator, because the transistor goes "on" more slowly, losses are somewhat greater. Efficiencies of a typical switching regulator power supply range from about 65 to 75% for a 5-volt output to about 85 to 90% for a 28-volt or higher output.

Greater efficiencies are important for a number of reasons. In airborne or shipboard applications where power is sometimes at a premium, a series-pass supply will generally dissipate more power than it delivers, while a switching supply will deliver at least twice what it dissipates. This means that a switching supply will reduce the heat given off by a complete system by more than one-third. This could easily mean that thermal problems will be reduced and reliability of the system (not just the power supply) will be increased. Because the switching supply itself doesn't dissipate much heat, heat sinks and other thermal conducting surfaces won't have to be quite so large, suggesting still further economies of volume and weight over series pass supplies.

Trade-offs of switching frequencies and efficiencies sometimes mean that although a higher frequency will reduce magnetic component sizes, the decrease in efficiency will necessitate larger heat-removal surfaces with no net decrease in the volume of the power supply.

Drop-Out

Since the input a.c. is rectified and filtered directly, storage of the raw d.c. is at a much higher voltage (165 volts). Since it takes a longer time to discharge the filter capacitors, a momentary decrease or drop-out of the input line will not cause a like drop in the output voltage. A typical switching regulator power supply will operate for 30 milliseconds (fully loaded) to 60 milliseconds (half load) after a.c. power has been removed. This is especially important in computer applications where power must be removed from the memory before the logic starts to shut down. The input line can be sensed as low and the memory voltage can be crow-barred long before other voltages in the system go out of regulation.

Electromagnetic Interference

To many engineers the "switching regulator" is associated with electrical noise headaches. In the past this feeling may not have been completely unjustified. SCR switching regulators or inverters were used extensively and suppression of SCR switching noise is a difficult task at best. However, because of the many new high-power transistors introduced in the past couple of years, SCR's need not be used except when power requirements reach about 1000 watts. Shown on the front cover is an off-the-shelf 500-watt (5-volt, 100-amp) transistor switching regulator supply. This supply could not have been built a year and a half ago, using transistors which were available at that time.

Aside from using transistors as the switching elements, many other techniques evolved which have been used successfully for years in military applications. Here, size and weight have made the switcher a "must", but EMI considerations are still critical. Some of these techniques include inverter oscillators using capacitive bridges which reduce switching spikes as they are produced, use of the boost (shunt) switching regulator which insures continuous current through the filter choke, careful wiring and printed-circuit card layouts, and proper shielding of magnetic components and the unit itself.

Conducted interference on the input lines seems to cause the worst EMI problems. In a recent test, conducted for the U.S. Navy, using a simple rectifier circuit with a purely resistive load, it was shown that the rectifiers themselves caused an out-of-specification (MIL-STD-461) condition on the input lines at frequencies up to 5 MHz. This means that the rectifiers themselves turning on and off are responsible for much of the conducted noise. This source of noise is present whether an off-the-line switcher is employed or a series-pass supply is used, with the rectifier switching reflected through the input transformer. Proper input filtering is needed in any case. Because an off-the-line switching supply can more easily handle the input attenuation of such a filter, filtering for input-line-conducted interference is actually simpler to obtain in a switching supply.

The switching regulator doesn't do quite as good a job on containing output ripple and noise as a series-pass supply. The switching regulator supply can generally be designed to have a maximum of 5 to 10 millivolts r.m.s. ripple and noise while the series-pass can get below 1 mV with no difficulty. For most applications, however, it makes no difference if the noise is 1 mV, 10 mV, or even 100 mV. Some logic designers will need the small size and weight of a switching supply, but will specify 1 mV of ripple and noise because that's what they saw on the data sheet for the series-pass supply they were using on the bench. Since most logic circuits have close to 1 volt of noise immunity, this is a clear case of over-specifying. Knowing exactly what the system requires is of prime importance in picking the right power supply.

Load Steps

One of the disadvantages in using a switching supply is its slow response to step-load changes. The feedback cannot be any faster than the maximum frequency of the switching regulator. Usually, because the switching regulator is ahead of the inverter, response times of several milliseconds are encountered. There are, however, a number of techniques for solving this problem. The best and most recent solution to this problem is the so-called "transient suppressor."

During a step decrease in the load, this circuit clamps the

voltage at a maximum level close to what it was before the step and absorbs the excess energy which is still being supplied to the output. During a step increase in load the voltage is clamped to a minimum level—again close to the original value—and the output is supplied energy until the switching regulator can meet the requirement. The transient suppressor is a passive-type circuit during normal power-supply operation and thus does not dissipate any power.

Another example of over-specifying is the case where a logic designer will call for a difficult dynamic-regulation parameter which increases the price of the power supply. In fact, a digital logic load will not vary more than 5% during a complete computation cycle.

Cost and Applications

A switching regulator power supply will *always* cost more than a series-pass supply with the same outputs. Presently, it costs anywhere from 25 to 100% more. As the price of switching transistors comes down (which they have already shown signs of doing), this gap will close, but the switcher will always be more expensive. To understand why is simple if you refer to Fig. 3. Even if the cost of the switching regulator and inverter approach the price of the series-pass circuitry, the over-all switching supply always contains two sets of rectifiers and filters, one off-the-line and one at the inverter output. The series regulator power supply, on the other hand, uses only one rectifier-filter combination.

Until recently the only people who would spend the extra dollars for a switching supply were those working on military contracts. For aircraft, shipboard, and mobile ground-support equipment weight, volume, and efficiency are of utmost importance. Where weight penalties can be applied, the added cost of a switcher was minor when compared to penalty dollars. Most pieces of gear had to fit in a fixed volume. When most of that volume was allotted to the rest of the system, the power supply had to fit into the tiny space that was left.

Now, with MSI and LSI, computer and peripheral manufacturers are able to make complex equipment in very small boxes. And because logic speeds are increasing along with the watts per logic function, these small boxes use huge amounts of power. There are now many instances where a series-pass supply is larger, heavier, and dissipates more power than the computer it is driving. If nothing else this is not aesthetically pleasing. If you are trying to sell a desk-top computer with a power supply which is as big as the desk, you can understand the problem. Thus many computer people are looking to switching supplies. Companies using switching regulators right now read like a "Who's Who" of the computer industry: *IBM*, *Honeywell*, *Univac*, *DEC*, *Burroughs*, and *RCA*, to name a few.

Besides aesthetics, there are solid dollar reasons why the switcher makes sense to the computer industry. Thermal problems which necessitate a complex cooling system with a series-pass supply are sometimes eliminated by using a switcher. The cooler running switching supply means less temperature stress on components and greater reliability or MTBF (mean-time-between-failure) which, in turn, means lower maintenance costs.

There are applications where a switching regulator would make sense, but often is not used simply because the engineer is unfamiliar with the technology or has doubts about EMI. As more and more switching regulator power supplies are designed into new hardware this reluctance will disappear. Of course, for every application where a switching regulator is a must, there are many more where the extra cost isn't justified. As new and better transistors are introduced and as the recent arrivals start to drop in price, it will become harder not to consider a smaller, lighter, more efficient, and more reliable power supply for tomorrow's state-of-the-art designs. ▲

This five-output supply provides 250 watts d.c. and 350 VA a.c. for fans. It supplies logic and memory sequencing circuitry built in to insure that memory is shut down before the logic. It is being used in the Honeywell H316R computer.

Electronic "Slide Rules"

New pocket-sized electronic calculators are a big hit with both students and traveling business executives.

By **John Frye**

THE October morning, crisp as a potato chip, had everyone in a happy mood. Matilda hummed to herself as she dusted her desk prior to starting the day's work at Mac's Service Shop. The humming expressed her contentment and also served to drown out Barney's off-key rendition of "September Song" emanating from the service department.

The front door opened and Mac, her employer, came in carrying something in a small leather case. He uttered not a word but deposited the object on her desk, unzipped the case, and with a flourish removed a little black-and-gray instrument with a compact colorful array of white, blue, and red keys on top. "Now," he said, "don't say I never buy you anything!"

"Gee, thanks; but what is it?"

"It's a miniature electronic calculator called the Compet ELSI-8, or EL-8 for short, made by *Sharp Electronics* in Japan but distributed in the U.S. by its Paramus, N.J. office. I know you're going to love it. Here, lift it. It weighs only a fraction over a pound and a half and is $6\frac{7}{16}$" long, 4" wide, and $2\frac{3}{4}$" thick."

"Where is the line cord?"

"That's one of the beauties of it. It operates on six self-contained 0.450 A/hr rechargeable NiCad batteries or on a.c. with this little adapter-charger," he explained, taking another little leather case from his pocket and removing a small black box measuring about 2" × 2" × 4". A line cord came out one end and a coiled cord with a special plug on the end came out the other.

"So what can it do to replace Humperdink in Matilda's affections?" Barney asked as he came through the door of the service department.

Mac flipped a little switch on the side of the case of the calculator and instantly an eight-digit display of bright green numerals appeared behind the tinted, sloping, rectangular window at the top of the instrument. The numbers on the right kept changing rapidly and a negative sign appeared at the top of the window. Mac punched a key marked *C*, and the numbers stopped changing. He punched the key again, and the negative sign was extinguished and all the digits became zeroes.

"Now we're ready for business," he announced. "Give me some numbers to add."

"Six dollars plus three dollars and fifteen cents," Barney offered.

Mac pushed a key marked 6, and instantly the right-hand 0 became a 6 with a decimal behind it. Then he pushed a *Plus-Equals* key, which had no effect on the display. But when he punched 3, the 6 disappeared and was replaced by a 3 with a decimal behind it. Pushing a blue key marked with a decimal did not change the display, but when the 1 was pushed the 3 and its decimal moved one place to the left and was replaced by a 1. Pushing a 5 moved both previously displayed numerals another space to the left, and the 5 showed up in the right-hand spot. Finally Mac pushed a *Plus-Equals* key, and instantly the display changed to 9.15.

"Hm-m-m, not even any kachunk, kachunk sound," Barney observed. "But I've got some questions. How come you didn't have to punch out a decimal and two zeroes on that six dollars? You did punch in the decimal on the three dollars and fifteen cents."

"That's part of the *Floating Decimal* feature," Mac explained. "As long as you're keying a whole number, no matter how many integers make it up, the decimal stays put on the extreme right behind the last integer displayed. But if you hit the decimal key before keying an integer, the decimal moves left along with that integer. Watch what happens when I punch out *pi*." He hit the *C* key to clear the machine and return all displays to zeroes, and then punched out 3.1416. Sure enough, the decimal marched left step by step behind the 3 as successive integers were keyed. "And the decimals line up for addition no matter how many integers appear to the right and left of those decimals in the numbers being added. Now you see why I didn't have to hit the decimal and two zeroes when I recorded six dollars."

"I assume it subtracts, too," Matilda said.

"Of course. The operation is only a little different. To subtract 3 from 9, you simply hit 9 first and then the *Plus-Equals* key, like so. Then you punch 3 and the red *Minus-Equals* key. There is your 6 answer. Continued subtractions require only that you punch out each subtrahend and then hit the *Minus-Equals* key to get the new remainder. If you wish, you can mix addition and subtraction by hitting the *Plus-Equals* or *Minus-Equals* key, respectively, after each number you wish to add or subtract. If, say in balancing your checkbook, the 'minuses' exceed the 'pluses,' the negative sign lights up to indicate that the number displayed reveals how much you are overdrawn; and it stays lighted as long as the displayed number is really negative."

"Can it multiply and divide?" Matilda pursued.

"It sure can. Suppose we want to multiply 9 by 3. I punch 9, hit the *Times-Divide* key, punch 3, and hit the *Plus-Equals* key, and there is the answer, 27, clear to the right. Now let's go backwards and divide 27 by 3. I key in 27, hit the *Times-Divide* key, and punch 3. Now watch closely as I hit the red *Minus-Equals* key." The 3 disappeared from its place on the right and in the same instant a 9 followed by a decimal and seven zeroes appeared in the window.

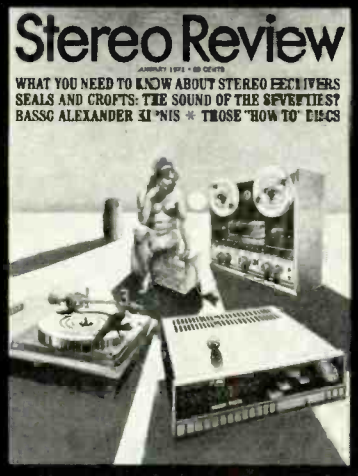
"That display really flips from the right to the left side in a hurry," Barney said. "How fast does that thing work?"

"Addition and subtraction are performed in 20 milliseconds; multiplication in 150 miliseconds; and division in 200 milliseconds. But let me show you something else. Suppose we want to multiply 824005.1 by 930047.2. Notice I get an answer of 76636363."

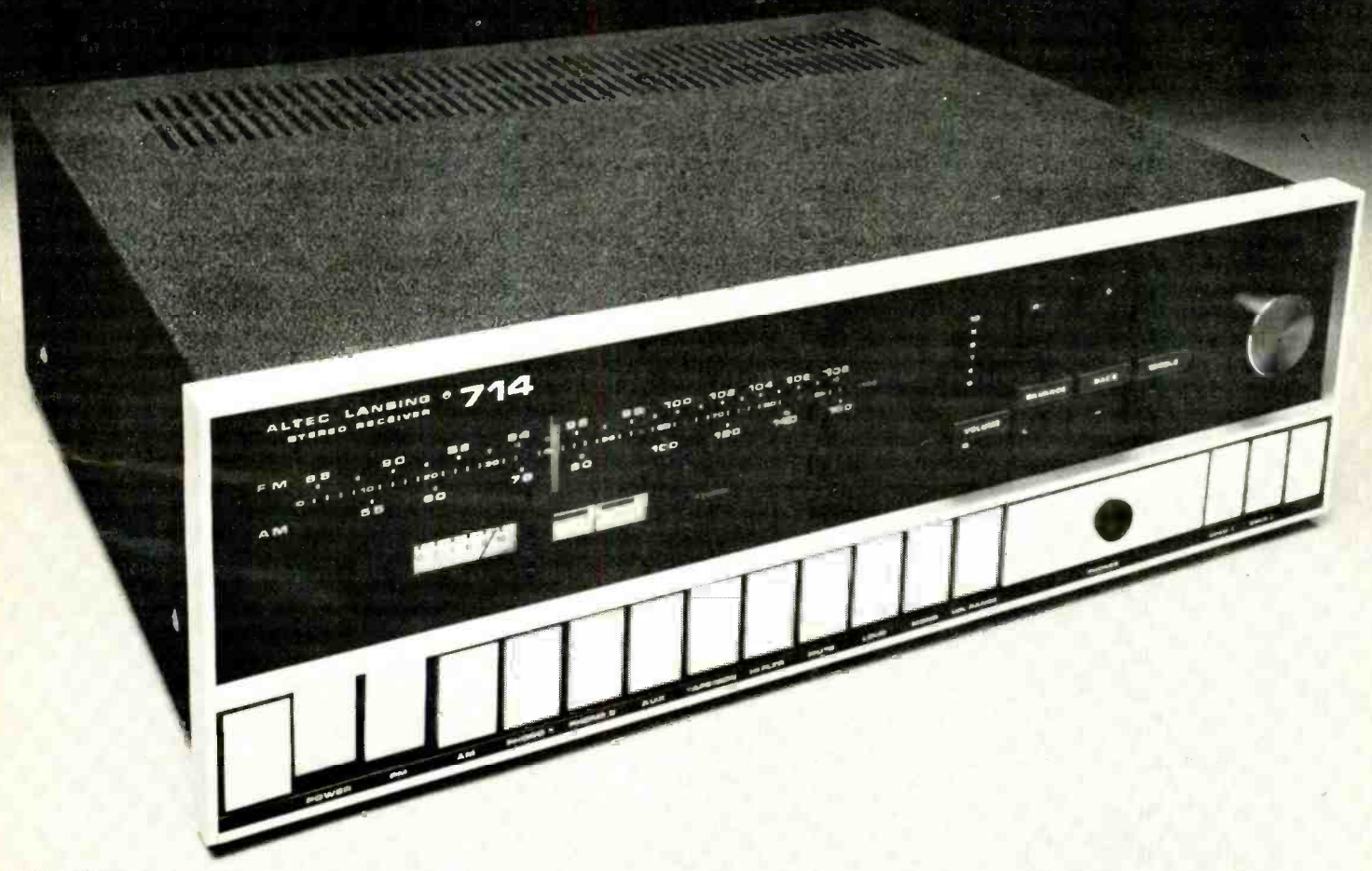
"Hey, that's too small an answer," Barney objected.

"Right you are. The complete answer is 7663636 36040.72. Notice the lack of a decimal on the right tells us the display is not a complete answer. The machine can handle eight digits multiplied by eight digits, but it can only display the first eight digits of the answer and discards the rest. This is called the *Underflow System*. However, it does keep track of the decimal beyond the eight displayed inte-

Test reports in both HIGH FIDELITY and STEREO REVIEW prove the Altec 714A receiver is built a little better.



In February, HIGH FIDELITY magazine printed a detailed two-page test report (by CBS Laboratories) on the Altec 714A stereo receiver. The wrap-up comment read as follows: "All told, the 714A is one beautiful piece of audio machinery that should be given a long serious look by anyone in the market for a new high-quality stereo receiver". And in January, STEREO REVIEW'S equipment test report (by Hirsch-Houck Laboratories) stated "In its general performance and listening quality, it is comparable to the best we have tested..."



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gers and the decimal can be recalled into the display by multiplying by .0000001, as I do now. See, our display now reads 76636.363. Since the decimal was called back seven places, we know it actually belongs four places to the right of the last integer in the original answer, which can be rounded off as eight significant figures and four zeroes."

"I see *Alarm* and *Error* printed on the display window. What are they for?" Barney asked.

"A green dot appears besides the *Error* sign and the display goes to all zeroes and only the *C* key will function when the integral number result in multiplication and division exceeds 16 digits, if addition and subtraction calculations are performed continuously when the decimal is not displayed, or when the battery voltage becomes too low to insure accurate performance. When the last happens, you connect the *Adapter-Charger* and throw the switch to *AC*. This powers the instrument and trickle-charges the battery at the same time. In 12 to 15 hours of this type of operation, the battery will be recharged. It can be quick-charged in 3 hours with the charger connected and the instrument switched Off. A red indicator lamp on the charger goes out when the battery is fully charged, but the batteries are protected against overcharge. If the instrument is connected to the charger but is switched to *DC* instead of *AC*, a red dot appears beside the *Alarm* sign to warn the operator the battery is not being charged."

"How long does a charge last?" Barney wanted to know.

"About three hours."

"Is the *C* key just used to clear the machine?" Matilda asked.

"No, it's also used to delete a mistaken entry. When I was adding 3.15 and 6, if I had accidentally keyed 3.16, I could have hit the *C* key and the 3.16 would have disappeared and the display gone back to 6. Then I could have proceeded as before."

"I don't suppose it will handle powers and roots," Barney hazarded.

"Not directly, but a set of common logarithms, such as I just happen to have with me, reduces power and roots to multiplication and division, which the instrument can handle. For example, suppose you wanted to find $2.82^{4.15}$. You multiply the logarithm of 2.82, which is .4502, by 4.15, like so, and get 1.86833. The antilog, 73.84, is your answer. Or suppose you need the fifth root of 1.251. The logarithm is .0972. Dividing by 5 we get .01944. Your answer is the antilog, or 1.0458."

"How can so much smart math be wrapped up in such a small package?"

"Chiefly by the use of Extra Large Scale Integrated circuits, of which this instrument has four. Notice its name comes from the initials. Each ELSI measures only ⅛" square but does the work of 1875 resistors, diodes, capacitors, etc."

"I'm afraid to ask, but what does that thing cost?" Barney questioned.

"Three-hundred and forty-five dollars complete with adapter/charger."

"Does anyone but *Sharp* make them?"

"Oh yes. *Sharp* was the first, but lots of other companies, chiefly Japanese, are getting into the act. These include such firms as *Canon*, *Sanyo*, *Busicom*, *Hitachi* operating through the *Frieden Division* of *Singer*, *Monroe Division* of *Litton Industries*, *Commodore Business Machines* of Toronto, etc. Some of these are 12- and 16-digit machines that display six or eight digits and view the rest through a lens system. Others provide a paper print-out in addition to the light display. The ELSI-8 uses mini fluorescent display tubes, but others are trying LED's and liquid-crystal displays. Competition is fierce; lightning advances in microcircuitry are being snapped up; low-cost solid-state keyboards have been developed; there has been overproduction in some areas; and such widespread price-cutting that the Japanese are working toward an export cartel to establish a minimum price structure for calculators produced for overseas markets."

"I get the idea Japan is pretty big in the calculator business."

"Very big. In fact, Japan produces 70% of the world's calculators and exports half of this. The U.S. took 40-50% of the $181-million worth of calculators exported last year and is Japan's best customer. On the other hand, we manufacture most of the integrated circuits used in the calculators. *North American Rockwell* has a $30-million contract with *Sharp* for advanced MOS/LSI circuits. *Texas Instruments* makes them for *Canon*. *Mostek Corp.* of Dallas supplies MOS chips for *Busicom*. *General Instrument* makes LSI chips for *Sanyo*."

"Well," Barney said, patting the little instrument, "I certainly forecast a bright future for these devices, especially if the price keeps coming down. Think how handy one would be for a college kid taking engineering. It is almost as portable as a slide rule and is faster, more accurate, and keeps track of the decimal. It can add and subtract, which a slide rule can't."

"I'd like to take it with me when I'm buying groceries," Matilda admitted. "Actually, it could be all the calculator most professionals or small businessmen would need. But now will you two lugs go on back into the service department and let Elsie and me become acquainted? After all, I thought you bought this calculator for *me*!" ▲

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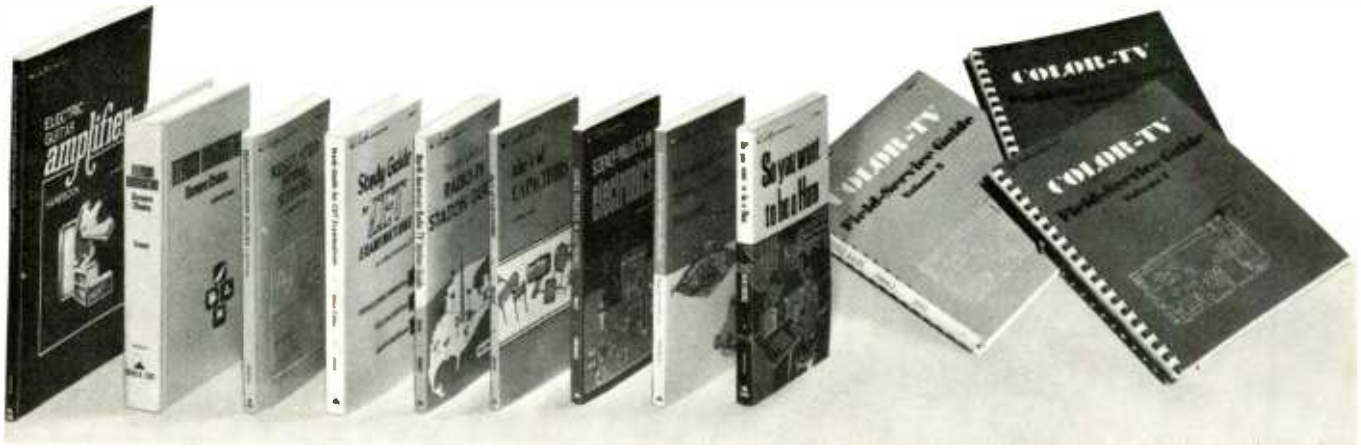

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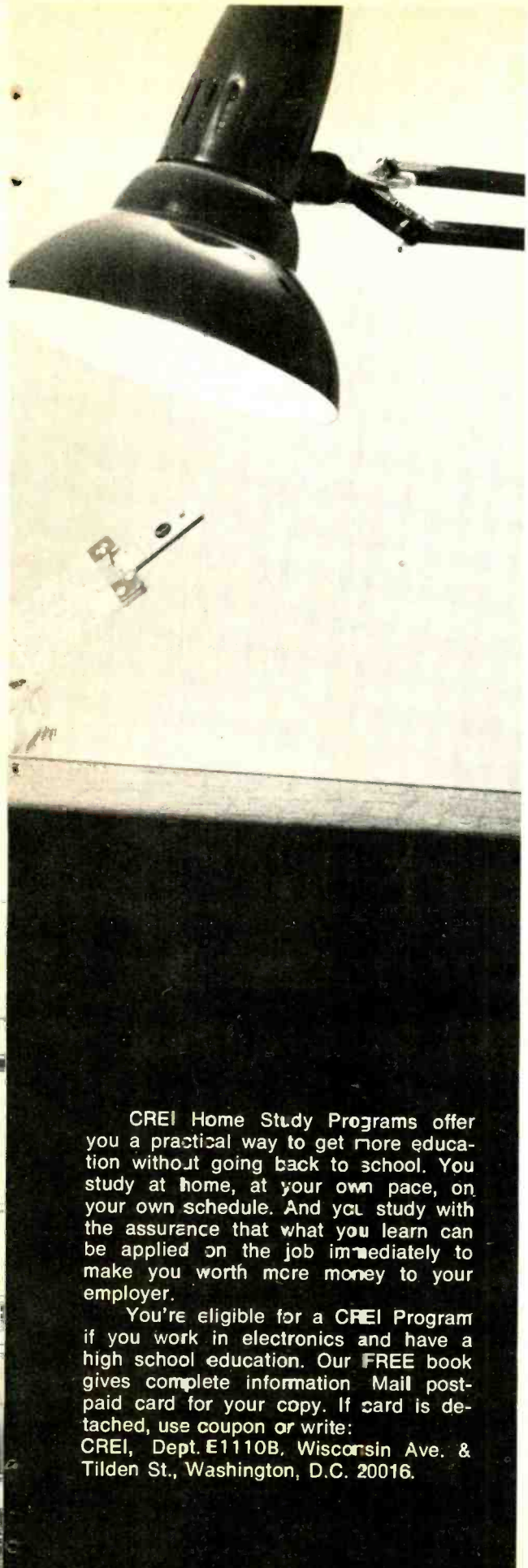

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Interstellar Communications

(Continued from page 35)

If, for example, wavelengths longer than 300 meters (1 MHz) were used, they would be absorbed by the interstellar medium. Further, since it must be assumed that given planets have ionospheres of one type or another, only wavelengths of less than 10 or 15 meters are likely to pass through and reach the planets' surfaces. After considering the effects of cosmic radio noise, things were narrowed down to wavelengths between 3 and 30 cm, finally to 21 cm or 1.420 GHz.

The reason was that Nature itself provides a fixed, "standard" calibrating frequency in the spectrum of interest to communicators: the precession frequency of hydrogen atoms. Since hydrogen is the most abundant thing in the universe, we can assume that 1.420 GHz is the fundamental frequency of Nature and known to technical interstellar societies.

Unfortunately, the 21-cm channel is a noisy one. In order to recognize data contained in such a carrier as an artificial signal, the thing to assume is that it might have a narrow-band character and would vary with time. A signal sequence might be in the form of dots and dashes, giving a binary counter-input pattern such as that shown in Fig. 3. The ones given at (A) have been expressed as dark spaces in the readout matrix (B), while the zeros are entered as light spaces.

While little more than a two-dimensional pattern, a readout of this basic type would contain an enormous amount of information. First, *they* use a decimal system for their purpose. Next, they are bipeds—just like ourselves. And that, in turn, would allow us to reason that there might be similar traits in behavior, thinking, and expressiveness. Further, being intelligent beings, they would not overwhelm us with complex dimensions in their communications simply because we couldn't understand them. Again, the 21-cm hydrogen line appears to be a logical choice for data transport because of its universality.

Subscribing to the 21-cm channel theory, Dr. Drake's famous "Project Ozma" used the 85-foot radio telescope at the National Radio Observatory during the months of May, June, and July, 1960 for actual listening attempts.

The instrument employed two horns and a semiconductor-diode parametric amplifier as the first amplifying stage. During the entire search for intelligent signals, a bandwidth of 100 Hz was used. One of the two antenna horns received radiation from a small area near a star of interest (where one might expect to find a transmitting planet). Entering the other horn was radiation from a neighboring region of the sky. Using electronic antenna switching and synchronous detection at the receiver, a good degree of sensitivity was obtained—but, unfortunately, no results.

Today, many astronomers still share the conviction that deep-space searches for intelligent life should be concentrated on stars which are less than 15 or so light-years away from our solar system.

Interstellar Event or Mythology?

Interstellar spaceflight is technically feasible, even though it is an enormously expensive and difficult undertaking. Perhaps this has been developed to absolute perfection by extraterrestrial societies whose worlds were old when the Earth was young. Thus, if we assume scientific developments a million or billion years ahead of our own, an altogether different approach to interstellar communications and physical commerce emerges.

Some local field investigations tie in with such and similar considerations. The objective is a geophysical definition of dated American Indian legends which imply the presence of celestial beings within or near tribal systems that have long ceased to exist. Unavoidably, stories of this kind smack of UFOistic hocus-pocus and can be considered valid only after their contents have been verified by impartial scientific methods.

The Yuman-speaking Mohaves, Cocopas, Halchidhomas, Yumas, and Maricopas, together with the Chemehuevis of the Utaztecan language family, all lived, at one time or another, along the lower Colorado River and shared certain legends of space and time. The Chemehuevis, in particular, originally came from the eastern Mohave Desert in California and it was in this approximate region that the legend of "the mountain of the bearded god" was born.

According to the story, a "humming star" came from the sky, landed in the desert near a dry lake and—as Indians watched with great fear from a respectful distance—dug in and triggered massive lava flows from what are now known as the Pisgah and Amboy craters near U.S. 66, going east. A short time later, strange men were seen after whom the *mountain of the bearded god* was named. This is an outrunner of the Cady Mountains and, if looked at from the spot the Indians once stood, shows a distinct forehead, a nose, and a small mouth with a massive beard.

The question is: Was a real interstellar experience witnessed by an unsophisticated people or is it mythology and nothing but? ▲

Do You Know These **Electronic Abbreviations?**

By SOL D. PRENSKY

Can you "translate" expressions such as:

"The TTL is compatible with the LSI of the ROM" or "The IGFET is a suitable amplifier for the PIN diode in the VCO."

Test yourself on your recognition of these electronic abbreviations and check your answers by matching the numbered abbreviations in the left column with the corresponding numbers in the upside-down column at the right.

A score of 20 or more correct answers is excellent, 13 to 19 correct is very good, but if you score less than 13, you need to study your electronic alphabet again.

Electronic Abbreviation	English "Translation"
1. ADC	27. Video tape recorder
2. DAC	26. Voltage-controlled oscillator
3. DCU	25. Unijunction transistor
4. DPM	24. Transistor-transistor logic
5. DVM	23. Single sideband
6. ECG	22. Silicon controlled switch
7. EEG	21. Silicon controlled rectifier
8. ESR	20. Read-only memory
9. FF	19. Positive-intrinsic-negative
10. IGFET	18. Nuclear-magnetic resonance
11. JFET	17. Non-destructive testing
12. LED	16. Medium-scale integration
13. LSI	15. Metallic-oxide semiconductor FET
14. LVDT	14. Linear-variable differential transformer
15. MOSFET	13. Large-scale integration
16. MSI	12. Light-emitting diode
17. NDT	11. Junction field-effect transistor
18. NMR	10. Insulated-gate field-effect transistor
19. PIN	9. Flip-flop
20. ROM	8. Electron-spin resonance
21. SCR	7. Electroencephalograph
22. SCS	6. Electrocardiograph
23. SSB	5. Digital voltmeter
24. TTL	4. Digital panel meter
25. UJT	3. Decimal-counting unit
26. VCO	2. Digital-analog converter
27. VTR	1. Analog-digital converter

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Solid-State — the newest development

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SCR Power Supplies

(Continued from page 38)

age applied to the very low d.c. primary resistance causes a large d.c. primary current to flow, tripping the circuit breaker or blowing the fuses. However, at least one manufacturer's SCR supplies incorporate a circuit that senses the line-voltage imbalance (within a certain limit) and adjusts the firing time of one of the three SCR's accordingly, thus eliminating the problem completely.

Finally, the unusually large output filter capacitor used on most SCR supplies causes a large initial current surge when the output terminals are short-circuited, even if the supply is in constant-current operation, because the capacitor is nearly always outside the constant-current feedback loop.

Applications

As previously mentioned, SCR supplies were developed for applications requiring large amounts of fixed or slowly varying, moderately well-regulated, moderately ripple-free d.c. power. Presented below are ten of the most typical applications with such requirements:

Life testing and aging large quantities of such components as power transistors, rectifier diodes, zener diodes, incandescent lamps, circuit breakers, and d.c. contactors.

Supplying power to computer mainframe and memory systems (8 volts at 1000 amperes is a typical supply rating used here).

Magnet supplies for cyclotron, magnetohydrodynamic, and cryogenic (superconducting) magnet applications.

Battery charging and discharging. SCR supplies with constant-voltage/constant-current automatic crossover are frequently used to charge and discharge large storage batteries (such as those used in electric warehouse trucks) at constant current. In charging applications, when the maximum charge voltage is reached, the supply automatically switches to constant-voltage operation and supplies a trickle charge sufficient to maintain full charge. Taper charging is accomplished with the same supply by inserting a small resistance between the supply and the battery; this causes the normally flat constant-voltage output characteristic to take on a finite slope.

Supplying d.c. filament current for superpower tubes, such as those used in linear accelerators (3.5 V, 3500 A is a typical supply rating used in this application).

Precision tungsten/inert-gas arc welding for cleanliness and hermetic seals in such components as crystal-case relays and aneroid bellows; precision aluminum welding during aircraft assembly. SCR supplies are also used to test welds such as those between storage-battery plates and terminals; in this application, a 1000-A current is put through the weld, and the resulting millivolt drop is measured across the weld using the four-terminal Kelvin method. The same Kelvin method is also used when testing high-current meter shunts.

Precision electroplating, usually with precious metals. SCR supplies are also used in chrome-plating large quantities of machine parts, and in other high-current electrochemical processes.

Testing high-current electrical systems such as large telephone switchboards and luxury automobile electrical systems. Also in this same area, SCR supplies are used in processing (forming) electrolytic capacitors.

Controlling and operating d.c. motors; replacing motor-generator sets in older industrial operations.

Powering air-conditioning systems using the Peltier effect (the production or absorption of heat at the junction of two metals when a current is passed through the junction).

What's Ahead?

What's ahead in SCR power supplies? Perhaps the largest factor on the near horizon is the gate-controlled switch (GCS). These are SCR's that can be turned *off* as well as on by the application of a pulse; their future availability in high-power ratings may cause major changes in the design philosophy of SCR supplies.

First, SCR regulators will no longer be limited to operation at the line frequency; with the ability to turn off the SCR when desired, the regulator can be made to operate at a higher frequency. This will result in an even smaller supply due to smaller transformers and filters. Second, the higher operating frequency will result in improved transient response and programming speed. Third, the ability to turn off the SCR at any time during the a.c. input cycle will provide greater supply reliability. In present supplies, a fault occurring immediately after an SCR fires may cause the peak current in the SCR to exceed the safe maximum because the device cannot be turned off until the end of the a.c. half-cycle. With GCS's, a fast-acting electronic circuit (rather than the presently used electromechanical devices) could turn off the gate-controlled switch early enough to avoid any possibility of damage.

Finally, there will undoubtedly be a continuing improvement in value (cost per watt) and output range of SCR supplies as prices of semiconductors continue to fall and maximum device voltage ratings continue to rise. ▲

The Minicomputer

(Continued from page 25)

somewhat more expensive. However, the minicomputer has something that the programmable desk calculator has not: expansion potential. The range and type of peripherals available for a minicomputer, plus the memory that can be added, permit a basic minicomputer to be expanded into a reasonably sophisticated data-processing system (and, in addition, it can be used for specialized analytical operations with instruments). By contrast, the expansion of a programmable desk calculator is quite limited.

When comparing the minicomputer to time-sharing service, another factor must be considered—the economics of the situation. To be sure, the large time-sharing computer has considerably more power than a minicomputer; however, it is rarely that an engineer needs the very powerful "number crunching" that a time-sharing computer affords. Most routine calculations can be performed on a smaller computer. For that reason, the smaller minicomputer systems—when operating with a high-level language like Focal or Basic—can almost be thought of as the equivalent of time-sharing terminals without the large computer. Since the average rental of a time-sharing terminal will cover the cost of a basic minicomputer system within six months to a year, it usually makes more sense for the user to own his minicomputer.

Using individual minicomputers rather than a time-sharing network to perform equivalent calculations offers another dividend besides economy. In a time-sharing network, if there should be a computer malfunction, all terminals would go "off the air." By contrast, independent minicomputers do not face that problem; if one should malfunction, it would not affect the activities of the others. It is the equivalent of not putting all one's eggs in a single basket.

Of course, time-sharing's chief advantage is that many users have access to the same data base. Indeed, some minicomputer systems are capable of time sharing—and some users employ minicomputer systems for time sharing routinely—but here the large computer system with its greater capacity has a decided edge.

But what about those jobs that a minicomputer is unable to handle by itself? A minicomputer can often "go into partnership" with a large computer to solve such problems. In what is known as a "hierarchical" arrangement, a minicomputer can be connected to a large computer over communications lines just like a time-sharing terminal. But the difference in operation is this: a minicomputer will handle all the problems it can cope with by itself. When it runs into the occasional problem beyond its capabilities, it will "preprocess" the problem, translating it into machine-language instructions which are, in turn, sent to the large computer. The large computer solves the problem and then sends the answer to the minicomputer, which accepts the problem solution as if it had solved it by itself. The large computer is thus used only when needed and the operating costs of using it can be cut drastically.

Minicomputer Costs

This brings up the question of overall minicomputer costs. "How much?" is a question with no easy answer, because it can range from very inexpensive to prohibitive. The hardware costs of a minimum configuration are around $6000-$7000 including the Teletype or equivalent input/output device; this will usually include a program that will permit you to get "on the air" with some calculations, although the power and accuracy of the program depends on the manufacturer.

The reason costs are hard to pin down, however, is that different people require different configurations. Some just need a desk-sized minicomputer for simple calculations. Some want to store programs or data and require a system with a mass-storage device like tapes or a magnetic disk. Some need interfacing to instruments. Others may want a visual display.

The best rule-of-thumb for determining computer-system costs is that, in general, a system will cost about six times the cost of its minicomputer (that is, an average system containing a $5000 basic minicomputer will cost around $30,000); but such a system will be a lot more powerful than a mere calculator. Of these costs, part will be for the additional hardware, part for specialized programming, and part for interfacing devices. The percentages tend to vary with the applications. In some cases, small systems are "expanded" at a later date by adding more equipment to the basic system after it has been in operation for a while. Thus a system can "grow" as extra features are required.

Computers have come a long way from the old punch-card monsters living in isolated glory in an air-conditioned comp center. Minicomputers and systems built around them are helping engineers solve their problems "on location." Rather than having to take problems to the computer, the minicomputer is brought to where the problem is. And that can make a big difference in the way a problem can be tackled. ▲

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The demand for licensed men is enormous. Ten years ago there were about 100,000 licensed communications stations, including those for police and fire departments, airlines, the merchant marine, pipelines, telephone companies, taxicabs, railroads, trucking firms, delivery services, and so on.

Today there are over a million such stations on the air, and the number is growing constantly. And according to Federal law, no one is permitted to operate or service such equipment without a Commercial FCC License or without being under the direct supervision of a licensed operator.

This has resulted in a gold mine of new business for licensed service technicians. A typical mobile radio service contract pays an average of about $100 a month. It's possible for one trained technician to maintain eight to ten such mobile systems. Some men cover as many as fifteen systems, each with perhaps a dozen units.

Coming Impact of UHF

This demand for licensed operators and service technicians will be boosted again in the next 5 years by the mushrooming of UHF television. To the 500 or so VHF television stations now in operation, several times that many UHF stations may be added by the licensing of UHF channels and the sale of 10 million all-channel sets per year.

Opportunities in Plants

And there are other exciting opportunities in aerospace industries, electronics manufacturers, telephone companies, and plants operated by electronic automation. Inside industrial plants like these, it's the licensed technician who is always considered first for promotion and in-plant training programs. The reason is simple. Passing the Federal government's FCC exam and getting your license is widely accepted proof that you know the fundamentals of electronics.

So why doesn't everybody who "tinkers" with electronic components get an FCC License and start cleaning up?

The answer: it's not that simple. The government's licensing exam is tough. In fact, an average of two out of every three men who take the FCC exam fail.

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COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • COMMUNICATIONS

4-CHANNEL ADAPTER

A 4-channel adapter, the QA-4 "Quatrasonic," designed to be used with almost any stereo amplifier or receiver is now available in both kit and factory assembled versions.

Designed to recover the "hidden" sound on

most stereo records, the new unit is a passive device which is connected to the speaker outputs of the amplifier. It requires no a.c. power. It will work with 4-, 8-, or 16-ohm speaker output terminals. Two controls are provided: a 4-position switch permits selection of 4-channel operation, front speakers only, or rear speakers only; while a level control on the front panel permits rear-speaker level adjustments. Eico

Circle No. 1 on Reader Service Page

DECAPSULATION KIT

A decapsulation kit that dissolves most cured plastics used to package electronics assemblies is now available. It is useful in failure analysis, depotting for repair and retrieval, chemical deflashing, and cleaning equipment.

Materials removed by the solvents include epoxies, both cast and transfer molded; silicones; RTV's; varnishes; urethanes; elastomers; coatings; and foams. Some are selective solvents and attack only one type of plastic while others dissolve several.

The kit includes a quart each of Dynasolve 160, Uresolve HF, Decap, Dynasolve 190, Uresolve Plus SG, and Dynasolve 100 or a polysulfide dissolver. Dynaloy

Circle No. 2 on Reader Service Page

TRANSISTOR TESTER

A new transistor tester which uses a visual display on the face of a small CRT to indicate the type and quality of the transistor under test has been introduced as the "Q-Check."

The instrument is designed to be operated by unskilled personnel and will find application in quality control, incoming inspection, maintenance, engineering lab, radio and TV servicing, medical electronic, and other applications.

The transistor is inserted in the test socket and a display indicates a good "p-n-p" or "n-p-n" or a fault such as short, leakage, or open—each with its characteristic pattern.

In addition to testing power or small-signal transistors, the tester can be used to check zener diodes, SCR's, unijunction transistors, rectifiers, and signal diodes.

The instrument is housed in a two-tone green cabinet measuring 6½" × 8" × 8" and has a sturdy plastic carrying handle and tilt stand. J & J Electronics

Circle No. 3 on Reader Service Page

"DIGITAL-CLOCK" TRANSCEIVER

A new solid-state CB transceiver which features a digital clock and a built-in illuminated "on-the-air" indicator has been introduced as the "Conqueror."

This new transceiver can be turned on at any given time by pre-programming the digital clock. While transmitting, the on-the-air sign remains illuminated and an exclusive flickering

red light behind the sign indicates the modulation level.

The 23-channel selector switch has an extra position for operating in the p.a. mode. Backlighting of the selector identifies the channel or mode, with channel 9 and p.a. keyed in red. Crystals to cover all 23 channels are included in the design. Courier

Circle No. 4 on Reader Service Page

PROGRAM EQUALIZER

The Model PEQ-4 mid-range program equalizer and filter is designed to provide exact control of the "power region" in program material. This "region" is that frequency range of approximately 200 to 7500 Hz in which most of the sound energy is concentrated.

With six selectable low-frequency points for each peak and dip position, the unit can simultaneously boost or attenuate from 200 to 1000 Hz. An additional seven positions each for mid-frequency dip and boost perform the same function for the frequency range from 1250 to 7500 Hz.

Six selectable low-frequency positions and seven mid-frequency positions comprise the filter family. Power and equalization indicator lamps with separate equalization and filter in/out switches complete the front panel of this solid-state package which measures 3½" × 19" standard rack mount. Lang Electronics

Circle No. 5 on Reader Service Page

DIRECT/INDIRECT SPEAKER

The new Model 601 speaker system has a flat response +3 dB over the 40-18,000 Hz audio range and can be easily driven by an amplifier with only 30 watts per channel output. Each speaker will handle a maximum of 100 r.m.s. watts.

Because the output is as linear as the input, the 601 requires no equalizer. A total of six drivers is housed in the walnut 24" × 16" × 15"

cabinet, arranged in three woofer-tweeter modules. The rear-facing modules are placed 90° to each other to eliminate mutual coupling and each has an 8-inch long-excursion woofer and a 1-inch wide-dispersion tweeter. The forward-facing module has another 1-inch tweeter and a specially designed 6-inch long-excursion woofer.

Individual controls balance the ratio of direct and reflected sound to match the acoustics of the listening room while separate tweeter controls adjust for the room's sound absorption. EPI Speakers

Circle No. 6 on Reader Service Page

FOUR-CHANNEL HEADPHONE

The "Quadrafone" Model K2+2 four-channel headphone is engineered with four separate dynamic drive elements which reproduce sound from four-channel amplifiers. A versatile feature of the new phone is its compatibility with conventional stereo amplifiers as well as four-channel and augmented two-channel stereo. It operates from standard stereo phone jacks on receivers and amplifiers.

The K2+2 is a compact headset—no larger than conventional stereo phones. Each earcup houses two drivers, situated in standard four-channel array: left front and left rear receive channels 1 and 3; right front and right rear reproduce channels 2 and 4. Koss

Circle No. 7 on Reader Service Page

SOLID-STATE G.D.O.

A solid-state grid-dip oscillator which the company claims performs as well as the best vacuum-tube models but with the additional advantage of being battery powered is now on the market as the No. 90652.

Operating features include a sensitive oscillator-dipper for checking resonant frequencies of non-energized resonant circuits and an absorption-type wavemeter with the oscillator arranged to act as a Q-multiplier amplifier, providing both a sharp tuning response and great sensitivity.

The frequency range of 1.7 to 300 MHz is covered by seven plug-in coils, with some over-

lap between ranges. The lowest frequency coil (1.7-4.0 MHz) is wound on a powdered-iron core to increase Q and improve coupling to circuits being checked.

The instrument measures 7¼" long × 3½" wide × 3¼" high and weighs just 2½ pounds with battery. James Millen

Circle No. 8 on Reader Service Page

CONDENSER MICROPHONE

The Model MKH 415 is a professional condenser microphone which combines the best features of both cardioid and shotgun designs, according to the company.

Because of its directional characteristics, wind- and pop-suppression, ruggedness, long length, small diameter, and flat response, the microphone is suitable for both outdoor and critical indoor broadcast or recording applications. Sennheiser

Circle No. 9 on Reader Service Page

STEREO MIKE MIXER

A stereo microphone mixer, designed to offer unusual flexibility for the serious audiophile as well as the professional sound engineer, has been introduced as the Model M688.

The mixer accepts four high- or low-impedance microphones through four inputs, plus a stereo auxiliary high-level input, each with its own volume control. Three microphone inputs have front-panel switches for left- or right-channel output. The fourth microphone input has a pan control which allows this input to be directed to the left channel, the right channel, or anywhere in between. A stereo master volume control adjusts the level of all inputs simultaneously. If additional inputs are needed, the unit can be paralleled with the M67 mixer or another M688 via mix bus jacks. Shure

Circle No. 10 on Reader Service Page

SWEEPER/MARKER GENERATOR

A jitter-free sweeper/marker generator designed specifically for the professional service technician is now available as the Model SMG-39.

The instrument uses post-injection markers for fast, accurate alignment of a TV receiver

when used with any standard oscilloscope. The generator provides all needed bias and linear sweeping signals for negligible error in alignment, according to the company. All output signals are provided: TV i.f., FM i.f., VSM, chroma, 4.5-MHz, and v.f.o. The circuit is all solid-state and the PC boards are glass epoxy for stability and long life. All necessary cables, probes, and leads are included. Lectrotech

Circle No. 11 on Reader Service Page

STEREO PREAMP/AMP

The Model TRM-400 stereo preamp/amplifier has a power output of 56 watts ±1 dB at 8 ohms, Music power (IHF) is 45 watts at 8 ohms. Rotary controls are used to control bass, treble, balance, and volume while push-buttons are used to handle speaker/mode selection, high/low filters, loudness, and tape monitor. The headphone jack is located on the front panel.

The back panel has a six-function input terminal board, color-coded spring-loaded connectors for speakers and antennas, and independent channel outputs for the preamp section for connecting other components.

The unit measures 3¾" high × 12" wide × 8½" deep and weighs 8.6 pounds. Nikko

Circle No. 12 on Reader Service Page

SEMICONDUCTOR TESTER

The TT-7 is a new semiconductor tester that permits checking transistors and diodes and troubleshooting solid-state equipment. It provides dynamic "go/no-go" indication of semiconductor status in-circuit or out. No clip leads are required and there is no meter to watch, thus providing single-handed, eyes-on-work testing. The special probe conforms to all transistor configurations and styles without adjustment.

The tester operates on two inexpensive penlight cells and will work for months without being turned off. Ramko Research

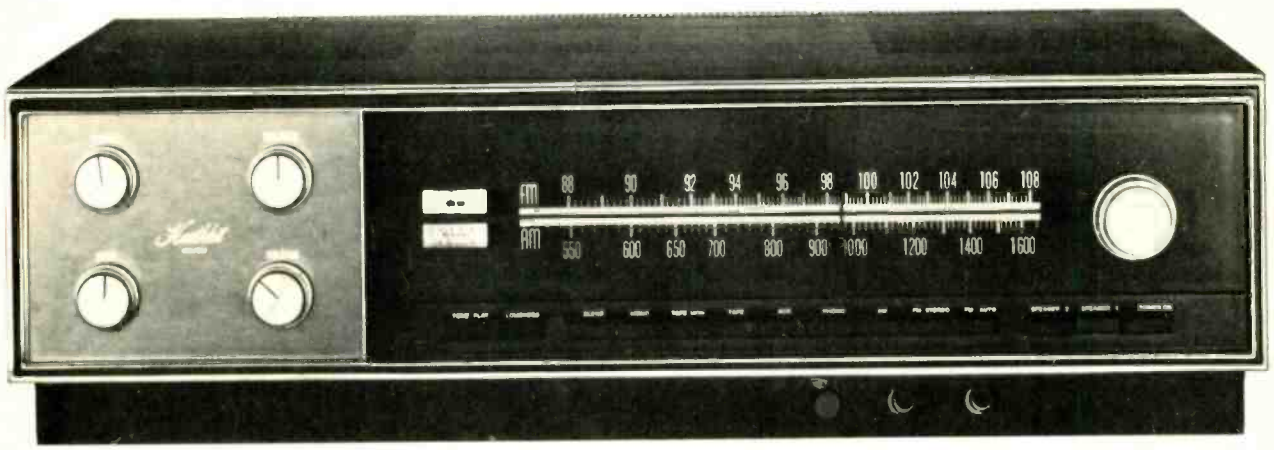
Circle No. 13 on Reader Service Page

60-WATT SPEAKER SYSTEM

The Model 878A "Santiago" is the newest addition to the company's line of dynamic force speakers. It incorporates the firm's "Voice of the Theatre" components. The low-frequency speaker is a 411-type 15-inch woofer with a 3-inch edge-wound copper voice coil. A 17-pound magnetic structure is capable of producing a compression force of up to 16 psi. The 18-inch high-frequency sectoral horn, Model 811B, coupled with an 807-type compression driver pro-

(*Continued on page 76*)

Announcing 16 exciting new Heathkit projects for wintertime kitbuilding fun!



Meet the second generation AR-15 ...new Heathkit AR-1500!

From the AR-15, hailed at the time of its introduction in 1967 as the most advanced receiver of its kind, comes the AR-1500... with impressive improvements in every critical area! *180 Watts Dynamic Music Power,* 90 watts per channel (8 ohm load); 120 watts dynamic music power per channel under 4 ohm load, with less than 0.1% intermod distortion, less than .25% harmonic distortion. A 14-lb. power transformer and massive output transistor heat sink are mute testimony to the power at your command. Direct coupled output and drive transistors are protected by limiting circuitry that electronically monitors voltage and current. *FM selectivity greater than 90 dB,* better phase linearity, separation, and less distortion are the result of two computer-designed 5-pole LC Filters. An improved 4-gang 6-tuned circuit front end offers better stability, 1.8 uV sensitivity, 1.5 dB capture ratio, and 100 dB image and IF rejection. Four ICs are used, three in the IF and one in the Multiplex. Patented automatic FM squelch is both noise and deviation activated, fully adjustable for sensitivity. *Vastly Superior AM,* an "also ran" with many receivers, has two dual-gate MOSFETS in the RF and Mixer stages, one J-FET in the oscillator, 12-pole LC Filter in the IF, and broad-band detector. Result: better overload characteristics, better AGC action, and no IF alignment. *Greatly simplified kit construction.* Ten plug-in circuit boards, two wiring harnesses and extensive use of pre-cut wiring with installed clip connections make the AR-1500 a kit builder's dream. Built-in test circuitry uses signal meter to make resistance and voltage checks before operation. *Other advanced features* include Black Magic panel lighting that hides dial markings when set is not in use; flywheel tuning; pushbutton function controls; outputs for two separate speaker systems, bi-amplification, oscilloscope monitoring of FM multipath; inputs for phono, tape, tape monitor and aux. sources — all with individual level controls. *Versatile installation* in optional new low-profile walnut cabinet, in a wall, or black-finish dust cover included. Join the "NOW" Generation in audio technology... order your Heathkit AR-1500 today!

Kit AR-1500, less cabinet, 42 lbs. **349.95***
ARA-1500-1, walnut cabinet, 6 lbs. **24.95***

New Heathkit Stereo Cassette Recorder

119.95*

Frequency response of ±3 dB, 30-12 kHz, brings your stereo system into the cassette age. Features built-in bias adjustment to accommodate the new chromium dioxide tape; counter; automatic motor shutoff; preassembled and aligned transport mechanism. The AD-110 offers fidelity recording and playback of stereo or mono when used with your stereo system.

Kit AD-110, 10 lbs. **119.95***

New Heathkit Stereo-4 Decoder

29.95*

Compatible with your present stereo system and FM receiver, lets you hear all Stereo-4 material currently being broadcast by a number of stations across the country. Additionally, imparts a 4-channel effect to your existing stereo library. Requires second amplifier and 2 speaker systems for installation with conventional stereo system.

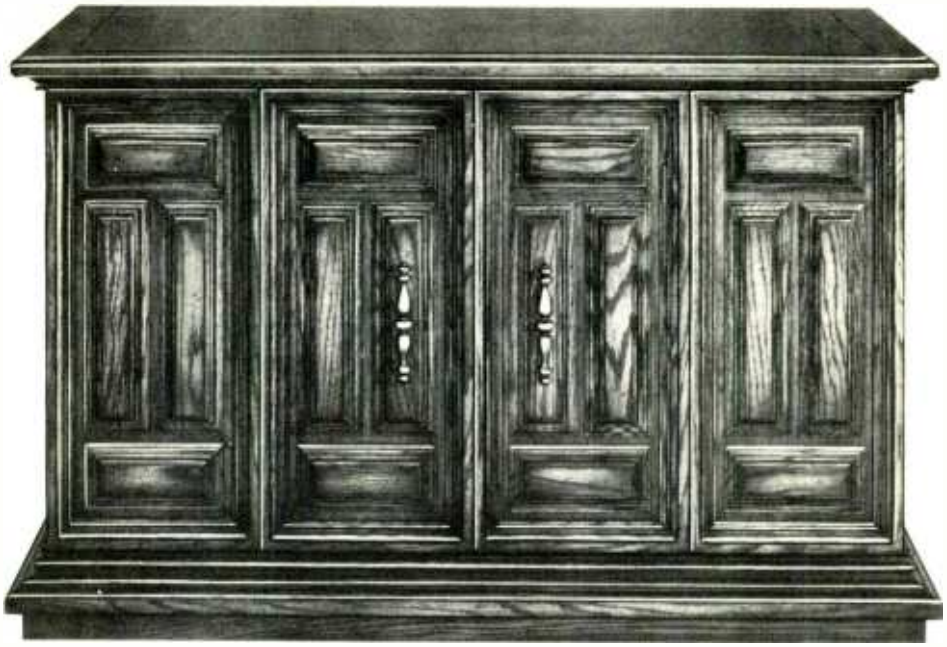
Kit AD-2002, 5 lbs. **29.95***

New Heathkit Stereo Phonograph with AM Radio

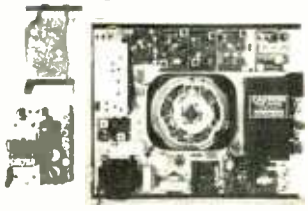
109.95*

Gets it together in a portable package with a purple plum snakey skin that's as far out as today's sounds. Solid-state 18-watt amplifier, fold-down 4-speed automatic changer and swing-out high compliance speakers. Speakers can be separated up to 5'. A flip of the mode switch and you're into AM radio! 45 spindle adapter included.

Kit GD-111, 50 lbs. **109.95***



Now Heath's finest color TV package comes wrapped in a handsome new optional cabinet!



Here's the inside story:...the Heathkit 25" solid-state color TV with exclusive MTX-5 ultra-rectangular tube to bring you the largest color picture in the industry! The etched, bonded tube face cuts glare, increases contrast for sharper picture, purer colors, more natural flesh tones. But the true story of color TV reliability starts in the solid-state modular circuitry ... 45 transistors, 55 diodes, 2 silicon-controlled rectifiers, 4 ICs containing another 46 transistors, 21 diodes, and just two tubes (picture and high-voltage rectifier). Major circuit functions are contained on individual plug-in glass epoxy boards (see chassis inset above) to simplify assembly, service and adjustment. And, of course, only Heathkit color TV offers you the money-saving advantages of home-serviceability...with the built-in dot generator and tilt-out convergence panel to let you perform the periodic adjustments required of all color receivers.

Other advanced design features include solid-state VHF tuner with MOSFET for greater sensitivity, lower noise and cross modulation; solid-state UHF tuner with hot-carrier diode design for greater sensitivity; 3-stage solid-state IF for higher gain and superior picture quality; Automatic Chroma Control for constant color quality under different signal conditions; adjustable video peaking; adjustable noise limiting and gated AGC; "Instant-On"; VHF power tuning on 13 channels plus one preselected UHF channel; Automatic Fine Tuning; Tone-Control; and an output to your stereo/hi-fi system for the ultimate in sound reproduction.

And to wrap it all up ... your Heathkit GR-371MX is available in a magnificent new Mediterranean cabinet with doors that transform your home television theater back into an attractive center of decor. This finest cabinet in the Heathkit line features deep-grained pecan veneers on hand rubbed furniture grade hardwood solids. Two beautifully scalloped double-hinged bi-fold doors hide the TV screen when it's not in use, fold neatly to the cabinet sides when opened. Ornate brass "Canterbury Antique" handles add the perfect finishing touch. Measures 29⅝" H x 56¼" W x 22⅜" D.

Kit GR-371MX, TV less cabinet, 125 lbs. **579.95***

GRA-404-25, assembled cabinet, 87 lbs. **139.95***

New Heathkit Solid-State Wireless Intercom

29.95*

Plug two of them into standard 105-130 VAC outlets for 2-way communications. Three channels let you carry on 3 conversations in a 6-unit system, call one unit without disturbing the others in a 3-unit network. Intercoms have channel selectors, spring loaded "talk" button, slide-action volume control, and "dictate" for extended one-way communication.

Kit GD-113, 5 lbs. . . . . **each 29.95***

New Heathkit Solid-State Shortwave Receiver

59.95*

Four over-lapping bands provide continuous coverage from 550 kHz to 30 MHz, giving you local AM plus international, amateur, marine & weather and citizens band broadcasts. Features band-spread tuning for close station separation; BFO control for receiving code; signal meter; front-panel headphone jack; noise limiter; built-in AM antenna.

Kit SW-717, 10 lbs. **59.95***

New Heathkit Automatic Battery Charger...

Charges 12-volt batteries automatically. 10 amp max. charge rate. Impossible to hook up wrong. No charge setting to make ... can be left hooked up indefinitely. Meter monitor charge. **Kit GP-21,** 13 lbs. **29.95***

New Heathkit Automotive Timing Light...

Completely self-contained. Bright flash lets you work in sunshine. Adapter for connecting to distributor. Hi-impact plastic case.

Kit CI-1020, 2 lbs. **19.95***

duces a smooth response up to 90° off-axis. An N801-8A dividing network provides a crossover frequency of 800 Hz with complete control of the high-frequency output by a continuously variable shelving control.

Frequency response is 20-20,000 Hz. Continuous power rating is 60 watts and the impedance is 8 ohms. Housed in a natural oiled-walnut cabinet, the enclosure measures 29¾" high × 26$^{11}/_{16}$" wide × 9¼" deep. Altec Lansing

Circle No. 14 on Reader Service Page

CASSETTE DECK WITH DNL

The first cassette tape machine to incorporate the company's new dynamic noise limiter (DNL) system has been introduced as the 2100. It is a stereo record/playback deck and because

of its playback compatibility, the DNL circuitry will permit greatly improved performance from all pre-recorded cassettes, according to the company.

The Model 2100 has a slanted front control panel which permits its use in shallow and recessed areas. An exclusive three-position bias/equipment selector makes it possible to optimize the performance from different types of tapes; regular, high-performance, or chromium dioxide.

The solid-state unit records through microphones or from external sources such as phonograph, radio, tuner, or another tape recorder. Operation is by simple fingertip push-button/slide potentiometer and the jacks for microphones and stereo headphones are front-mounted for user convenience. Norelco

Circle No. 15 on Reader Service Page

MANUFACTURERS' LITERATURE

TOOLS FOR ELECTRONICS

A 36-page catalogue picturing and describing an extensive line of tools for electronics, telecommunications, and precision applications is now available for distribution.

The listing is divided into eleven categories covering adjusting tools, cleaning equipment, screw and nut drivers, extraction and insertion tools, gages, tool kits, production assembly and service tools, pliers, soldering equipment, telecommunications tools, and wrenches. Jonard

Circle No. 16 on Reader Service Page

MAGNETIC RECORDING DIGEST

A 28-page "Design Digest" for mini-digital magnetic recording has been issued. It is a comprehensive collection of applications information specifically compiled for personnel working with minicomputers, programmable desk-top calculators, credit-card verifiers, input/output systems, point-of-sale terminals, and other peripheral equipment.

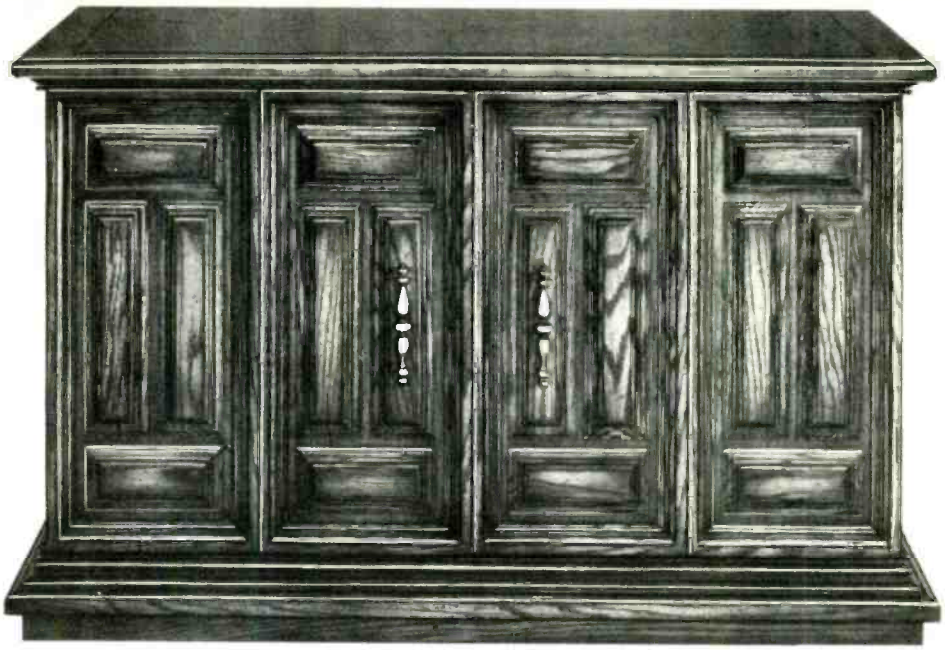
It features a detailed 9-page discussion of technical considerations and applications data for designers of low-cost recording systems and components; in-depth information on test procedures; and a 16-page section devoted to the characteristics and specifications of the firm's state-of-the-art tape heads for this field. Nortronics

Circle No. 17 on Reader Service Page

TECHNICIANS' INSTRUMENTS

A new catalogue, "Precision Test Instruments for the Professional Technician," is just off the press and ready for distribution.

It contains complete specifications and prices on sweep/marker generators, oscilloscopes, vec-



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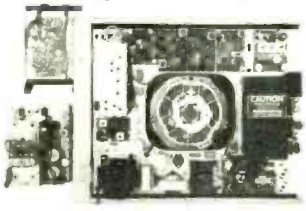

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New Heathkit Automotive Timing Light...

Completely self-contained. Bright flash lets you work in sunshine. Adapter for connecting to distributor. Hi-impact plastic case.

Kit CI-1020, 2 lbs. **19.95***

399.95*

New Heathkit DC-15 MHz Dual Trace Solid-State Oscilloscope...

The new Heathkit IO-105 is a high-performance scope designed to give you a wide range of measurements for use in instrumentation courses, engineering, R&D and electronics...at a fraction of the cost of comparable scopes! The IO-105 brings you complete dual trace and X-Y capability, allowing comparison of input/output for such parameters as loss, gain, phase shift and distortion. You can display two separate input signals in Channel 1 or Channel 2 modes of operation. Direct comparison of both signals is possible in alternate and chopped modes. In the alternate mode, both signals are alternately displayed on successive sweeps...at faster sweep speeds they are retained on the screen for time relationship comparison. In the chop mode, both signals are sampled at 100 kHz and appear as a function of the same time base. In X-Y, both channels are displayed as a function of each other...channel 1 controlling the vertical (Y) axis and channel 2 controlling the horizontal (X) axis. Both input channels are precision balanced for 5% or less phase shift to 50 kHz. Switch selected AC or DC coupling lets you trigger the time base at a given point on the signal or at a preselected DC level. Flipping a switch gives you automatic triggering at the crossover (O) point. You can also switch select positive or negative slope triggering. Internal, External and Line trigger inputs are provided. The convenient 18-position time base switch in a 1, 2, 5 sequence provides sweep rates from 100 msec/cm to 0.2 usec/cm. The separate vernier control with a calibrated position gives you continuous control between settings, while a 5-times magnifier switch allows detailed trace viewing. The DC-15 MHz bandwidth capability and 24 nsec rise time make possible analysis of high frequency signals and transient waveforms. Full bandwidth is featured from 20 V/cm to 50 mV/cm in 1, 2, 5 sequence. For special applications, a rear panel Sweep Gate output delivers a 3.5V pulse in sync with the sweep. A TTL-compatible external blanking input is also provided. Other features include a CRT bezel incorporating standard camera mount dimensions...flush mounted handle for easy stacking... easily-removable side panels for quick accessibility...compact, 15" depth for bench installation instead of cart. If you want to expand your analysis capability while holding the budget line, order your new Heathkit IO-105 now! Or send for more information and complete specification sheet.

Kit IO-105, 35 lbs. **399.95***

New Heathkit Vector Monitor...

49.95*

Designed for use with the Heathkit IG-28 Pattern Generator or similar units which display either "rainbow" (offset carrier) or NTSC patterns, the IO-1128 vector display helps you perform fine tuning, static and dynamic convergence, purity, 3.58 oscillator, reactance coil, phase detector transformer, demodulator angle check, and chroma bandpass adjustments. Represents exactly the color signals fed to CRT guns.

Kit IO-1128, 10 lbs. **49.95***

New Heathkit Electronic Switch... 39.95*

Provides simultaneous visual display of 2 input signals on a single trace oscilloscope. Has DC coupling and DC-5 MHz ±3 dB frequency response. Conventional binding posts permit fast hook-up. Can be left connected to scope. Ideally suited for digital circuit work; amplifier input and output for gain and distribution checks; simultaneous monitoring of 2 stereo channels.

Kit ID-101, 6 lbs. **39.95***

New Heathkit "Minimizer" kitchen waste compactor...

Today's most modern refuse handling method in easy-to assemble kit form! Now you can own the most exciting kitchen appliance on the market for less than you'd pay for any other comparable compactor. The Heathkit Minimizer lets Mom throw out the unsightly waste baskets and garbage cans for the latest in clean, convenient, odor-free disposal. The Minimizer handles all normal household trash — food wastes, glass and plastic containers, tin cans, wrappings, boxes, floor sweepings, light bulbs, etc. The packing ram descends with 2,000-lb. force to reduce refuse to almost ¼ of its original size, packaging the material in a strong disposable bag — one bag holds an entire week's trash for a family of four! When the bag's full, Mom simply folds over the top and removes a neat, dry package for normal rubbish pickup. And the Minimizer deodorizes the contents each time the drawer is opened and closed. The sanitation man will love Minimizer, too!

Simple, safe operation! To use, Mom merely inserts a Minimizer plastic-lined bag in the drawer and starts the compacting cycle. In less than a minute the ram forces down the trash, returns to its normal position, and the Minimizer shuts itself off. For maximum safety, the Minimizer uses a key lock switch and an interlock which automatically turns unit off if drawer is not fully closed or is accidentally opened during cycling. Your Heathkit Minimizer can be built-in under the kitchen counter or left free-standing. Its bright white enamel finish with marble-tone vinyl-clad top complements any decor. And you can build it yourself in 6 to 10 hours. Has long-life ⅓ hp motor, plugs into 110-120 VAC conventional household outlet. Kit includes 5 plastic-lined bags, one 9 oz. aerosol can of deodorant. Minimizer measures 34⅜" H x 15" W x 25½" D.

Kit GU-1800, 203 lbs. **199.95***

GUA-1800-1, 25 plastic-lined bags, 2 aerosol cans, 6 lbs. **10.95***

199.95*

New Heathkit Thermo Spotter

24.95*

Seeks out the temperature where your favorite fish live. Includes submersible sensing element, 100' of strong nylon cord, battery-powered solid-state meter circuitry . . . in high-impact plastic take-up reel case.

Kit MI-104, 3 lbs. **24.95***

New Heathkit Digital Depth Sounder

139.95*

Gives accurate, digital depth readings to 199'. Red warning light alerts you to shoals of 10' or less. Automatic noise rejection and range switching.

Kit MI-101-1 (w/thru-hull trans.) 6 lbs. **139.95***

Kit MI-101-2 (w/transom-mount trans.) 8 lbs. **139.95***

New Heathkit Economy Garage Door Opener

99.95*

Deluxe features include husky ¼ hp motor, heavy-duty chain drive, automatic safety reversing, automatic light. Preassembled transmitter & solid-state receiver.

Kit GD-309A, 43 lbs. **99.95***

Kit GD-309B (w/2 trans.) 43 lbs. **114.95***

SEE THESE KITS AT YOUR LOCAL HEATHKIT ELECTRONIC CENTER... or send for FREE catalog!

CALIF.: Anaheim, 330 E. Ball Road; **El Cerrito,** 6000 Potrero Avenue; **La Mesa,** 8363 Center Drive; **Los Angeles,** 2309 S. Flower St.; **Redwood City,** 2001 Middlefield Rd.; **Woodland Hills,** 22504 Ventura Blvd.; **COLO.: Denver,** 5940 W. 38th Ave.; **GA.: Atlanta,** 5285 Roswell Road; **ILL.: Chicago,** 3462-66 W. Devon Ave.; **Downers Grove,** 224 Ogden Ave.; **MD.: Rockville,** 5542 Nicholson Lane; **MASS.: Wellesley,** 165 Worcester St.; **MICH.: Detroit,** 18645 W. Eight Mile Rd.; **MINN.: Hopkins,** 101 Shady Oak Rd.; **MO.: St. Louis,** 9296 Gravois Ave.; **N.J.: Fair Lawn,** 35-07 Broadway (Rte. 4); **N.Y.: Jericho, L.I.;** 15 Jericho Turnpike; **New York,** 35 W. 45th Street; **OHIO: Cleveland,** 5444 Pearl Rd.; **Woodlawn,** 10133 Springfield Pike; **PA.: Philadelphia,** 6318 Roosevelt Blvd.; **Pittsburgh,** 3482 William Penn Hwy.; **TEXAS: Dallas,** 2715 Ross Avenue; **Houston,** 3705 Westheimer; **WASH.: Seattle,** 2221 Third Ave.; **WIS: Milwaukee,** 5215 Fond du Lac.

Retail Heathkit Electronic Center prices slightly higher to cover shipping, local stock, consultation and demonstration facilities. Local service also available whether you purchase locally or by factory mail order.

HEATH
Schlumberger

HEATH COMPANY, Dept. 15-10
Benton Harbor, Michigan 49022

☐ Enclosed is $_____, plus shipping.
Please send model (s)_____
☐ Please send FREE Heathkit Catalog.
Name_____
Address_____
City_____ State_____ Zip_____

*Mail order prices; FOB factory.
Prices & specifications subject to change without notice. CL-414

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Circle No. 14 on Reader Service Page

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The solid-state unit records through microphones or from external sources such as phonograph, radio, tuner, or another tape recorder. Operation is by simple fingertip push-button/slide potentiometer and the jacks for microphones and stereo headphones are front-mounted for user convenience. Norelco

Circle No. 15 on Reader Service Page

MANUFACTURERS' LITERATURE

TOOLS FOR ELECTRONICS

A 36-page catalogue picturing and describing an extensive line of tools for electronics, telecommunications, and precision applications is now available for distribution.

The listing is divided into eleven categories covering adjusting tools, cleaning equipment, screw and nut drivers, extraction and insertion tools, gages, tool kits, production assembly and service tools, pliers, soldering equipment, telecommunications tools, and wrenches. Jonard

Circle No. 16 on Reader Service Page

MAGNETIC RECORDING DIGEST

A 28-page "Design Digest" for mini-digital magnetic recording has been issued. It is a comprehensive collection of applications information specifically compiled for personnel working with minicomputers, programmable desk-top calculators, credit-card verifiers, input/output systems, point-of-sale terminals, and other peripheral equipment.

It features a detailed 9-page discussion of technical considerations and applications data for designers of low-cost recording systems and components; in-depth information on test procedures; and a 16-page section devoted to the characteristics and specifications of the firm's state-of-the-art tape heads for this field. Nortronics

Circle No. 17 on Reader Service Page

TECHNICIANS' INSTRUMENTS

A new catalogue, "Precision Test Instruments for the Professional Technician," is just off the press and ready for distribution.

It contains complete specifications and prices on sweep/marker generators, oscilloscopes, vec-

torscopes, color-bar generators, and other test equipment for the service technician. Lectrotech

Circle No. 18 on Reader Service Page

SERVICE REPLACEMENTS

A 20-page catalogue covering service replacement capacitors is now available. It contains descriptive information and rating charts for electrolytics, paper/film, filters, ceramic, mica, and a.c. capacitors. Listings include the more popular values for the servicing of radio and TV receivers, hi-fi stereo and associated audio equipment, ham radio, hearing aids, air conditioners, refrigerators, and industrial applications.

Also included in this new edition is a section of popular decade boxes featuring four resistance decades, three capacitance decades, and four inductance decade units. ARP/Aerovox

Circle No. 19 on Reader Service Page

HOME-TRAINING COURSES

An elaborate 96-page full-color catalogue of home-training course has been issued under the title "1971—NRI is the Way to Go!"

The booklet describes courses the school offers in color-TV, FCC license preparation, TV and radio servicing, communications electronics, computer electronics, electronics technology, automation, and applied mathematics in electronics. Information is also provided on the various kits which are used in the courses, material included in the companion lessons, and the job level of the student upon successful completion of the course or courses. National Radio Institute

Circle No. 20 on Reader Service Page

"HARD-TO-FIND" TOOLS

A 40-page catalogue covering an extensive line of professional tools for various applications has been published. This expanded listing covers not only tools normally associated with service work but tools used in other professions which can be readily, and usefully, adapted to servicing.

Each tool is pictured and described in detail and all options listed. Many of the tools are imported and some have been made especially for the company to its specifications. Brookstone

Circle No. 21 on Reader Service Page

POWER SUPPLIES

A new short-form catalogue containing condensed data on three- to five-output modular units; three- and four-output custom units for computer CRT terminal, card reader, and digital-cassette OEM applications; and three- to eight-output MIL-Spec custom units for avionics and mobile ground-communications terminal applications is available for distribution.

Astro-Space Laboratories, Inc., Research Park, Huntsville, Ala. 35806 will forward a copy on letterhead request.

NEW IEEE STANDARD

A new standard that provides guidance in the use of Le Système International d'Unités, otherwise known as SI (metric) units, and in forming and selecting decimal multiples and submultiples in science and technology has been published by the Institute of Electrical and Electronics Engineers.

The new standard, entitled "Rules for the Use of Units in the International System of Units," is designated IEEE Std. 322-1971. It uses standard U.S. spellings for such terms as kilogram, meter, liter, etc. The tables in the new standard have also been redesigned to present information in a more convenient format.

Single copies are $4.00 and may be ordered direct from the IEEE, 345 E. 47th Street, New York, N.Y. 10017.

MARKET DATA BOOK

The 1971 issue of the "Electronic Market Data Book" has just been published by the Electronic Industries Association.

Covering industry sales and trends through 1970, the 104-page book contains more than 50

charts and tables describing sales in the various segments of the industry. The book contains statistical data on consumer electronics, communications and industrial products, government products, components, world trade, industry employment, and earnings. Each section is illustrated with detailed tables and charts plotting sales patterns.

This data book should prove useful to market analysts, researchers, executives, stock analysts, technical librarians, and students. It is $15.00 a copy and may be ordered from the Publication Sales Office, EIA, 2001 Eye Street, N. W., Washington, D.C. 20006.

IR CRYSTAL SELECTION

Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. 06902 has issued a 32-page handbook entitled "Everything You've Always Wanted to Know About Crystals" for the benefit of spectroscopists.

The guide discusses the selection of suitable IR crystals for specific research studies. Considerations covered include transmission range, reaction to various samples, refractive index, reflection losses of crystals, and comparative cost. Charted properties and spectra illustrate advantages and limitations of seventeen different crystals.

A letterhead request to the company at the above address will bring a copy without charge.

FERRITE MAGNETS

The Arnold Engineering Company has issued a revised catalogue (Bulletin PM-133A) describing its line of "Arnox" hard ferrite permanent magnets.

Normal and intrinsic demagnetization curves are shown for six grades—1, 3, 5, 6, 7, and 8—along with other engineering information to aid in material selection. Data includes revised typical properties for grades 7 and 8, now with typical H_{ci} minimum of 4000 (min.) and 3000 (min.), respectively. The catalogue also contains a broader list of ring and rectangular block sizes available as well as a glossary of magnetic terms, typical uses, and advantages.

Letterhead requests should be addressed to J. K. Finn, sales manager of permanent magnets, The Arnold Engineering Company, P. O. Box G, Marengo, Ill. 60152.

FET's AND IC's

Siliconix Incorporated, 2201 Laurelwood Road, Santa Clara, California 95054 has just issued a new 16-page catalogue featuring a broad line of field-effect transistors and integrated circuits, with special emphasis on MOS and JFET switches, analog drivers, and gates.

This comprehensive short-form brochure also contains technical data on digital and linear IC's, current and voltage limiters, and high-frequency devices as well as information on CMOS multiplexers and switches, and the company's line of FET and IC chips.

INSTRUMENT DATA

The 1971-72 Instrument Databook and Rental Catalog provides coverage on over 3600 general-purpose electronic instruments. It logically divides the products and compares pertinent specifications.

Other sections cross-reference manufacturers' model numbers and contain some data sheets, simplifying alternate source selections. A special section is devoted to rental rates and further provides a "blue-book" of prices for instruments for sale.

Copies of this 264-page reference work are available on letterhead request to Leasametric, 822 Airport Blvd., Burlingame, California 94010.

LIGHTING CONTROLS

General Electric has announced publication of a newly revised 12-page brochure describing its full line of lighting controls for virtually every idustrial and commercial application.

Contacts may be inserted and coils changed

without disturbing the wiring. Included in the brochure are electrical ratings, dimensions, typical connection diagrams, and ordering information.

To obtain a copy of GEA-7873F, write General Purpose Control Products Dept., General Electric Company, Bloomington, Ill. 61701.

SOLID-STATE DEVICES

The 96 types of "Top-Of-The-Line" SK Series transistors, rectifiers, thyristors, and integrated circuits manufactured and tested for use specifically as replacements for over 20,000 semiconductor devices designed into original equipment are covered in a 72-page guide (SPG-202L) which is available for 35 cents.

The guide cross-references over 20,000 semiconductor devices numbers to SK-Series replacement semiconductors. In addition, a 23-inch x 35-inch (IL1367) Solid-State Quick Selection Replacement Chart (free) lists the 79 entertainment SK-Series devices by application for easy selection by service dealers and features performance data charts, dimensional outlines, and terminal diagrams for each type.

Letterhead requests (with payment) should be sent to RCA Distributor Products, Harrison, N. J. 07029.

R.F. INDUCTORS

An updated catalogue on r.f. inductors is now available from Airco Speer Electronics, St. Marys, Pa. 15857.

These inductors are made for use at radio frequencies and in pulse circuitry, with standard values ranging from 0.1 μH through 10,000 μH. The inductors offer high Q and SRF as well as high reliability and meet the requirements of MIL-C-15305, Revision D.

In addition to presenting revised data on the company's lines of conformal-coated, molded, and shielded inductors, the 12-page folder provides a key to the MIL-C-15305 color code plus procedures for measuring inductance and Q under this specification.

Requests for this catalogue should be addressed to the attention of Fred Darr at the company address.

NEON INDICATORS

A six-page, two-color brochure which provides detailed specifications, ratings, and physical dimensions on the "Elfin" neon 7-segment indicator has been announced.

A copy of Catalogue EL-77 can be obtained by writing to Tom Clark, Product Sales Manager, Alco Electronic Products, Inc. 8 Marblehead St., North Andover, Mass. 01845.

AUTOTRANSFORMER DATA

The choice and application of "Variac" adjustable autotransformers are simplified in the new 24-page Variac catalogue just issued by General Radio, 300 Baker Avenue, Concord, Mass. 01742.

The handbook starts with a general discussion of the selection and application of the units; proceeds through a complete listing of single-phase, three-phase, 400-Hz, and portable models; and concludes with a special section on how to get more out of a Variac. Also included is a description of the new "Minivolt," a miniature 50- to 400-HZ transformer for low-voltage a.c. control.

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ELECTRONICS MARKET PLACE

COMMERCIAL RATE: For firms or individuals offering commercial products or services. $1.00 per word (including name and address). Minimum order $10.00. Payment must accompany copy except when ads are placed by accredited advertising agencies. Frequency discount: 5% for 6 months; 10% for 12 months paid in advance.

READER RATE: For individuals with a personal item to buy or sell. 65¢ per word (including name and address). No minimum! Payment must accompany copy.

GENERAL INFORMATION: First word in all ads set in bold caps at no extra charge. All copy subject to publisher's approval. All advertisers using Post Office Boxes in their addresses MUST supply publisher with permanent address and telephone number before ad can be run. Closing Date: 1st of the 2nd month preceding cover date (for example, March issue closes January 1st). Send order and remittance to: Hal Cymes, ELECTRONICS WORLD, One Park Avenue, New York, New York 10016.

FOR SALE

GOVERNMENT Surplus Receivers, Transmitters, Snooperscopes, Radios, Parts, Picture Catalog 25¢. Meshna, Nahant, Mass. 01908.

CONVERT any television to sensitive big-screen oscilloscope. Only minor changes required. No electronic experience necessary. Illustrated plans, $2.00. Relco-A22, Box 10563, Houston, Texas 77018.

INVESTIGATORS, Latest Electronic Aids. Free Literature. Clifton, 11500-J NW 7th Ave., Miami, Florida 33168.

SENCORE, B & K Test Equipment Unbelievable Prices. Free Catalog and Price Sheet. Fordham Radio, 265 East 149th Street, Bronx, N.Y. 10451.

ELECTRONIC PARTS, semiconductors, kits. Free Flyer. Large catalog, $1.00 deposit. Bigelow Electronics, Bluffton, Ohio 45817.

NEW SEMICONDUCTOR LIGHT EMITTING DIODES. Bright red lights replace light bulbs. Typical life 100 years. Operate at 1.65 volts, 50 milliamps. Order 2 for $2.98 NOW. Data sheet and instructions included. Monsanto Company, Hobby Section, 10131 Bubb Road, Cupertino, California 95014.

ELECTRONIC COMPONENTS—Distributor prices. Free catalogue. Box 2581, El Cajon, California 92021.

ELECTRONIC Ignition. Various types. Information 10¢. Anderson Engineering, Epsom, N.H. 03239.

CONSTRUCTION PLANS: Laser . . . $2.00. Investigation aids—2-FM microphone transmitters . . . $1.00. FM telephone transmitter . . . $2.00. Sound telescope . . . $2.00. Space monitor-missile tracker . . . $2.00. Free equipment and kit catalog. Howard, 20174 Ward, Detroit, Michigan 48235.

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BURGLAR ALARM SYSTEMS. We manufacture intruder-fire detection systems, radar and perimeter types. Accessories available. Free Literature. Inquiries for dealership and wholesale prices must be on letterhead. U.S. and Canada only. Microtech Associates, Inc., Box 10147, St. Petersburg, Florida 33733.

EUROPEAN wholesale new products catalog $1.00 refundable. Deecow, P.O. Box 9308, North Hollywood, Calif. 91609.

INTEGRATED circuits, new TTL, DTL at very competitive prices. No minimum order. Send for list. Marco Enterprises, POB 216, Dayton, Ohio 45401.

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MECHANICAL, ELECTRONIC devices catalog 10¢. Greatest Values—Lowest Prices. Fertik's, 5249 "D", Philadelphia, Pa. 19120.

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ELECTRONIC IGNITIONS by Delta. Low discount prices. Write Southland Communications, Box 3591, Baytown, Texas 77520.

METERS Surplus, new, used, panel or portable. Send for list. Hanchett, Box 5577, Riverside, Calif. 92507.

BUILD your own Electronic Desk Calculator. Catalog 25¢. Digital Concepts, Box 5424, Charlottesville, Virginia 22903.

POTTER 906II-1 Computer Tape Transports—7 Track $295. 2400' computer tape from $2.50. Bellefleur, 229 West, Darien, Conn. 06820.

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PIV	25	50	100	200	400	600	800	1000	1200
1A*	—	.05	.06	.08	.10	.12	.16	.19	.24
3A	—	—	—	—	—	.23	.33	.45	.57
18A**	—	.15	.19	.29	.39	—	—	—	—
20A	—	—	—	.59	.75	1.13	1.35	1.73	2.10
40A	—	—	—	1.35	1.80	2.25	2.70	3.15	3.60

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PRV	25	50	100	200	400	600
1A*	—	—	—	.30	.55	.85
7A	—	—	—	.45	.90	1.20
18A**	—	—	—	.60	1.10	1.40
20A	.18	.30	.45	.70	1.15	1.95

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2N424, 85W, 80V—.65 2N498, 4W, 100V—.13
2N1724, 50W, 80V—.65 2N1719, 10W, 100V—.20

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Relays 6 different types .....6/$1.00
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Tie lugs, assorted .....50/$1.00
Push button switches, on-off, panel .....6/$1.00
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Output Transformer, 150 ohms-primary, 8 ohms-sec. ea. 69¢.
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1N 727A Zener, 36V, 250 MW .....1/75¢
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8H70 SIGNETIC Ultra high speed triple 3 input NANO ..... .40
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5942G Don Way, Carmichael, CA. 95608 916 966 2111

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LOWEST Prices Electronics Parts. Confidential Catalog Free. Knappco, 3174 8th Ave. S.W., Largo, Fla. 33540.

FREE Samples. Resistors, capacitors. Send 25¢ postage-handling. Comet Communications Company, 639 — 50th Street, Brooklyn, New York 11220.

OLD Radio Programs. Catalog $1.00. D.P. Parisi, 38 Ardmore Place, Buffalo, New York 14213.

ELECTRONICS HOBBYIST and professional builders love our 3¢ film resistors; 16¢ electrolytics and 1% micas, Great catalog, 35¢. Electrovalue-America, Box 27E, Swarthmore, PA 19081.

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WANTED

QUICKSILVER, Platinum, Silver, Gold. Ores Analyzed. Free Circular. Mercury Terminal, Norwood, Mass. 02062.

QUICK CASH . . . for Electronic Tubes, Semi-conductors, Equipment (Receivers, Transmitters, Scopes, Vacuum Variables, etc.) Send lists now! Write: BARRY ELECTRONICS, 512 Broadway, New York, N.Y. 10012 (212-WA 5-7000).

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PROFESSIONAL ELECTRONICS PROJECTS—$1.00 up. Catalog 25¢. PARKS, Box 25665A, Seattle, Wash. 98125.

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STEREO TAPE RENTAL for particular people. Free catalog. Gold Coast Tape Library, Box 2262, Palm Village Station, Hialeah, Fla. 33012.

RENT 4-track open reel tapes—all major labels—3,000 different—free brochure. Stereo-Parti, 55 St. James Drive, Santa Rosa, California 95401.

BARGAIN MUSIC, Tape, Equipment Catalog 25¢. Saxitone. 1776 Columbia Road, Washington, D.C. 20009.

VIDEO TAPE, 1 inch. x 1 mil x 1700 feet. Used. On computer reels. $6.00 each. Lahill, P.O, Box 656, Martinsburg, W. Va. 25401.

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LOW, LOW quotes: all components and recorders. Hi-Fi, Roslyn, Penn. 19001.

HI-FI components, tape recorders, sleep learning equipment, tapes. Unusual Values. Free catalog. Dressner, 1523 R Jericho Turnpike, New Hyde Park, N.Y. 11040.

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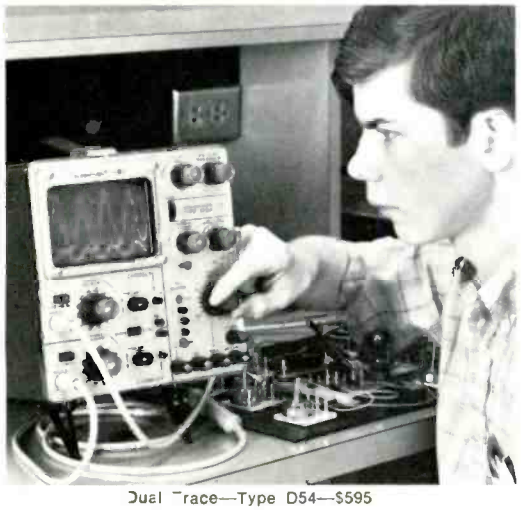

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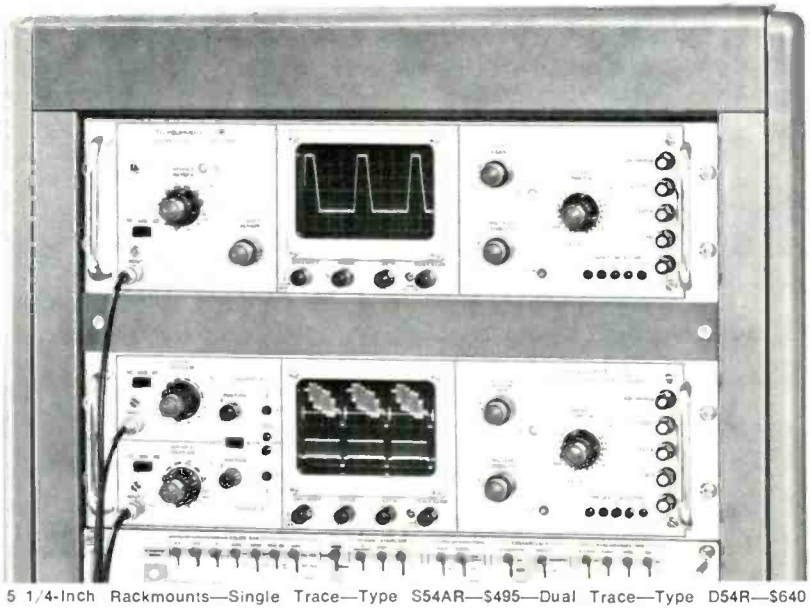

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