

16-PAGE BONUS! SPECIAL FOCUS ON AUDIO

# Popular Electronics®

WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE SEPTEMBER 1977/\$1.25

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**BUILD A 1/2-OCTAVE "REAL TIME" AUDIO ANALYZER**

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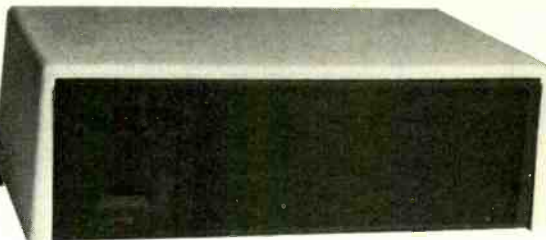
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# UPWARD MOBILITY.



# Burglar Alarm Breakthrough



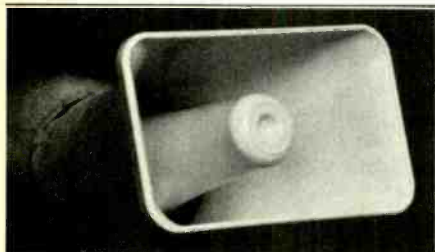
*A new computerized burglar alarm requires no installation and protects your home or business like a thousand dollar professional system.*

*The Midex security computer looks like a handsome stereo system component and measures only 4" x 10 1/2" x 7".*

It's a security system computer. You can now protect everything—windows, doors, walls, ceilings and floors with a near fail-safe system so advanced that it doesn't require installation.

The Midex 55 is a new motion-sensing computer. Switch it on and you place a harmless invisible energy beam through more than 5,000 cubic feet in your home. Whenever this beam detects motion it sends a signal to the computer which interprets the cause of the motion and triggers an extremely loud alarm.

The system's alarm is so loud that it can cause pain—loud enough to drive an intruder out of your home before anything is stolen or destroyed and loud enough to alert neighbors to call the police.



*The powerful optional blast horns can also be placed outside your home or office to warn your neighbors.*

Unlike the complex and expensive commercial alarms that require sensors wired into every door or window, the Midex requires no sensors nor any other additional equipment other than your stereo speakers or an optional pair of blast horns. Its beam actually penetrates walls to set up an electronic barrier against intrusion.

## NO MORE FALSE ALARMS

The Midex is not triggered by noise or sound, temperature or humidity—just motion, and since a computer interprets the nature of the motion, the chances of a false alarm are very remote.

An experienced burglar can disarm an expensive security system or break into a home or office through a wall. Using a Midex system there is no way a burglar can penetrate the protection beam without triggering the loud alarm. Even if the burglar cuts off your power, the four-hour rechargeable battery pack will keep your unit triggered, ready to sense motion and sound an alarm.

## DEFENSE AGAINST PEEPING TOMS

By pointing your unit towards the outdoors from your bedroom and installing an outside speaker, light, or alarm, your unit can sense a peeping tom, and frighten him off. Pets are no problem for the Midex. Simply put them in one section of the house and concentrate the beam in another.

When the Midex senses an intruder, it remains silent for 20 seconds. It then sounds the alarm until the burglar leaves. One minute after the burglar leaves, the alarm shuts off and resets, once again ready to do its job. This

shut-off feature, not found on many expensive systems, means that your alarm won't go wailing all night long while you're away. When your neighbors hear it, they'll know positively that there's trouble.

## PROFESSIONAL SYSTEM

Midex is portable so it can be placed anywhere in your home. You simply connect it to your stereo speakers or attach the two optional blast horns.

Operating the Midex is as easy as its installation. To arm the unit, you remove a specially coded key. You now have 30 seconds to leave your premises. When you return, you enter and insert your key to disarm the unit. You have 20 seconds to do that. Each key is registered with Midex and that number is kept in their vault should you ever need a duplicate. Three keys are supplied with each unit.

As an extra security measure, you can leave your unit on at night and place an optional panic button by your bed. But with all its optional features, the Midex system is complete, designed to protect you, your home and property just as it arrives in its well-protected carton.

The Midex 55 system is the latest electronic breakthrough by the Midex Corporation—a company that specializes in sophisticated professional security systems for banks and high security areas. JS&A first became acquainted with Midex after we were burglarized. At the time we owned an excellent security system but the burglars went through a wall that could not have been protected by sensors. We then installed over \$5,000 worth of the Midex commercial equipment in our warehouse. When Midex announced their intentions to market their units to consumers, we immediately offered our services.

## COMPARED AGAINST OTHERS

In a recent issue of *Consumers Report*, a leading consumer publication, there was a complete article written on the tests given security devices which were purchased in New York. The Midex 55 is not available in New York stores but had it been compared it would have been rated tops in space protection and protection against false alarms—two of the top criteria used to evaluate these systems. Don't be confused. There is no system under \$1,000 that provides you with the same protection as the Midex 55.

## YOU JUDGE THE QUALITY

Will the Midex system ever fail? No product is perfect but judge for yourself. All components used in the Midex system are of aerospace quality and of such high reliability that they pass the military standard 883 for thermal shock and burn-in. In short, they go through the same rugged tests and controls used on components in manned space ships.

Each component is first tested at extreme tolerances and then retested after assembly. The entire system is then put under full electrical loads at 150 degrees Fahrenheit for a full week. If there is a defect, these tests will cause it to surface.

## PEOPLE LIKE THE SYSTEM

Wally Schirra, a former astronaut and scientist, says this about the Midex 55, "I know of no system that is as easy to use and provides such solid protection to the home owner as the Midex. I would strongly recommend it to anyone. I am more than pleased with my unit."

Many more people can attest to the quality of this system but the true test is how it performs in your home or office. That is why we provide a one month trial period. We give you the opportunity to personally see how fail-safe and easy the Midex system is to operate and how thoroughly it protects you and your loved ones.

Use the Midex for protection while you sleep, to protect your home while you're away or on vacation. Then after 30 days, if you're not convinced that the Midex is nearly fail-safe, easy to use, and can provide you with a security system that you can trust, return your unit and we'll be happy to send you a prompt and courteous refund. There is absolutely no obligation. JS&A has been serving the consumer for over a decade—further assurance that your investment is well protected.

To order your system, simply send your check in the amount of \$199.95 (Illinois residents add 5% sales tax) to the address shown below. Credit card buyers may call our toll-free number below. There are no postage and handling charges. By return mail you will receive your system complete with all connections, easy to understand instructions and one year limited warranty. If you do not have stereo speakers, you may order the optional blast horns at \$39.95 each and we recommend the purchase of two.

With the Midex 55, JS&A brings you: 1) A system built with such high quality that it complies with the same strict government standards used in the space program, 2) A system so advanced that it uses a computer to determine unauthorized entry, and 3) A way to buy the system, in complete confidence, without even being penalized for postage and handling charges if it's not exactly what you want. We couldn't provide you with a better opportunity to own a security system than right now.

Space-age technology has produced the ultimate personal security system. Order your Midex 55 security computer at no obligation, today.

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# NOW, SCANNING OVER 6000 FREQUENCIES IS AS EASY AS USING A PUSHBUTTON PHONE.



Introducing the incredible, new Bearcat 210.

The exciting, new Scanner Radio with the space-age, computer control center that brings in every available public service frequency with pushbutton ease.

Bearcat's new 210 is as easy to program as a pushbutton phone. You can select any of the public service bands (all the available local frequencies) simply by pushing buttons.

Simply punch in the frequency numbers on the computer control center keyboard. Hit the Enter button. And you're programmed.

A large, flashing, digital readout panel shows you each frequency you've selected.

The Bearcat 210 patented search capacity lets you explore the endless world of every available public frequency out there, too.

Best of all, you're no longer limited to a given band or set of frequencies. The new Bearcat 210 is synthesized. Space-age circuitry lets you forget crystals forever.

Let's look at some Bearcat 210 features. And facts.

**5 BAND COVERAGE**—Includes Low, High, UHF and UHF "T" public service bands, the 2-meter amateur (Ham) band, plus other UHF frequencies.

**SCANS 20 CHANNELS PER SECOND**—In half a second, the Bearcat 210 scans all 10 channels.

**CRYSTAL-LESS**—Space-age circuitry with 5 custom designed chips. You never have to buy a crystal.

**TRACK-TUNING**—Patented track tuning provides full-band coverage on every band.

**AUTOMATIC LOCK-OUT**—Locks out channels and "skips" frequencies not of current interest.

**AC/DC**—Mobile mounting bracket included.

**SELECTIVE SCAN DELAY**—Adds a two-second delay to prevent missing transmissions when "calls" and "answers" are on the same frequency.

**AUTOMATIC SEARCH**—New, patented feature searches out any active local public service frequency automatically. For more police, fire, marine, emergency calls. And much more.

## THE NEW BEARCAT 210

THE MOST EXCITING THING THAT'S HAPPENED  
TO SCANNING SINCE SCANNERS.

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WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE

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ZIFF-DAVIS PUBLISHING COMPANY  
Editorial and Executive Offices  
One Park Avenue New York, New York 10016  
212-725-3500

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Midwestern Office  
The Pattis Group, 4761 West Touhy Ave.,  
Lincolnwood, Illinois 60466, 312-679-1100  
Thomas Hockney, Michael Neri, Gerald E. Wolfe  
Western Office  
9025 Wilshire Boulevard, Beverly Hills, CA 90211  
213-273-8050, BRadshaw 2-1161  
Western Advertising Manager: Bud Dean  
Japan: James Yagi  
Oji Palace Aoyama, 6-25, Minami Aoyama  
6 Chome, Minato-Ku, Tokyo 407-1930/6821,  
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## Editorial

### TV ELECTRONIC GAMES GROW UP

The sale of home TV electronic games peaked during the Christmas season of 1976, followed by a severe decline in 1977. Was the estimated 3-million video games sold in '76 just a passing fancy of the American public? Obviously not, since manufacturers are now producing with the expectation that 1977 sales will easily be twice those of 1976. And nonvideo electronic games will certainly make their mark this year, too.

Home TV games did not move as well as anticipated during the first half of '77 for a variety of reasons: (1) Christmas doesn't last all year (though the interest in games should be year-round); (2) reduced selling prices on games disheartened many retailers, who placed them on the back shelves; (3) programmable games are just around the corner. Concerning the latter, there are two companies already marketing them—Fairchild, who can't seem to keep up with consumer demands at \$170 a game plus "cartridges," and RCA, just really entering the market with a \$150 programmable model.

Dramatic decreases in prices for the older, dedicated video games are anticipated, with prognosticators saying that they will simulate the price dip exhibited by calculators and digital watches. But with the new dedicated games, such as Atari's Tank™ (with sound effects and joy-stick controls) at a suggested retail price of \$65, don't expect \$9.95 paddleball/hockey sellers to be around just yet.

The future of home video games is extraordinarily bright. And speaking of brightness, I find it amusing that one major TV receiver manufacturer, who also produces a TV electronic game, indicates that its receiver CRT warranty will be voided if electronic games are displayed on it. I've been personally assured by a top executive in the company that they have not seen a single defective CRT with burn spots caused by video electronic games—even with "duds."

The burn-spot question arose last year because some coin-operated units in arcades did display such CRT marring after a considerable period of video-game use. Users of home video games, however, do not play them sufficiently, without shutoff, to cause CRT damage.

It's projected that programmable video games will account for some 20% of unit sales in 1977, rising to 33⅓% by 1980. The omnipresent microprocessor will also be utilized for nonvideo electronic games. Parker Brothers (of "Monopoly" fame) will soon market a nonvideo electronic game based on the old "Battleship" game, as an example. Another toy maker, Mattel, will offer hand-held missile, auto race and football games with LED score readouts . . . Fidelity Electronics will be presenting an electronic chess game that the user plays against . . . Tryom Inc. will enable you to pit your wits against a microprocessor in the game of backgammon . . . Unisonic has a four-function calculator that can also permit one to play blackjack, even changing the deal when 38 cards are played, a la Vegas rules.

Although the programmable microprocessor games are destined to take over the electronic game market, at least in dollars, the input medium used will not necessarily be the ROM-type cartridges now prevalent. Among other possibilities that may evolve are matchbook-size tape cartridges and magnetic cards. Regarding the latter, kilobyte cards can be produced much as record discs can and, therefore, offer the potential for very low costs. The four-stripe plastic cards now available provide 1024 bytes, enough for most game programs, unless you want a Star-Trek game. Then you'll need a full blown microcomputer system.

Clearly, microprocessors are changing the face of consumer electronic products for increased efficiency and, in the case of games, to add another leisure activity to our lives.

*Art Salsberg*

# ONLY PIONEER COULD INTRODUCE A QUARTZ PHASE LOCKED LOOP TURNTABLE AND CALL IT A BARGAIN.

Today, there's nothing more accurate than a quartz phase locked loop turntable.

It's the kind of turntable they use at radio stations and recording studios. Where people are more interested in getting a great sound than getting a great price.

Well, Pioneer has just introduced the same kind of quartz turntable. Except ours was designed for people who *do* care about price.

It's called the PL570.

And like the professional quartz turntables you'll find in all those radio stations and recording studios across the country, it features a direct-drive motor that's quieter than ordinary motors.

Plus an electronic strobe circuit that lets you adjust the PL570 far more accurately than conventional strobes.

And the same kind of quartz phase locked loop technology that automatically corrects the turntable speed to account for things like the weight of the record and even

the amount of stylus pressure. So your records can always sound perfect, because they're always spinning perfectly.

But where the average quartz phase locked loop turntable offers you all this accuracy for around \$800, our new PL570 does it for under \$400. Which, you'll have to agree, is quite a bargain. (And that's even before you find out that the PL570 is one of the few fully-automatic quartz-lock turntables available today at *any* price.)

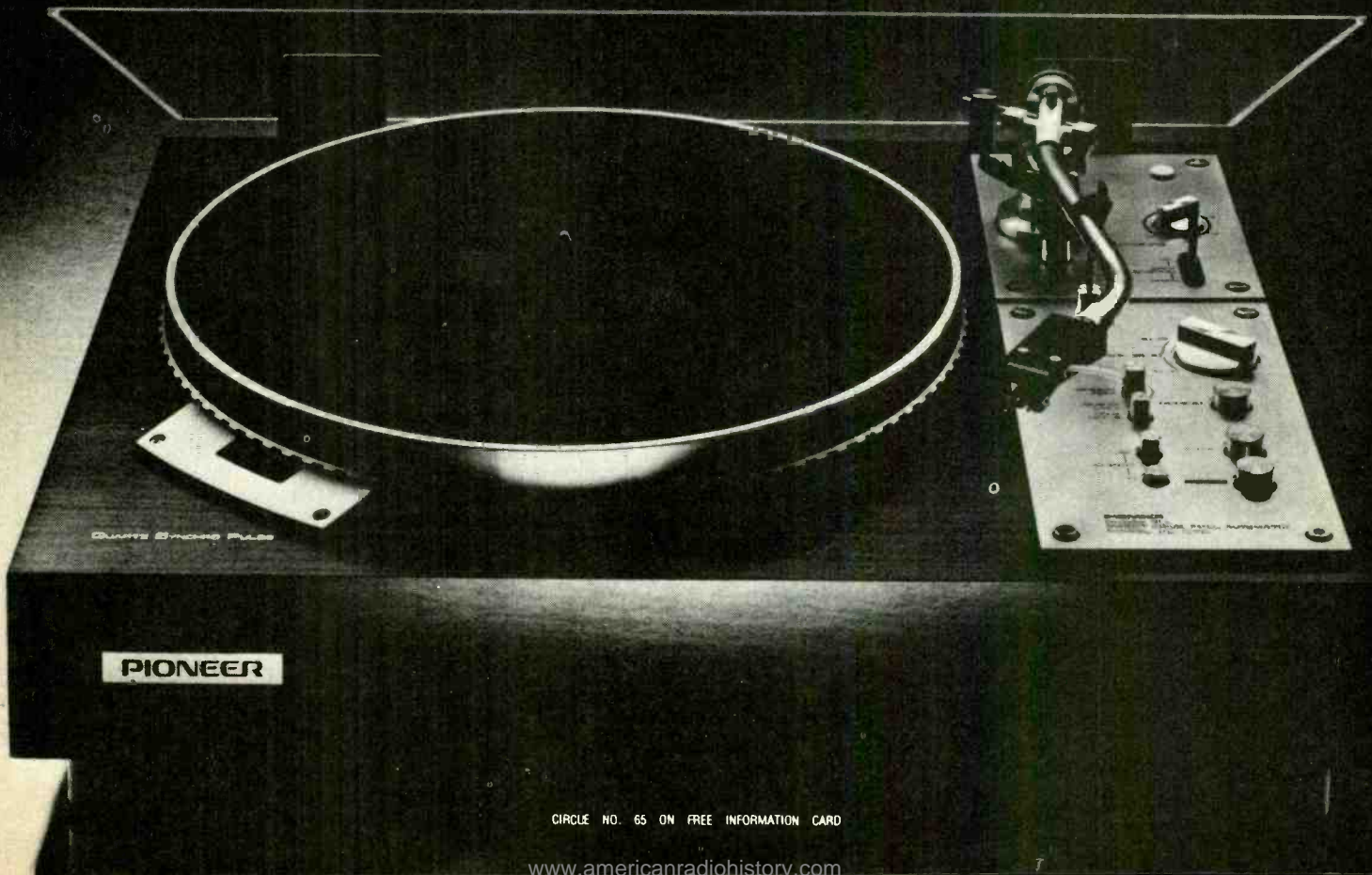
Of course, if you're looking for something a little less sophisticated than our PL570, there's still no need to look any further than Pioneer.

In all, we make eight high quality turntables. And while they may not all offer the same kind of features as our PL570, you can bank on at least one thing.

They all feature the same High Fidelity Components kind of value.

**PIONEER**  
WE BRING IT BACK ALIVE.

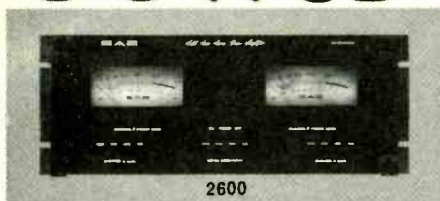
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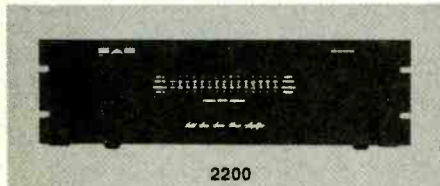
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2600



2400L



2200

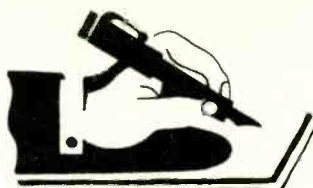
SAE's goal today, just as it has been for over 12 years, is the design and production of fine audio components; which offer the best value in both sonic performance and quality construction. Our line of amplifiers stand as a testament to this goal.

First, their design — all SAE amplifiers have fully complimentary circuitry. In this unique design approach, not only the output (as in conventional amplifiers), but the drive and input stages are completely complimentary. This ensures low transient and steady-state distortion, plus full stability and fast overload recovery. Combine this with our high slew rate for accurate transient response, feedback gain controls which will not degradate the input signal (2600, 2400L), and monocoque construction with its low weight and high reliability (2200, 2400L).

The result is state-of-the-art performance, but to realize this performance we must have the second part of our goal — production. In order to ensure optimum performance from these unique design concepts, SAE retains total control over the manufacture, selection, and assembly processes. We maintain 40,000 sq. ft. of production area where the latest techniques in metal and circuit board fabrication, component selection and product assembly are employed. The result of these efforts is the line of high quality amplifiers pictured here, each an outstanding value in its power range and each a true SAE component where performance and value come together — that's SAE Power!

# SAE

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## Letters

### CUTTING DOWN THREE BYTES

In "Debugging Aids" (Computer Bits, May 1977), Hal Chamberlain has mistakenly assumed that to insert a breakpoint in an 8080 program, a three-byte CALL instruction must be used. This gives the impression that a breakpoint feature on an 8080 is clumsy at best. We recommend that 8080 users initiate one of the RESTART (RST) instructions to implement a breakpoint feature in their software. The RESTART instructions are essentially one-byte CALL instructions and require only one memory location within the user's program for storage. In fact, the RST instruction is very similar to the BRK instruction of the 6502 microprocessor.

One nice feature of both the RST and BRK instructions is that both cause the incremented program counter (PC) to be saved on the stack. This makes the "print registers and continue" function very easy to implement on either of the microprocessors.—*Christopher A. Titus, Blacksburg, VA.*

### A QUESTION OF LEGALITY

Your May 1977 article titled "Build a Legal In-Flight Airline Receiver" was cause for inquiries from persons concerned with the requirements of the Federal Aviation Regulations (FAR) and the legality of using the receiver while on board an airliner. From the description of the receiver, it would be considered a "portable electronic device" and, therefore, comes under the requirements of FAR 91.19, titled "Portable Electronic Devices." This regulation places the responsibility for determining that the receiver will not cause interference to the aircraft navigation and communication systems with the air carriers, who should approve its operation while on board their aircraft.—*John W. Flavin, Chief Avionics Staff, Flight Standards Service, FAA, Washington, DC.*

### HI-FI FEEDBACK

I commend Ralph Hodges for the honesty of his observations and opinions expressed in the June 1977 Stereo Scene. I concur with his skepticisms on the validity of the "phase coherence" technique in speaker systems. While in theory it may produce better patterns on the CRT of an oscilloscope, its improvement of the sound as interpreted by the human ear-brain combination is questionable. The human brain is a remarkable decoding device of audio signals and is able to perceive "true" sound even through the phase distorting motion of turning one's head a fraction of an inch. The phase-coherent speaker

system can be valid only for a controlled and stationary listening device. Otherwise it becomes no better than a conventional speaker system.—*Michael P. Liben, New York, N.Y.*

I found "Instruments I Have Miked" (Stereo Scene, July 1977) totally engrossing. The article delivered a tantalizing amount of tips to use in professional recording that whetted my appetite to pursue a career in professional recording engineering. I would like to see a great deal more material published on this topic.—*H. Douglas Black, Raleigh, NC.*

### APPRECIATES "ELF"

I would like to express my appreciation for the best project I have ever built from the pages of POPULAR ELECTRONICS—the "Cosmac Elf" microcomputer (August 1976). Now I would like to see you publish plans for a cassette interface and other peripherals, plus appropriate programming, for the Elf. Keep up the good work.—*Louis Choiniere, Barton, VT.*

### HERB BRIER

Herbert S. Brier, W9AD, ex-W9EGQ, died May 21, 1977 at age 63. Herb was crippled by rheumatoid arthritis at the age of 12 and was unable to attend school past grade 7. In spite of this, he taught himself advanced mathematics, electronics, Spanish, and Braille. For 17 years he was POPULAR ELECTRONICS' Amateur Radio editor, and for years wrote the Novice column in CQ magazine. He wrote one book on amateur radio, and co-authored the VHF Handbook with William Orr, W6SAI. He held an Extra Class amateur license. During World War II, he ran the Gary (Indiana) emergency radio station, for which he received a citation. In later years, he maintained industrial electronic equipment in Gary and Chesterton, Indiana, and tutored local residents in electronics and amateur radio.

## Out of Tune

In "Digital Capacitance Meter" (April 1977), one end of C3, in Fig. 2, should be connected to pin 9 of IC1, not pin 13 as shown. The normally open contact of S1 should be connected to pin 13 of IC1, not pin 9 as shown. Also, at the center of Fig. 3, the 1.5-k resistor should be 1.5 ohms. The second lowest range measures capacitances from 0.01 to 0.99  $\mu$ F. When the switch is placed in this position, it automatically inserts a decimal point in the proper location and the display gives the capacitance directly in microfarads.

In "RC Circuit Quiz" (July 1977), the differentiator should be circuit H, and the integrator circuit J. The answers, as given, were reversed.

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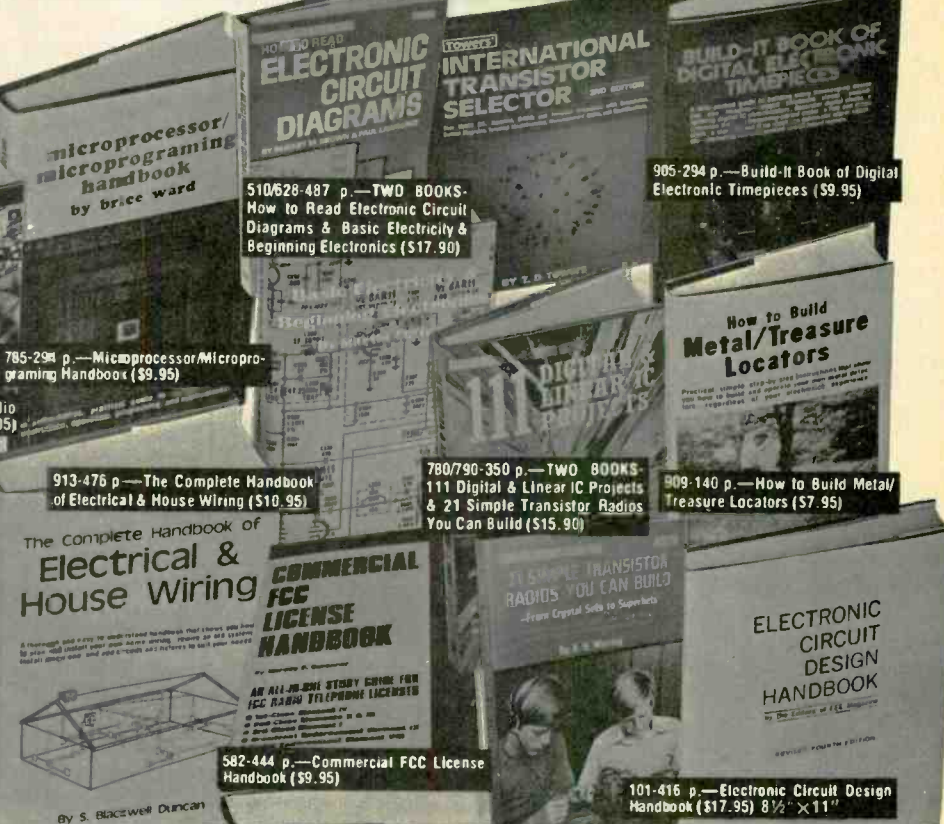
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## New Products

Additional information on new products covered in this section is available from the manufacturers. Either circle the item's code number on the Reader Service Card inside the back cover or write to the manufacturer at the address given.

### SONY THREE-WAY SPEAKER SYSTEM

Sony's Model SU-3000 speaker system features a "carbocon" cone material that is claimed to provide reproduction that virtually mirrors the original sound. The three-way bass-reflex system is rated to be driven by 20 watts of amplifier power and to handle up to 150 watts over a frequency range of 35 to 20,000 Hz. Crossovers are at 600 and 5500 Hz, while woofer rolloff and tweeter turn-on are at a 12-dB/octave rate. The midrange driver and tweeter are fronted by radial diffusion elements which are said to smooth the frequency response and provide improved dispersion and imaging. Dual-slope level control network and adjustable midrange and tweeter controls permit adjustment to suit the listening room. Size is 34¼"H × 14¼"D × 13½"W (87 × 36.2 × 34.3 cm) and weight is 59 lb 9 oz (27 kg). \$300.

CIRCLE NO. 89 ON FREE INFORMATION CARD

### BEARCAT PROGRAMMABLE SCANNER

Communications Electronics' new Bearcat 210 five-band programmable "super" synthesized scanning receiver needs no crystals. It gives the user push-button access to more than 16,000 different frequencies in the 32-to-50-, 146-to-174-, and 416-to-512-MHz ranges, which include frequencies on 2 me-



ters and the entire 0.75-meter amateur band. The synthesizer permits one to enter or change any 10 frequencies in seconds. The receiver scans entered frequencies at a rate of 20 channels per second. A digital input and display allows the operator to see the frequencies selected as well as those being received. Automatic search scanning and lock-out are included. Sensitivity is rated at 0.6µV for 12 dB SINAD on the low and high bands. \$319.95.

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### MARANTZ STEREO RECEIVERS

Marantz has added three popularly priced AM/FM receivers to its line. Featuring dual-gate MOSFET front ends, the receivers are equipped with zone-detented tone controls for convenient variation of bass, midrange, and treble frequencies. Other features include Dolby FM de-emphasis (25-µs), full complementary symmetry direct-coupled amplifier section, phase-locked-loop multiplex demodulator, and quadraxial-ready jack so



that a 4-channel decoder can be connected should a standardized 4-channel FM broadcast system be approved by the FCC. The three new models are 2226 (26 watts), 2238 (38 watts), and 2252 (52 watts), all into 8-ohm loads. The 2226 is rated at no more than 0.2% THD with an 8-ohm load; the other two models, 0.1%. All models include separate FM-tuning and signal-strength meters.

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### McKAY DYMEK COMMUNICATIONS RECEIVER

McKay Dymek has introduced an all-wave, fully synthesized communications receiver covering the frequency range of 50 kHz to 29.7 MHz. The DR-22 is equipped with switch-selectable 4- or 8-kHz bandwidth ceramic filters. Preceding the ceramic filters are crystal filters at 30 MHz and 10.7 MHz. All AM broadcast, international shortwave, ham radio contacts, and CB channels are tuned in by means of a digital phase-locked-loop tuning system. A large five-digit LED readout indicates the frequency being received, which is selected by four rotary switches and a fine-tuning control with a ±5-kHz tuning range. Standard features include high-impedance audio output for recording, 455-kHz i-f output jack, mute control for use with transmitters, front-panel headphone jack, internal speaker and control switch, and external speaker connections. The receiver is housed in a textured black enamel case with teak wood sides and brushed aluminum face. Measures 17.5"W × 16"D × 5.1"H (44.5 × 40.7 × 13.0 cm). \$2,900.

CIRCLE NO. 93 ON FREE INFORMATION CARD

### CONTINENTAL SPECIALTIES SOCKETS

Continental Specialties has two new "Experimenter" 300 and 600 solderless breadboarding sockets, which provide 94 five-point terminals, plus two 40-point bus strips for a total of 550 solderless tie-points. The 600, priced at \$10.95, has a 6/10" center channel, making it suitable for microprocessors, clock chips, RAM's, ROM's, and other larger DIP

packages. The 300 has a 3/10" center channel that is right for smaller DIP's. Both sockets also accept transistors, LED's, resistors, capacitors, pots and virtually all types of discrete components.

CIRCLE NO. 94 ON FREE INFORMATION CARD

### HEATH AUDIO OSCILLATOR

Heath's IG-1272 low-distortion oscillator is designed for a variety of audio uses. It provides a low-distortion sine-wave output over a frequency range from less than 5 Hz to 100 kHz. It offers both pushbutton and variable-frequency operation. Output is said to be flat across its entire frequency range. Attenuation accuracy is ±0.2 dB. Hum and noise are rated at 0.01% or less. Includes an ac rms volts meter with a dB scale and a level control, plus an interval load (600 ohms) and external load switch. It comes with cable and clip leads as a kit for \$129.95, factory assembled (SG-1272). \$190.

CIRCLE NO. 90 ON FREE INFORMATION CARD

### PANASONIC MOBILE CB TRANSCEIVER

Panasonic's Model RJ-3450 is a two-piece AM 40-channel rig. The CB transceiver is separate from its controls to allow the bulkier section to be hidden away under a seat or, with an optional extender cable, in the car's trunk. The remote-control microphone contains all controls, switches, and displays



(LED), as well as the speaker. The RJ-3450 also features a built-in scanner system that can be operated either automatically or manually. It can be set to either V (vacant) or B (busy) to automatically locate an open or a busy channel. In the manual position, channels can be stepped through, up or down, one at a time. Other controls are a squelch control, noise-blanker/ant switch, and a REG/CH-9 switch. \$229.95.

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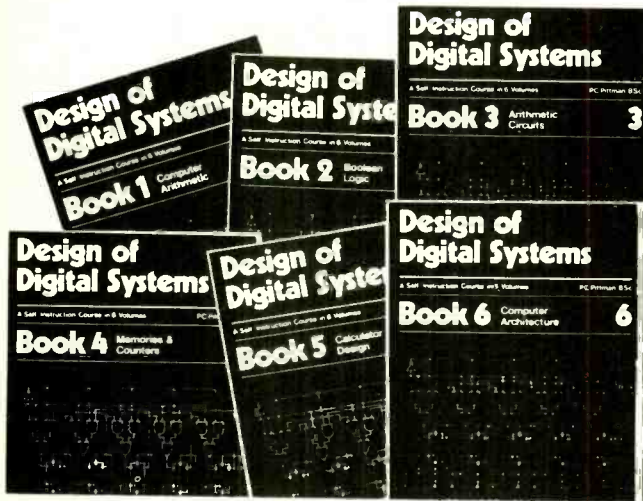
### EDMUND SCIENTIFIC BURGLAR ALARMS

Two new security alarms are being offered by Edmund Scientific. One is a portable that can

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# Understanding Digital Electronics

## New teach-yourself courses



Design of Digital Systems is written for the engineer seeking to learn more about digital electronics. Its six volumes — each 11-1/2" x 8-1/4" — are packed with information, diagrams and questions designed to lead you step-by-step through number systems and Boolean algebra to memories, counters and simple arithmetic circuits, and finally to a complete understanding of the design and operation of calculators and computers.

The contents of Design of Digital Systems include:

**Book 1** Octal, hexadecimal and binary number systems; conversion between number systems; representation of negative numbers; complementary systems; binary multiplication and division.

**Book 2** OR and AND functions; logic gates; NOT, exclusive-OR, NAND, NOR and exclusive-NOR functions; multiple input gates; truth tables; De Morgans Laws; canonical forms; logic conventions; Karnaugh mapping; three-state and wired logic.

**Book 3** Half adders and full adders; subtractors; serial and parallel adders; processors and arithmetic logic units (ALUs); multiplication and division systems.

**Book 4** Flip flops; shift registers; asynchronous and synchronous counters; ring, Johnson and exclusive-OR feedback counters; random access memories (RAMs) and read only memories (ROMs).

**Book 5** Structure of calculators; keyboard encoding; decoding display data; register systems; control unit; program ROM; address decoding; instruction sets; instruction decoding; control program structure.

**Book 6** Central processing unit (CPU); memory organization; character representation; program storage; address modes; input/output systems; program interrupts; interrupt priorities; programming; assemblers; computers; executive programs; operating systems and time sharing.



Digital Computer Logic and Electronics is designed for the beginner. No mathematical knowledge other than simple arithmetic is assumed, though the student should have an aptitude for logical thought. It consists of four volumes — each 11-1/2" x 8-1/4" — and serves as an introduction to the subject of digital electronics. Everyone can learn from it — designer, executive, scientist, student, engineer.

Contents include: Binary, octal and decimal number systems; conversion between number systems; AND, OR, NOR and NAND gates and inverters; Boolean algebra and truth tables; De Morgans Laws; design of logic circuits using NOR gates; R-S and J-K flip flops; binary counters, shift registers and half adders.

In the years ahead the products of digital electronics technology will play an important part in your life. Calculators and digital watches are already commonplace. Tomorrow a digital display could show your automobile speed and gas consumption; you could be calling people by entering their name into a telephone which would automatically look up their number and dial it for you.

These courses were written by experts in electronics and learning systems so that you could teach yourself the theory and application of digital logic. Learning by self-instruction has the advantages of being faster and more thorough than classroom learning. You work at your own pace and must respond by answering questions on each new piece of information before proceeding.

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be carried anywhere, while the other is designed for permanent installation. The latter is useful for cars, trucks, RV's, boats, and industrial plant protection, while the portable unit is for office and personal security. The portable alarm uses ultrasonics to secure a "protected" area. Each alarm is programmed with its own specific two-digit "off" code. Portable alarm No. 61,119 with 9-volt battery: \$79.00. The No. 61,120 12-volt permanent alarm, with lead-in wires: \$79.00.

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#### MXR NOISE-REDUCTION ACCESSORY

The MXR Componder is a noise-reduction device that is said to be capable of doubling the dynamic range of most open-reel and cassette tape decks. In operation, it compresses the dynamic range of signals being recorded and then expands them upon playback. The compression/expansion process is claimed to reduce noise and allow quiet passages to be heard while, at the same time, allowing musical peaks to be reproduced without distortion. The Componder is designed to process all frequencies at all levels in a similar manner, thereby eliminating the need for critical level adjustments. A switch is provided to bypass the Componder's circuitry, and a LEVEL MATCH control allows for compensation of level differences between the inputs and outputs of a tape deck. The system is designed for use on

three-head decks. Dynamic range is specified as being 100 dB and frequency response at 30 to 20,000 Hz  $\pm 1$  dB at 0 dBV.

CIRCLE NO. 97 ON FREE INFORMATION CARD

#### OK WIRE WRAP DISPENSER

The new WD Series Wire Wrap wire dispenser from OK Machine and Tool Corp. features a unique cutting and stripping capability. Wire is drawn out of the dispenser to the required length. Then a built-in plunger cuts the wire free, while a pull on the cut wire through the stripping blade removes the insulation without nicking the wire. The other end of the wire is just as neatly and quickly stripped away. The dispenser comes with a 50' (15-m) spool of AWG 30 (0.25-mm) industrial-quality Kynar<sup>®</sup> insulated silver-plated solid copper wire. Insulation is available in blue, white, red, and yellow. The dispenser is reusable when the wire runs out simply by inserting a new spool.

CIRCLE NO. 98 ON FREE INFORMATION CARD

#### JVC PORTABLE/HOME CASSETTE DECK

JVC America's Model CD-1636 portable/home stereo cassette deck, with its new super ANRS, is said to have reduced tape hiss and expanded dynamic range at high frequencies. A monitor speaker for field use is built-in. The deck is designed to operate for up to 12 hours with D-size batteries, but will

also operate from a 120 V ac power source for home use. Features include dual VU meters and battery condition checker, 3-digit tape counter with reset button, automatic tape stop, Sen-Alloy tape head for record/play and ferrite head for erase. Signal-to-noise ratio is rated at 54 dB, improved by 10 dB above 5 kHz with ANRS; wow and flutter, 0.08% rms; THD, 1.2% at 0 VU with standard tape, 1.5% with chrome tape. Frequency response is 45 Hz to 16 kHz  $\pm 3$ dB (chrome). Weight is 10.1 lbs. Measurements are 14%<sup>W</sup>  $\times$  9%<sup>D</sup>  $\times$  3%<sup>H</sup> (37  $\times$  24  $\times$  10 cm). \$350.

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#### TURNER AM/FM/CB CAMOUFLAGE ANTENNA

A new "camouflage" AM/FM/CB antenna that features a new, easy-to-install design is available from Turner Division of Conrac Corp. The Model SK750 antenna is made to look and function like any other auto antenna, but provide full 40-channel coverage on CB with minimal VSWR. It has a removable 42" (106.7-cm) stainless steel whip and a mounting that adapts to sloping surfaces. The filters in the hermetically sealed watertight housing act as "band separators" to keep the AM/FM and CB signals from mixing. Suggested retail price is \$25.00. (The same antenna configuration is also available for CB only as the Model SK755 for \$19.95.)

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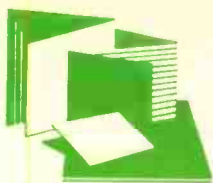
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## New Literature

### CB INTERFERENCE CURES

Electronic Specialists offers a flyer describing cures for common FM, TV and audio interference caused by CB radios. Featured are solutions to problems such as interference picked up by stereo speaker leads and hi-fi phono inputs, and interference conducted over ac power lines. Address: Electronic Specialists Inc., Box 122, Natick, MA 01760.

### RCA REPLACEMENT GUIDE

RCA offers its 1977 Solid State Replacement Guide, SPG-202T. The new 195-page guide cross references more than 123,000 solid-state devices, transistors, rectifiers, thyristors and IC's that can be replaced with RCA SK-Series types. Features of the publication are an index of SK-Series semiconductors and accessories, application information, line

drawings of dimensional outlines and terminal arrangements, and a listing of mounting hardware. Cost, \$1.50. Address: RCA Distributor and Special Products Div., PO Box 85, Rùnnemede, NJ 08078.

### SILTRONIX ANALOG SWITCH HANDBOOKS

Two new publications from Siltronix facilitate analog switch system design. The first, titled "Analog Switches and Their Applications," is a 352-page handbook covering the theory and practical application of analog switches. It begins with an explanation of FET switch characteristics and driver circuits and moves on to multiplex systems, signal conversion, and n-path filters. Cost \$4.00. The second, "High Speed CMOS Analog Switches," is a 20-page catalog of Siltronix's DG3000 series CMOS analog switches. Available free. Address: Marketing Services Dept., Siltronix, Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054.

### MARINE RADIOTELEPHONE CATALOG

A new booklet from Motorola describes its line of Triton marine radiotelephones. Featured are the Triton 55/75, a fully synthesized unit with simplified channel identification, and the Triton SSB marine radiotelephone, which has FM reliability at distances greater than 30-40 miles. Other models described are

bridge-to-bridge marine radio telephones, vhf-FM limited Coast Guard Station models, and FM portables. Accessories are also listed. Address: Motorola Communications Group, Literature Distribution center, 1301 E. Algonquin Rd., Schaumburg, IL 60196.

### MEMOREX VIDEO TAPE NEWSLETTER

Understanding the video picture is the topic of Vol. 3, No. 1 of SCAN, a 4-page newsletter for video-tape users offered by Memorex. The issue discusses how a video picture is created within a monitor/receiver and gives tips on troubleshooting the video playback system. Address: SCAN, Memorex Corp., PO Box 420, Santa Clara, CA 95052.

### NEDA 1977 BATTERY INDEX

The National Electronic Distributors Association (NEDA) offers the 1977 Battery Index. A replacement guide for over 182 battery types, the index uses number suffixes to list batteries according to their group; rechargeable NiCd batteries and various groups of non-rechargeable types. Major manufacturers included are Bright Star Industries, Eveready, Mallory, Burgess, Inc., and Ray-O-Vac. Price 50 cents. Address: National Electronic Distributors Association (NEDA), 3525 W. Peterson Ave., Suite 601, Chicago, IL 60659.

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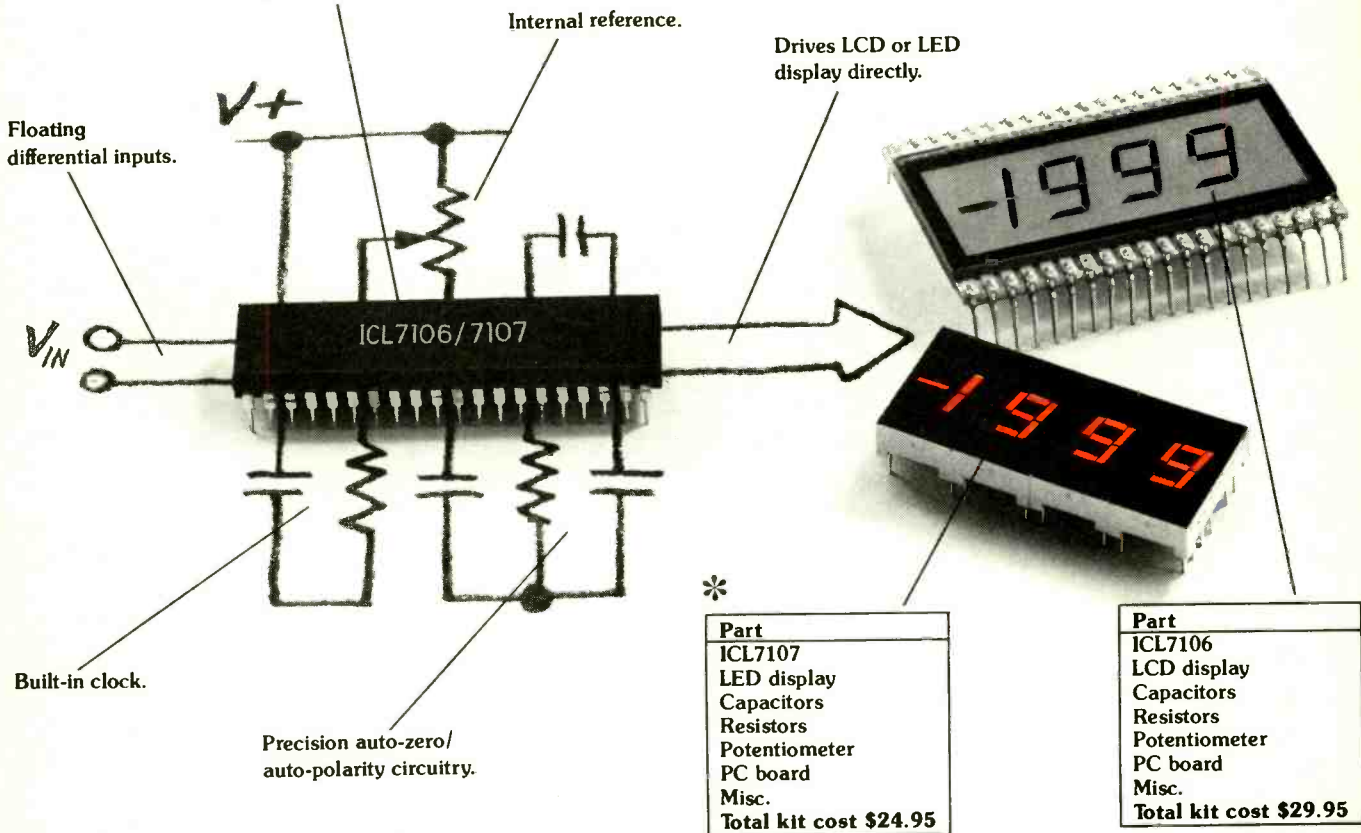


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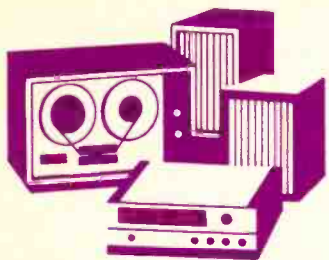
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# INTERSIL



# Stereo Scene

By Ralph Hodges

## RECORDS AND THE VERTICAL ANGLE

**W**HAT THE world still lacks, surprisingly enough, is a really adequate conceptual model for a record player. To be sure, the overall principles have always been obvious: the groove undulates, thereby wiggling the stylus, which is connected to an electrical generator, etc. But the intimate geometry of the way a record is played, taking place as it does on what is really a submicroscopic scale, remains somewhat obscure. Vinyl indentation affects stylus tracing in ways that are not wholly understood; frictional drag and other forces on the stylus assembly alter the geometry of the tracing and transduction situations in complex ways: the rate of stylus and record wear—and the form in which it manifests itself—is not completely predictable. Periodically there are technical papers written to expand or refute existing theories of stylus-groove interaction, but the ultimately authoritative paper has yet to appear.

Fortunately, we don't have to fully understand the record player to use it. In fact, the system seems to be surprisingly tolerant of human error. A cartridge can be installed in a tonearm in five minutes, using the crudest "eyeballing" techniques for alignment, and almost no one will object to the audible results achieved thereby. Considering that the stylus inhabits a world in which the mi-

niscule wavelengths of visible light are beginning to become significant dimensions, its apparently obliging response to very slapdash alignment is a little unexpected.

In the back of many a well-furbished mind there has always been the nagging idea that this can't be right; that closer attention to record-player alignment *must* result in superior reproduction. The trouble is, no one's been able to demonstrate this to the satisfaction of the record-playing world at large.

**The Shreve-Rabco Arm.** About a year ago (November 1976) I wrote in this space of a modification to the Rabco SL-8 and SL-8E tonearms performed by Dr. David Shreve (Department of Mathematics, University of Wisconsin). At that time I referred only obliquely to several interesting claims made by Dr. Shreve, among them being that the vertical angle (the "rake angle," as it is often called) at which the stylus impinges on the record surface as viewed from the side is critical to within a very small fraction of a degree.

Dr. Shreve referred to his findings as being totally empirical, and he has never shown any inclination to "dignify" his claims with any nice, neat explanatory theory (although there are some very attractive ones free for the taking). His attitude has always been: "I can demonstrate the phenomenon, and if you can hear it (and apparently everyone has so far) you're free to make of it what you will."

I have been "making what I will" of all this ever since, and my conclusion—supported by the informed opinions of others who have looked into the matter—is that we have at hand a very basic and nontrivial demonstration of how disc-playing systems can be significantly improved.

**The Scanning Aperture.** Shortly after my first meeting with Shreve, I brought his work to the attention of Mitchell Cotter, founder and chief executive of Verion Audio and a researcher with a long and varied background in many areas of practical and theoretical audio. As it happened, Cotter was already convinced of these effects' existence, although he had not fared notably better than others in demonstrating their audibility. He was, however, somewhat surprised by Shreve's reports on the criticalness of the vertical angle. True, theory seemed to predict this, but theory had not quite been batting 1000 in corresponding to the perceived and/or measurable world of record playing.

What exactly *does* theory seem to predict? I couldn't begin to deal with the complexities here, even if they could be pursued profitably in a nonmathematical presentation. But some of the individual effects can be mentioned. Imagine viewing the stylus (a Shibata or other type of "line-contact" CD-4 stylus) from the side as it traces a record groove. If the rake angle is correct, the stylus' contact line will be parallel with the modulation angle of the groove. If it is not, the upper part of the stylus will either lead or lag the lower part in tracing the groove.

So far the situation seems analogous to tape-head alignment. When the azimuth of a playback head is disturbed, the "scanning aperture" corresponding to its gap becomes effectively wider, and high-frequency response begins to fall off in the same way as it would if the gap were physically wider. However, while the "effective" edge of the stylus is also a scanning aperture, a simple loss of high-frequency response is not the only predictable result of incorrect rake angle. Whether azimuth is right or not, a tape head is always scanning the flat plane of the tape surface. The stylus "sees" a flat plane from a modulated groove only when its rake angle is absolutely on the button. Otherwise it traces—or tries to trace—a curvature that can become rather complex, with the skewed contact line of the stylus doing its best to strike a rough average between the various groove contours it is encountering. Also, groove curvature is a definite factor in stylus indentation of the record material, so that a further ambiguity in tracing is introduced.

At this point, let's consider the several dimensions in which a stylus moves. Ideally, all its excursions take place within a curved plane—a section of the shell of a sphere that has its center at the sty-

(continued on page 20)

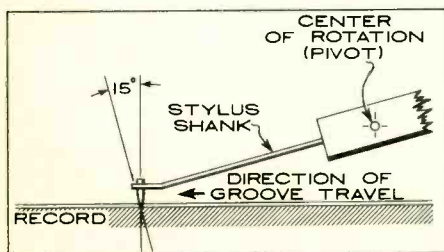


Diagram shows vertical tracking angle and stylus pivot point.



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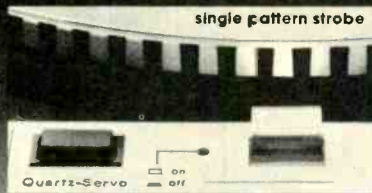
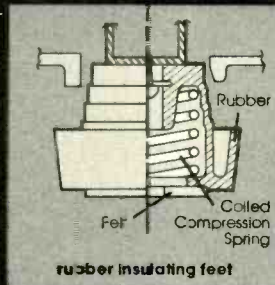
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lus's pivot point. Also ideally, the shell is almost infinitely thin. However, especially in the case of a line-contact stylus, an error in rake angle "thickens" the shell, with resulting phase-time ambiguities. Such errors are inevitable; even vertical stylus excursions produce them. But at what point, if any, do they become audibly detrimental? And what is their effect when they combine with other errors in tracing geometry?

**The Listening Approach.** Since the means (the Shreve/Rabco arm) seemed to be at hand, we decided to let theory rest for the time being and work toward empirical findings with listening tests. The Rabco SL-8/SL-8E arm, as you may be aware, is (or was; it is no longer made) a radial-tracking mechanism. The arm carriage transits on an aluminum track that has vertical screws at either end to facilitate height and levelling adjustments. Thus the stylus rake angle can be varied minutely and repeatably even while a record is playing, without doing any great violence to other parameters of cartridge alignment (we invariably found ourselves working with a range of rake angles spanning considerably less than a degree of difference). This, plus its other refinements, made the arm a viable experimental tool in our judgment.

Once we (Dr. Shreve, Mitchell Cotter, and I, for the most part) had confirmed that we could hear these seemingly small differences and could agree on what the "right" sound was, we evolved individually for the most part, but with close agreement later on) a number of working hypotheses.

(1) The optimum vertical adjustment should not be the same for every record. Variables such as different record-cutter geometries, different cutting practices, and even different record thicknesses would logically prevent this.

(2) A warped record should make the optimum vertical adjustment less easy to achieve, if it could be achieved at all.

(3) Adjusting the carriage track of the arm so that it is not quite parallel with the record surface should result in a change of vertical angle over the record side, and therefore a change in the "sound." (It would also result in slight changes of other alignment parameters; the big questions concerned which changes, if any, would be most audible.)

(4) A true line-contact CD-4 stylus should be quite critical to adjust; and once properly adjusted, it might conceivably yield performance superior to that of a "conventional" stylus.

(5) A change in stylus force should change the rake angle, and hence the "sound."

After about a year of listening, our general observations are as follows.

(1) The optimum vertical angle is not the same for every record. With the records we have sampled we've encountered a range of "optima" spanning a mere 25 minutes (!) of arc. However, some records audibly perform quite badly when used with a different record's optimum setting, although they may sound very good when individually compensated for.

(2) Warped records are not as difficult to adjust for as anticipated. An attempt at explaining this must await further work. It is true that we've not been extraordinarily successful in obtaining warped and unwarped copies of the same record. It almost appears that a given release is either unwarped or warped, although the warps are usually not the same. We have not attempted to deliberately warp any records.

(3) Making the carriage track nonparallel to the record surface alters the sound over a record side in an identifiable way. Deliberately misaligning the effective length of the radial arm to create a similar change in lateral tracking-angle error over the record side does not seem to alter the sound as recognizably. But this test lacks a certain amount of rigor.

(4) CD-4 styli are typically easier to set at optimum vertical angle; the "optimum" is much less ambiguous. When so set, they consistently (audibly) outperform comparable cartridge models fitted with spherical or "conventional" bi-radial stylus tips.

(5) Altering the vertical stylus force seems to produce the expected change in "sound." In fact, in some cases small changes in stylus force have seemed to be as effective as small changes in vertical angle in achieving the most listenable results. (In all cases the stylus-force changes have been very small, and always well within the recommended tracking-force range of the cartridge's manufacturer. Measurement of the force, with one exceptional instance, has always been consistently repeatable with the Shreve arm and a tracking-force gauge of high reliability and resolution [within 1/10 gram].)

**And What Is the Sound?** While we agree when the verticle adjustment is correct to our ears, we do not always use the same language to describe what we hear when it is not to our liking. High

frequencies are affected most profoundly, to the point where sharp sibilance on voice recordings can be reduced to almost no sibilance. There is a noticeable change in the quality of whatever noise is present on the record, so that it becomes subjectively smoother, less obtrusive, and less troubled by what subjectively seems to be a periodic modulation effect. Whatever stereo perspective is present on the record seems dramatically enhanced, with sharper and stabler positioning of sound sources both left to right and forward to back (although we think we have occasionally discovered "faults" in the stereo perspective of some recordings as a result of optimum adjustment).

**The Unanswered Questions.** The vertical cutting angle adopted in making a record is established at the discretion of the mastering engineer. A fairly common practice is to use a special test record as a vertical reference while the cutting head is set up. However, we have heard of instances in which the cutter's vertical angle has been slightly modified to achieve a smoother or quieter cut.

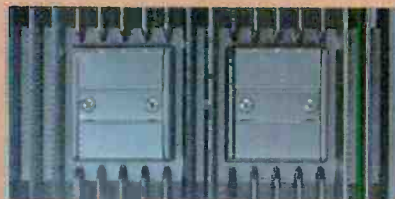
The variations in vertical angle from record to record we have found are probably small enough to be accounted for by differences in test records, or even differences in set-up procedures when the same test record is used. However, the precise roles that these and other factors play in the vertical-angle situation are far from clear to us at present.

Several other questions remain. One concerns the matter of deformations in the ideally flat surface of the record, and what part they could or should play in properly defining the correct vertical angle. Another question asks whether there is (as would seem logical) an optimum relationship between rake angle, vertical tracking angle, and stylus force, since the first two would certainly change with an alteration of the third, but not necessarily in the same direction with respect to an optimum adjustment.

Perhaps the ultimate question is whether a significant number of commercially available arms and record players (as opposed to the custom-built and carefully adjusted equipment in our hands) can reveal the effects of these minute variations in alignment. Thanks to Mr. Cotter's efforts, the first tentative answer to this question seems to be moving toward a qualified "yes." And thus it appears certain that you'll have heard far from the last of this matter when you lay down this magazine. ◇



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## Audio Reports

### PROS AND CONS OF MULTI-WAY SPEAKER SYSTEMS

**I**T HAS long been recognized that a single loudspeaker cone cannot properly reproduce the full audible frequency range. Nevertheless, a single speaker is still widely used, as in TV receivers, automobile radios, and low-priced home radios and record players for that impossible task. Here, a degree of effectiveness is made possible only by a reduction in quality standards, which would not be acceptable in a high-fidelity system.

The examples mentioned above cannot be called "hi-fi" by any stretch of the imagination, although sometimes, against all reason, that claim is made for them. Even a minimum quality component speaker system uses at least two drivers to cover the audio range, and more expensive ones divide the audible spectrum into three or even four bands. It is thus quite natural to assume that more separate frequency bands in a speaker system result in better quality.

The foregoing assumption may be natural, but it is not necessarily correct. In fact, in the absence of other information, there is no reason to conclude that a three-way system is better than a two-way system or even as good. To see why this is so, let us consider the reasons for dividing up the reproduction task among several drivers.

To generate appreciable amounts of acoustic power at low frequencies, a large volume of air must be moved by the speaker cone. This can be done by using a large cone area with a relatively small excursion, or a smaller cone with a large excursion. Both methods are capable of good results, but the popular acoustic suspension speakers are based on the latter approach. To get a reasonably flat, smooth bass response, it is not sufficient simply to use the largest possible speaker diameter, or to increase the size of the enclosure. These two factors, together with a host of other speaker parameters, are interrelated. Once a certain performance standard has been decided upon, neither can be changed without a corresponding change in the other. The value of a proper bass speaker design is demonstrated by the many small speakers, with woofers only 6 to 8 inches in diameter, whose bass response extends to 40 Hz or even lower.

A larger cone diameter gives the designer several possible options for improved performance. The lower limit of the speaker's response could be extended (perhaps together with reduced distortion), or its efficiency could be increased. Since nothing in this

world is truly free, what disadvantages might result from such a change?

A woofer cone can deliver its calculated flat response only in the limited frequency range within which it moves as a piston. At higher frequencies, where the speaker diameter becomes an appreciable fraction of the acoustic wavelength, the response becomes irregular, as well as increasingly directional. The massive cone, which is advantageous for a woofer, becomes a liability at higher frequencies. Here, low moving mass is necessary to allow the cone to reverse direction hundreds or even thousands of times each second. Therefore, whatever the size of the woofer, above some selected frequency the signal energy must be diverted from it to another speaker more suitable for that range. The choice of a "crossover" frequency is not entirely arbitrary since it must take into account the high-frequency aberrations in the woofer's response, and the low-frequency limitations of the smaller speaker. A "tweeter," as the high-frequency driver is usually called, is much smaller in diameter than the woofer, and has a much lighter cone and voice coil structure. The low mass allows it to respond more rapidly to high-frequency signals, while its smaller diameter gives the sound a wide polar dispersion instead of "beaming" it forward, as happens when the cone diameter is comparable to the wavelength of the sound. At very high frequencies, even an ordinary tweeter cone may be too large to give the desired response, necessitating a second crossover to a still smaller speaker. This is known as a "three-way" system, in contrast to the simple "two-way" system comprised of a woofer and a single high-frequency driver.

Here are some considerations on the relationship between the size of the several drivers and the choice of crossover frequencies. In a typical small speaker system, with a woofer 8 inches or less in diameter, it is feasible to cross over to the tweeter as high as 2000 Hz, or even higher in some cases. At that frequency, a specially designed dome or small cone tweeter is used instead of merely a miniature version of the woofer. With a cone diameter of 1 to 1½ inches such a speaker can give satisfactory results up to 15,000 Hz or even beyond. While it is possible (and sometimes done) to cross over to a third "super tweeter" at a very high frequency, such as 7,000 to 10,000 Hz, the benefits would be negligible. The high-frequency dispersion

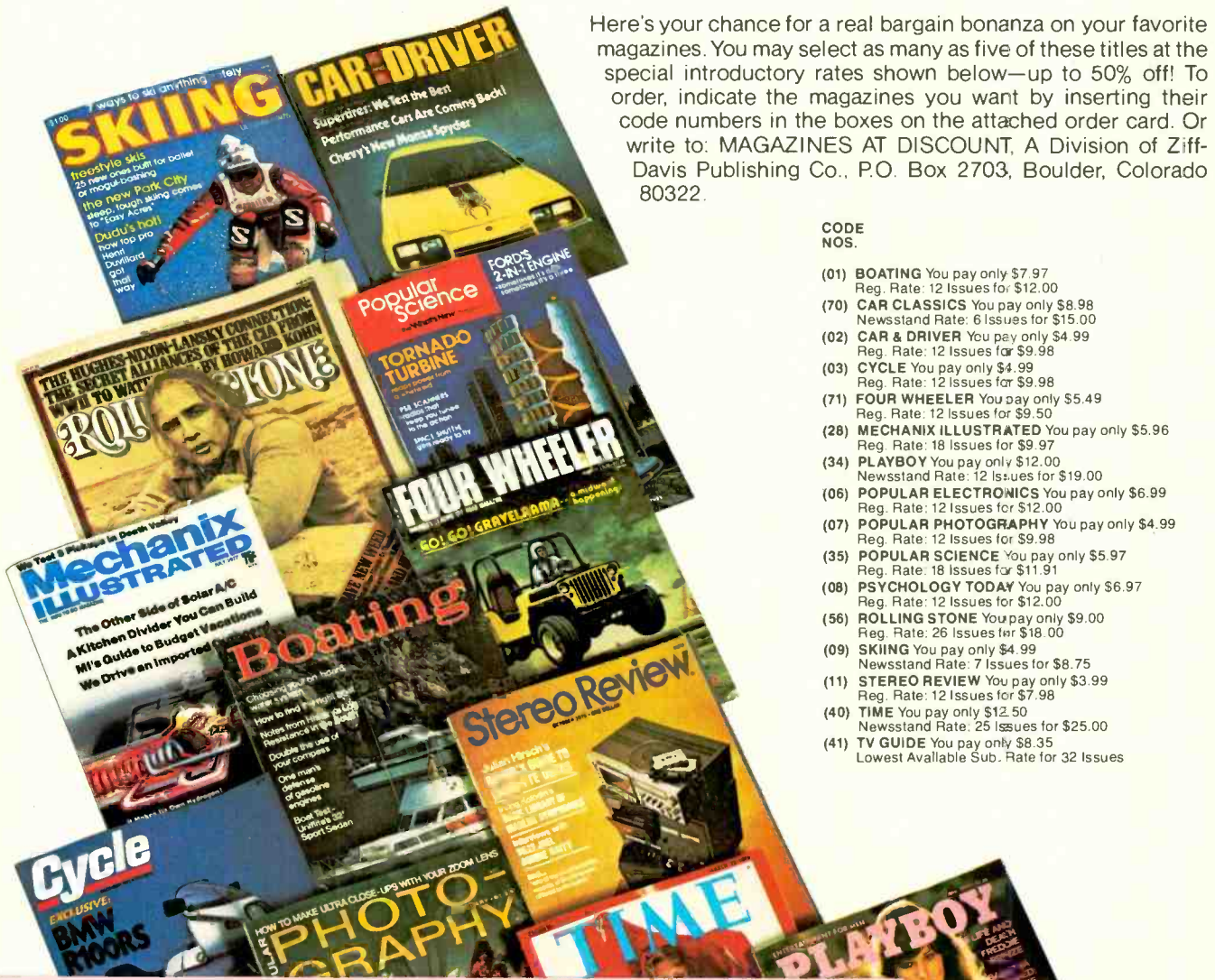
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might be improved by using a second, smaller tweeter, but the effect is likely to be rather subtle.

Suppose that a larger woofer, 10 or 12 inches in diameter, is used. Such a speaker cannot function optimally much above 1000 Hz, and the crossover to the next driver usually takes place between 500 and 1000 Hz. At that frequency, a small dome tweeter cannot be used either because its light voice coil could easily be burned out by the concentration of program energy in the midrange. Furthermore, the large cone excursions needed would be impractical for such a driver.

To cover this frequency, a larger version of the dome tweeter is sometimes used (this can be expensive). But more frequently, the midrange driver is a conventionally appearing cone unit that's about 3 to 5 inches in diameter. This can handle the midrange power, but its useful upper frequency limit is perhaps several thousand hertz. For full-range reproduction, there is a second crossover to a true tweeter, usually in the 3000-to-5000-Hz range. From this we can see that a speaker based on large low-frequency drivers or designed for use at high volume levels has to have three drivers do what can be done fairly well at lower levels by a smaller two-way system.

Sometimes we encounter four-way systems, although this is a refinement limited to fairly exotic and expensive speakers. Usually, a very small super-tweeter is added to a more conventional three-way system, with a crossover at 10,000 Hz or even higher. Alternatively, the fourth driver can be added at the

low-frequency end, crossing over from the woofer to an upper-bass or lower mid-range driver in the 100-to-300-Hz region. The upper-bass speaker is normally a small woofer that measures about 8 inches in diameter. Together with the higher frequency drivers, it acts as the woofer of a three-way system.

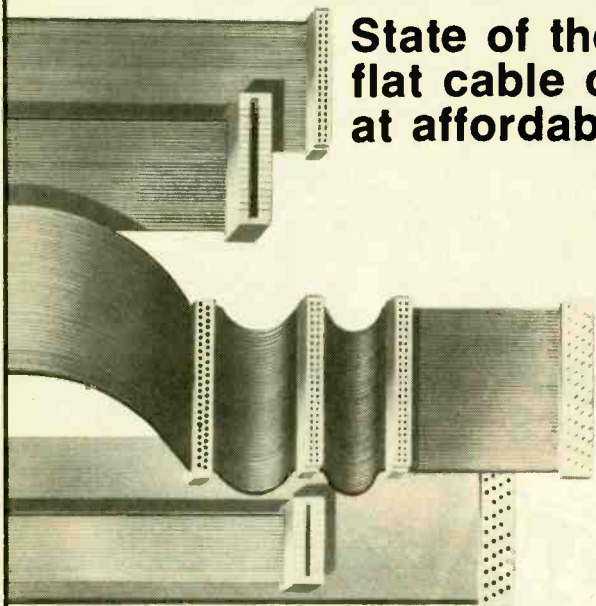
If a super tweeter is used, especially at frequencies near the limits of human hearing, its benefits may be marginal. Little program material has much content in that range, except for noise. Thus, the principal benefit of a super tweeter may be an airier quality due to improved dispersion.

The rationale for using a very low woofer crossover frequency is that the large woofer cone excursions at low frequencies tend to modulate higher frequencies in the program band handled by the woofer. Even if the speaker is perfectly linear, high frequencies radiated by a cone simultaneously handling low frequencies will be frequency-modulated (the Doppler effect). This produces a modulation distortion very much like that resulting from woofer nonlinearity. By restricting the woofer to a narrow frequency range, the likelihood of such intermodulation is reduced. Of course, this places an added burden on the next higher frequency driver, which often carries the bulk of the audible program content and must do so with a minimum of distortion.

We have seen how the number of crossovers in a speaker system is determined by the limitations of its individual drivers, the cabinet size, and the degree of

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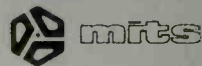
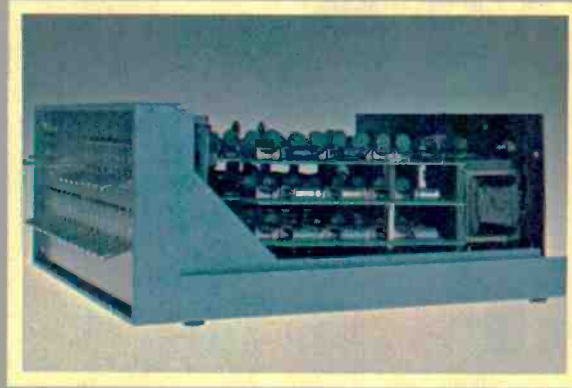
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subjective refinement that is desired. (It is difficult, if not impossible, to actually measure the benefits of some multi-way speaker systems, especially in view of the aberrations introduced by *any* crossover network, let alone a four-way network.)

Having made side-by-side comparisons between two- and three-way systems based on similar drivers and cabinet dimensions, we can attest to the added openness imparted by a good three-way design. It is a fairly subtle effect, however, and might not be detectable without such a comparison. On the other hand, we have often been impressed by the similarity in sound quality between some good, small two-way speaker systems and vastly larger (and more expensive) three- or four-way systems. There is not much mystery to this effect, since it means that the speakers involved have been designed to give a uniform energy response with better than average dispersion. Their similarity is clearly evident in the measured frequen-

cy response. Consequently, it is not surprising that they sound very much alike in their basic octave-to-octave balance and freedom from coloration. The low-frequency limitations of the small speakers are usually evident only below 50 Hz or so, where most programs have little energy.

The Speakerlab 7 speaker reviewed here is a three-way system, and from its use of two full-size (10- and 12-inch) woofers it is easy to understand why a three-way design was necessary. The first crossover at 700 Hz was dictated by the high-frequency limitations of the woofers, and a rather large horn driver was needed in the midrange to operate down to that frequency. A horn of this size cannot do a good job at the highest audio frequencies, making it necessary to cross over to a second smaller horn at 5000 Hz. A speaker with the efficiency and power handling ability of this one could not have been made with a simple two-way configuration or in a smaller cabinet. ◇



## AKAI MODEL GX-270D-SS FOUR-CHANNEL TAPE RECORDER

*Synchronous recording function permits multitrack taping.*



Paradoxically, at a time when interest in quadraphonics is not especially strong,

a number of open-reel tape recorders on the market feature 4-channel capabilities. The indication here is that home recordists are using these decks to build up multitrack recordings in a manner similar to that used by professional recording studios, rather than for recording and listening to 4-channel tapes.

Akai's Model GX-270D-SS 4-channel open-reel tape recorder is in this category, having the synchronous recording capability that makes it possible to obtain multitrack recordings. Its "Quadra Sync" recording system can be used in both the 2- and 4-channel modes. The deck also features a direct-driven cap-

stan, 7½- and 3¾-ips (19.1 and 9.5 cm/s) speeds, and a bidirectional playback feature for stereo operation. The transport is solenoid controlled.

The recorder measures 18.3"H × 17.3"W × 7.5"D (46.5 × 44 × 19.5 cm) and weighs 39.2 lb (17.8 kg). Its nationally advertised value is \$875.

**General Description.** An ac servo motor is used to directly drive the capstan of the recorder, eliminating the belts and pulleys usually found in tape drives. Pushbutton switches are used to select the operating speed and simultaneously switch in the appropriate equalization characteristic. The hubs can accommodate tape reels up to 7" (17.8 cm) in diameter. Each hub is driven by its own eddy-current motor.

The bidirectional playback mechanism can be initiated either automatically by conducting foil on the tape's leader or manually by pressing a switch. The main transport functions are controlled by six pushbutton switches, through solenoid actuators. They include normal and fast speeds in both directions, STOP, and REC interlock functions. A "flying start" recording can be made from play by simultaneously holding down the normal play button and pressing the REC button. A separate PAUSE button stops the tape without disengaging the recording function.

A small PITCH CONTROL knob to the left of the tape heads can be used to adjust the tape speeds over a nominal ±5% range. It has a detented center position, which gives the nominally correct tape speed. This control operates when the transport is in both the record and the playback modes. So, it can be used to correct the pitch of a reference track when making a Quadra Sync recording. Below the PITCH CONTROL are the POWER switch and two TAPE SELECTOR buttons (for low-noise and wide-range tapes) and the speed selector buttons.

There are five pushbuttons in the Quadra Sync system. Four are for individual channel selection and the fifth allows you to select either the 2- or the 4-channel mode of operation.

Four VU meters light according to the mode selected. In the 2-channel mode, only the channels 1 and 3 meters light, while in the 4-channel mode, all four meters light. A red light above each meter glows when that channel is in the recording mode. This gives a very clear indication of the operation of the Quadra Sync system, since pressing any of the system's buttons disables the erase and record function for that channel, simultaneously extinguishing the corresponding red light.

The settings of the concentric playback level controls do not affect the meter readings. A MONITOR switch con-

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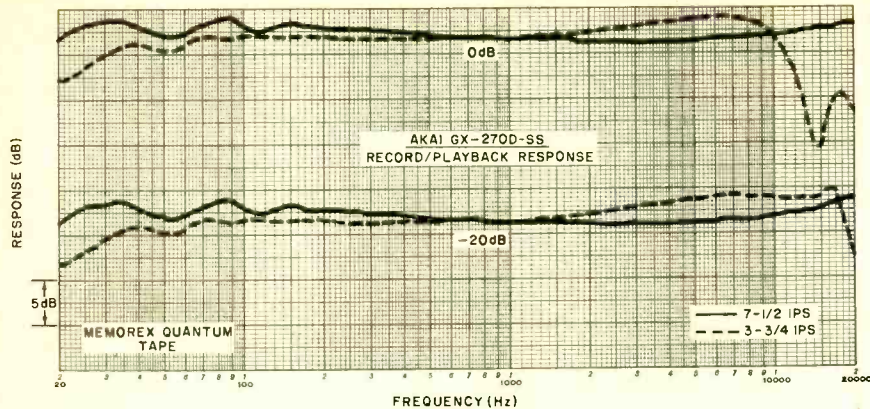
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Record/playback response using Memorex Quantum tape at 7½ and 3¾ ips.

nects either the input signal or the playback amplifier output to the line output terminals. Four separate ¼" (6.4-mm) phone jacks are provided for the microphones, which should be medium impedance (600-ohm) dynamic types. There are also two stereo phone jacks for monitoring the front and rear channels. For best results, the phones should have an 8-ohm impedance. Below each VU meter is a concentric pair of recording level controls for that meter's channel (one each for the mic and line inputs, which can be mixed).

On the rear of the recorder are the four pairs of line inputs and outputs and a socket for an optional remote control accessory.

The specifications of the Model GX-270D-SS are consistent with the requirements for a high-quality home tape recorder. Based on the use of Scotch 211 or an Akai tape, they include: frequency response to 21,000 Hz at 7½ ips and to 15,000 Hz at 3¾ ips; with wow and flutter less than 0.07% and 0.1% at the two speeds; less than 1% distortion at 1000 Hz and 0 VU; and better than 54 dB S/N ratio, referred to a +6-VU recording level.

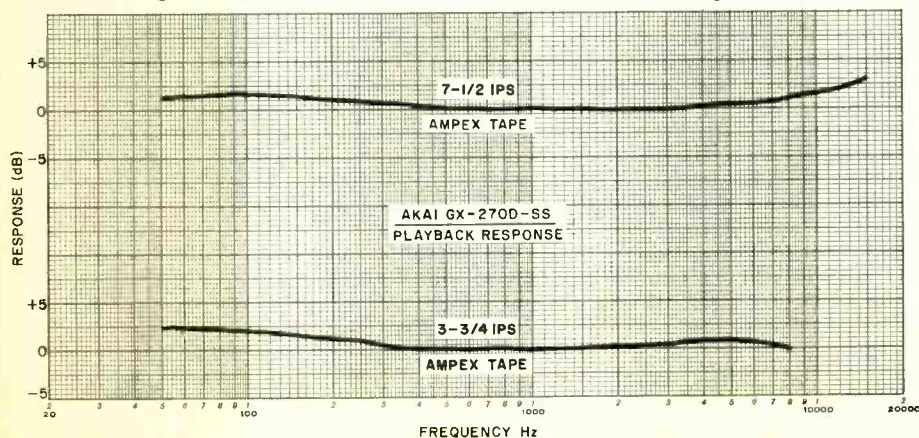
**Laboratory Measurements.** The

record/playback frequency response of the tape deck was measured with several types of tape, using the "wide range" selector position, to determine which best matched the factory settings of the recorder. Although the differences were not large, we found that Memorex Quantum gave the best results; it was subsequently used for the remainder of the tests. Akai SRT-F and Scotch 212 were quite similar to it in performance, while TDK Audua and Maxell UD35-7 had a rising high-end response.

The 7½-ips frequency response was ±2 dB from 20 to 24,500 Hz at a 20-dB recording level and was virtually the same at 0 dB. There was no sign of tape saturation at 0 dB with any of the tapes used. The 3¾-ips response was within ±2.5 dB from 30 to 18,500 Hz, and tape saturation rolled off the 0-dB output above 7000 Hz.

The playback frequency response, measured with Ampex test tapes, was within ±1.5 dB from 50 to 15,000 Hz at 7½ ips. It was ±1.5 dB from 50 to 7500 Hz at 3¾ ips. Both results represent the frequency limits of the tapes.

A line input of 75 mV or a microphone input of 0.28 mV was necessary for a 0-dB recording level. The playback level from a 0-dB recording was 0.89 volt with



Playback frequency response of the recorder using Ampex test tapes.

the Memorex tape. (It varies somewhat with the tape used.) The playback distortion at 0 dB at either speed was 0.38% to 0.40%, which is well below the rated value. The reference 3% distortion was reached at a recording input of +10 dB.

The unweighted S/N ratio, referred to the 3% distortion level, was 59 dB at both speeds. With IEC "A" weighting, it was 65.5 dB. With CCIR/ARM weighting, the S/N was 61 dB at 3¾ ips and 64 dB at 7½ ips. The noise level through the microphone inputs was only 3.5 dB higher than through the line inputs.

The flutter of the GX-270-SS was a very low 0.04% at both speeds, which is probably the result of using a direct-drive capstan motor. The PITCH CONTROL had a range of +6.6% to -4.8% at 3¾ ips, and from +5.5% to -4.1% at 7½ ips. In fast forward and rewind, an 1800' (550-m) reel of tape was handled in 100 seconds. The meters responded more slowly than real VU meters, indicating 80% of steady state on 0.3-second tone bursts. The headphone volume was not adjustable and was quite low with 200-ohm phones but fairly good with 8-ohm phones.

**User Comment.** The operation of the recorder was simple and straightforward, for both conventional operation and for making "Quadra Sync" recordings. The solenoids, which operated with audible "clunks," had a logic system that enabled the buttons to be operated in any sequence without going through STOP. Pressing a normal speed button while the tape was in fast motion (or going in the opposite direction) brought the tape to a smooth, swift stop, after which it paused for a few seconds before resuming play.

On the machine tested, we did not find any effect on the sound when we operated the TAPE SELECTOR buttons. Neither the frequency response, nor the distortion, nor the noise level were affected by this control in any way that we could hear or measure. Also, although the head cover carries the inscription "Auto Reverse," this feature is not mentioned in the instruction manual, nor are there any instructions given on how to install the conductive tape for automatic reversal. A couple of pieces of foil are included with the recorder, with a cryptic statement that they should be installed on either the dull side or the shiny side of the tape. We tried both, and the system operated properly with the foil on either side of the tape. Even if the autoreverse feature is not used, it is still very convenient to be able to play the second pair of

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Just as television is only one part of the consumer field, these other fields of electronics are made up of many career areas. For example, there are computer electronics, microwave and satellite communications, cable television, even the broadcast systems that bring programs to home television sets.

As you may realize, career opportunities in these other areas of electronics are mostly for advanced technical personnel. To qualify for these higher level positions, you need college-level training in electronics. Of course, while it takes extra preparation to qualify for these career areas, the rewards are greater both in the interesting nature of the work and in higher pay. Furthermore, there is a growing demand for personnel in these areas.

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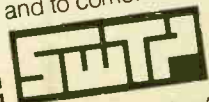
The SWTPC 6800 comes complete with 4K memory, serial interface, power supply chassis, famous Motorola MIKBUG<sup>®</sup> mini-operating system in read-only memory (ROM), and the most comprehensive documentation with any computer. Our growing software library includes 4K 8K BASIC (cassettes \$4.95 and \$9.95), paper tape \$10.00 and \$20.00. Expanding memory, \$100/4K or \$250/8K.

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tracks at the touch of a button, without interchanging the reels.

At 7½ ips, the sound quality of the recorder leaves little to be desired. When we recorded interstation hiss from an FM tuner, we could hear only a minute brightening of the playback in comparison to the incoming signal. This was

consistent with the measured frequency response of the recorder. But at 3¾ ips, the brightness was quite noticeable, even without an A-B comparison.

This deck will appeal most to the serious amateur recordist who wants to try his hand at multi-track-sync recording. It is a versatile machine, equally at home

with recording and playing back 2- and 4-channel tapes or with creating one's own "professional"-style recordings. We were impressed by the manner in which it surpassed every one of its published specifications, usually by a wide margin.

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## SPEAKERLAB MODEL S7 SPEAKER SYSTEM KIT

*Assemble-it-yourself, three-way speaker system employs four drivers.*



**Kit Assembly.** The Speakerlab kit contained everything required to assemble, wire, and finish the speaker system except scissors, stapler, caulking gun, and sandpaper. (The last item is used to gently sand the edges of the box and any rough spots.) A cartridge of silicone rubber adhesive, supplied with the kit, is used instead of screws for driver and subassembly mounting.

The prewired crossover network/input terminal/L pad assembly mounts first over its cutout in the cabinet via a bead of silicone adhesive. Next, the fiberglass wool sheets are cut with scissors to rough sizes and then stapled to all internal walls of the speaker cabinet except the front panel. Once this is done, short lengths of Velcro fastener tape are stapled to the front panel at all four corners.

The front board on which the drivers mount fastens to the cabinet via a thick bead of silicone rubber adhesive between it and the enclosure's particle board liner. A 2" x 2" (5.1 x 5.1 cm) brace is then white-glued between the inside rear wall and the rear wall of the front panel between the woofer cutouts to add rigidity and to reduce the possibility of mechanical resonances in the bass range. Finishing nails driven through both walls into the ends of the brace keep the brace from moving while the glue is setting.

Heavy-gauge wires with push-on terminals connect to the drivers from the crossover/L-pad assembly. The drivers then mount in their respective cutouts with the aid of beads of silicone rubber adhesive. No screws are used to hold the drivers in place. The silicone adhesive

*(Continued on page 42)*

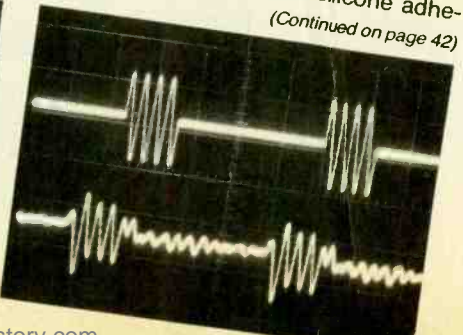
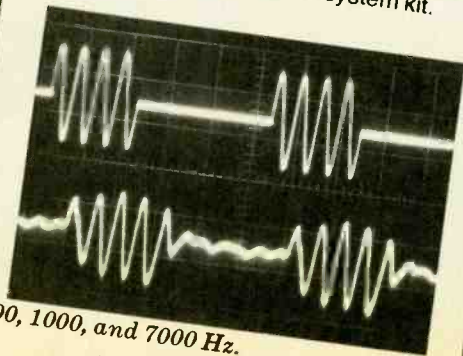
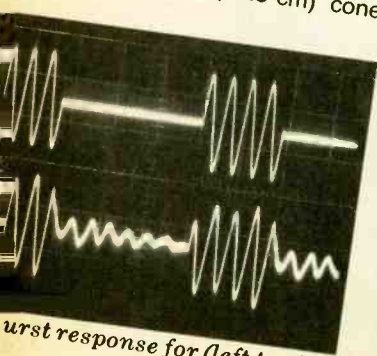
type woofer, and 10" (25.4-cm) cone-type woofer. Crossover frequencies are nominally at 700 and 5000 Hz, and L pads are provided for adjusting the mid-range driver and tweeter balance. Zeners protect the tweeter.

Speakerlab recommends that an amplifier rated at a minimum of 15 to 25 watts/channel be used to drive the Model S7 speaker systems. Maximum guaranteed safe power for the speaker systems is 150 watts rms/channel. Nominal impedance is 4 ohms.

The front and back of the speaker system's walnut-veneer enclosure are made of ¾" (19.1-mm) thick particle board, while the remainder of the box has an additional layer of ¾" plywood added to its thickness. The enclosure measures 29"H x 18"W x 15½"D (73.7 x 45.7 x 38.4 cm). The assembled speaker system weighs 85 lb (38.6 kg). Price is \$279 per speaker system kit.

The Model S7 three-way speaker system is one of the six speaker kit models from Speakerlab. This second from the top-of-the-line kit features an air-suspension system to achieve good bass response in a relatively small enclosure. (Top of the line has a folded-corner-horn design.)

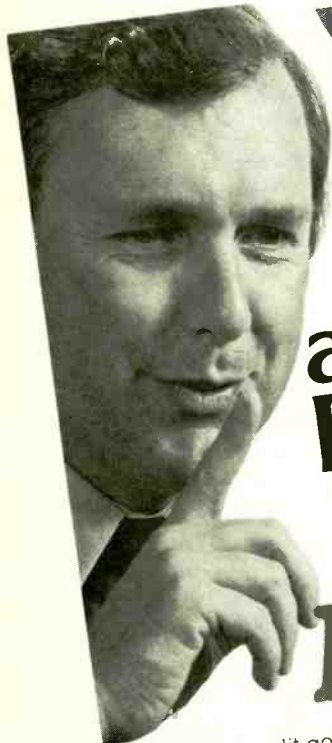
As with all speaker systems kits from Speakerlab, the Model S7's enclosure box is supplied already assembled, requiring only the application of an oil finish (materials supplied) to complete the wood work." The various elements in the kit—drivers, crossover network, fiberglass insulation, etc.—are mechanically mounted and interconnected. The Model S7's transducer complement consists of a horn tweeter, horn range driver, 12" (30.5-cm) cone-



Frequency response for (left to right) 100, 1000, and 7000 Hz.

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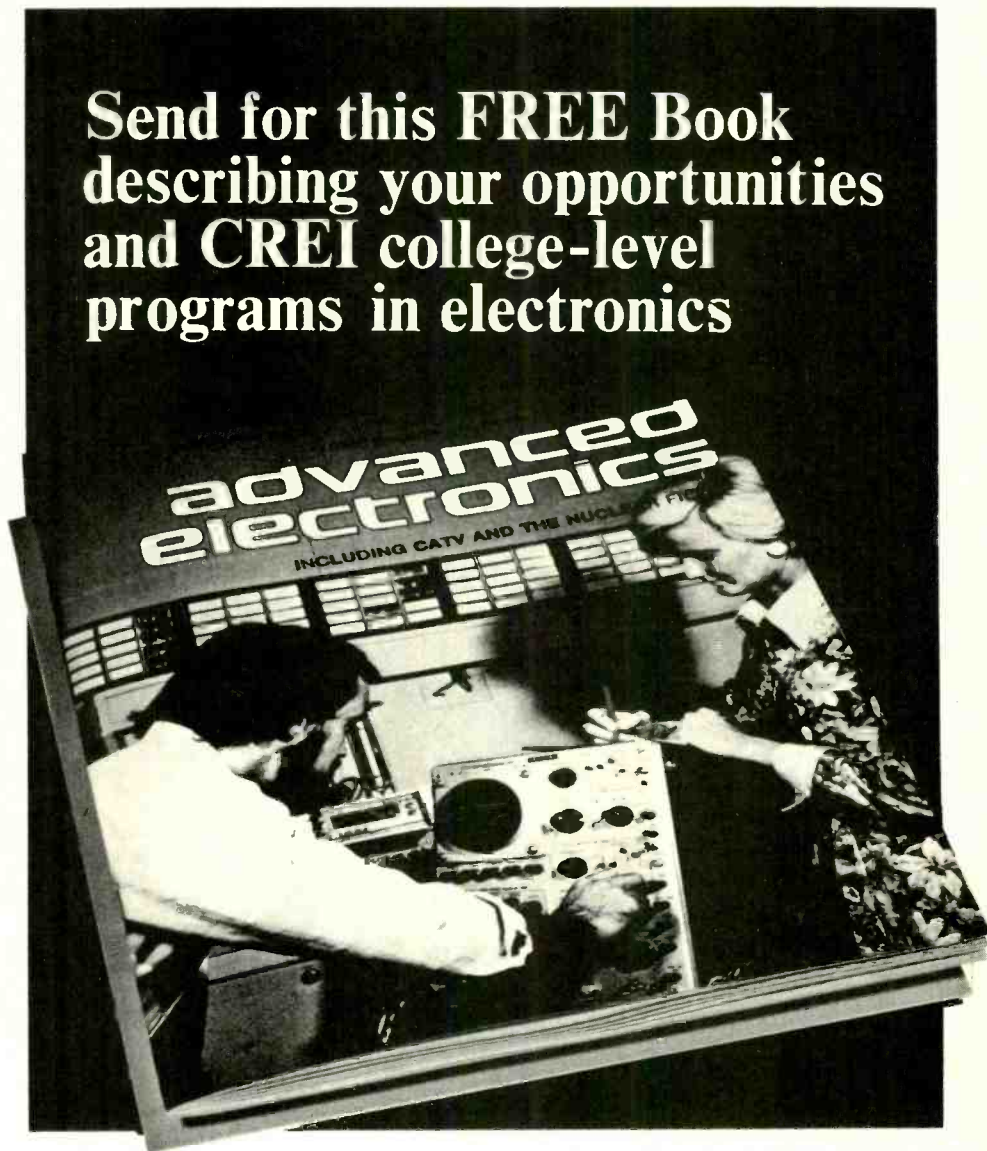
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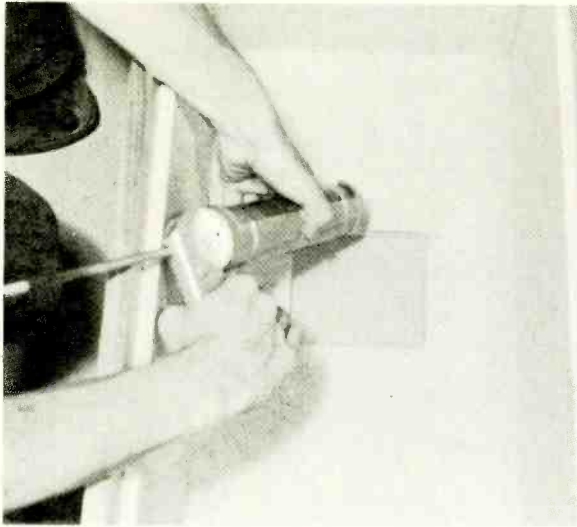
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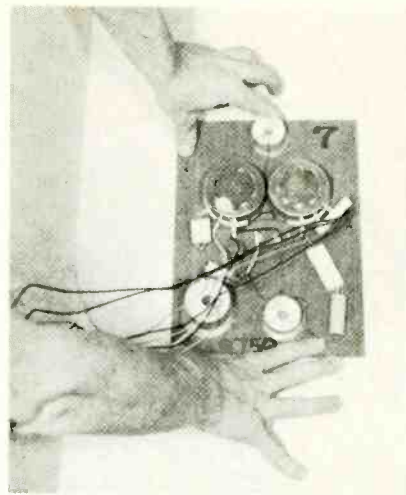
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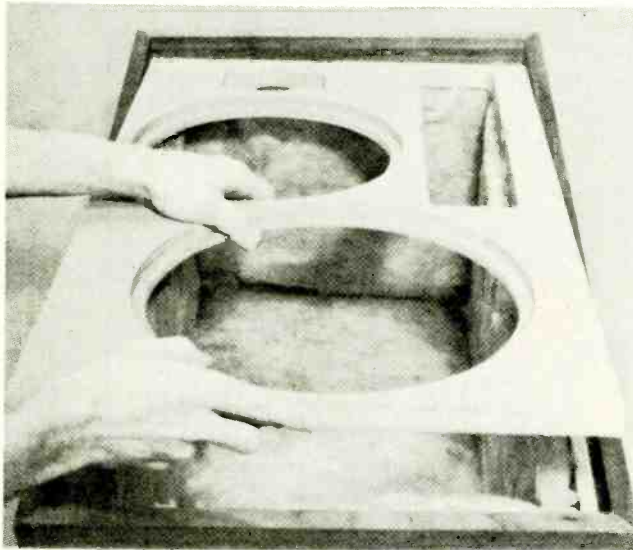




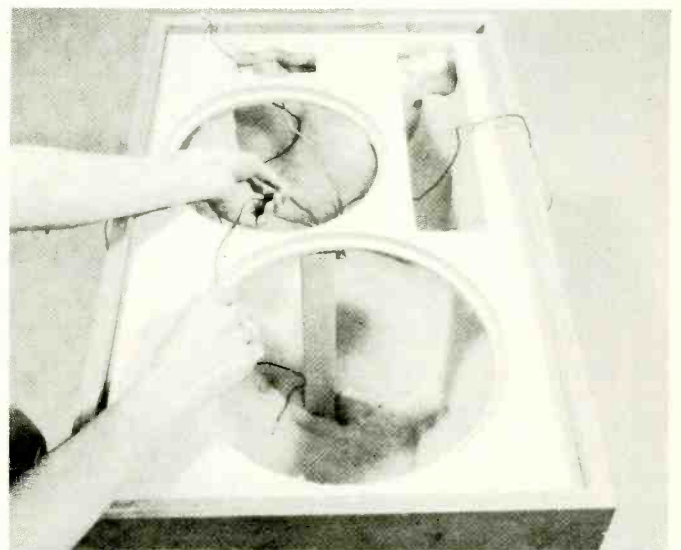
Using a caulking gun, a bead of silicone rubber adhesive is applied around the opening in the enclosure for mounting the electronic assembly.



The prewired assembly, holding the crossover network, input terminal, and L pads is pressed into the adhesive.



Cabinet is lined with fiberglass and front panel attached, the latter again secured by adhesive.



Crossover network leads are pulled through the driver openings. Note supporting wood brace.

sive serves as both mounting and air sealing mediums. The front panel cutout for the horn tweeter is slightly longer in length to permit the driver to slip into place. Consequently, once the tweeter is in place, two small pieces of wood, supplied trimmed to the proper sizes, are glued to the panel to cover up the openings at both ends of the driver horn.

A choice of two different ways of finishing the grille assembly is possible with the materials supplied in the kit. One is a plain flat grille that merely requires the grille cloth to be stretched over and stapled to a ready-made frame. The other is to make the grille assembly three dimensional. To do this, four pieces of wood are glued together to form a frame that is then glued to the ready-made frame. After rounding the edges of the frame, the grille cloth is

stretched over the whole and stapled into place. In either case, Velcro strips are fastened to the frame at the inside rear corners to hold the grille assembly in place.

We allowed four hours for the cemented pieces to set before using the speaker system, which was lying on a floor so that the full weight of the drivers bore down on the silicone adhesive cement/gaskets. We tested the speaker systems beforehand, though, propping them up just enough to permit us to connect cables from our amplifier to them and to permit us to adjust the balance controls.

Once the cements had set and we were satisfied with the operation of the speaker systems, we used No. 150 dry sandpaper to smooth all exterior surfaces of the cabinets. Then we proceeded to pour small amounts of the oil sup-

plied with the kit on one side after another, rubbing it in lightly with No. 400 wet-paper sandpaper. Excess oil was wiped off with a paper towel. Then we allowed the wood to soak up the oil and dry for about two hours. For the finishing touch, we installed the grille assembly, and the system was ready to go to work.

**Laboratory Measurements.** The middle and high-frequency response of the speaker system was measured in the reverberant field of our room at a distance of 12' to 15' (3.7 to 4.6 m) from the drivers and with the midrange and tweeter level controls set to maximum. To eliminate room interactions at low frequencies, the woofer response was measured separately, with the microphone placed in the plane of the mounting board. Since the system has two dif-

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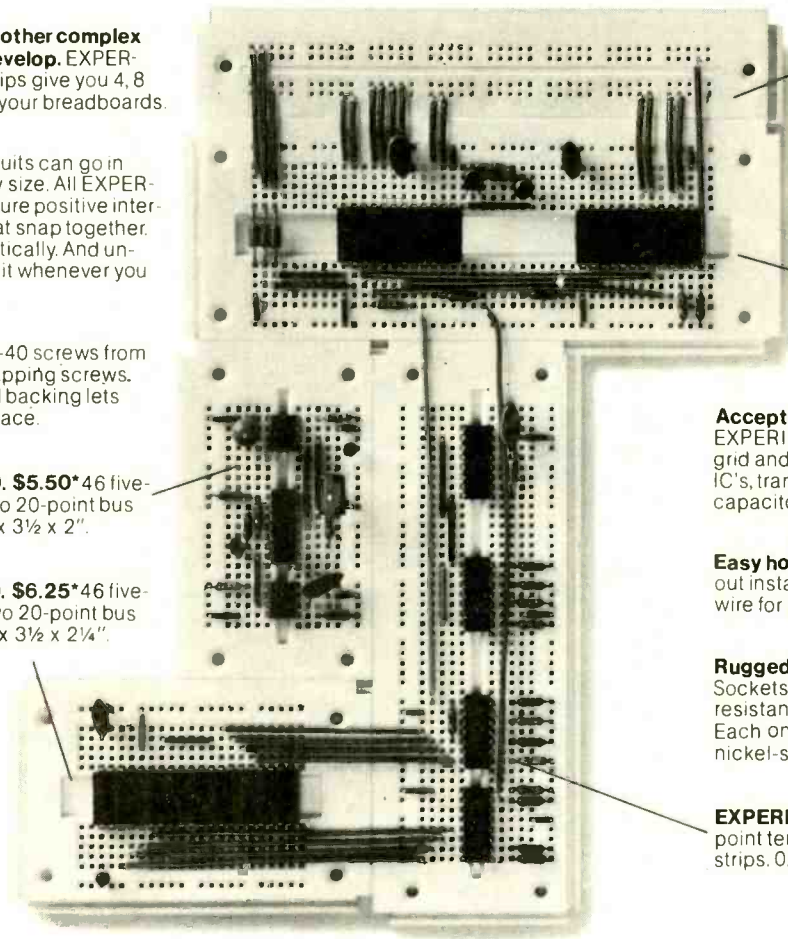
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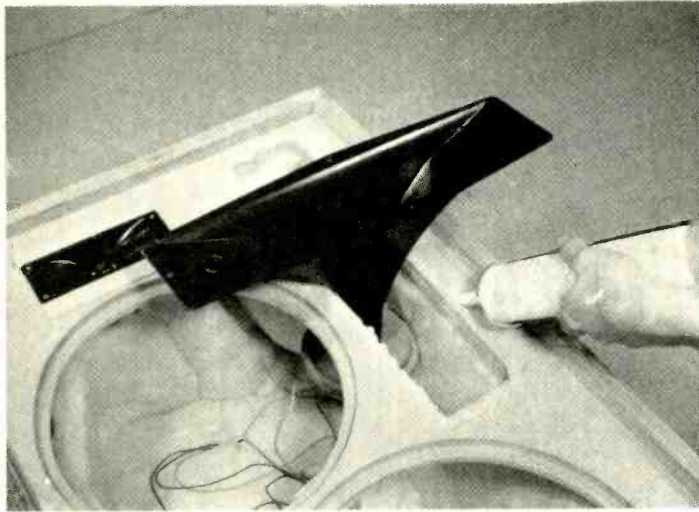


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*The midfrequency horn driver is prepared for enclosure mounting.*



*Completed system without grille.*

ferently sized woofers, separate measurements were made on each.

The reverberant frequency response was very good. Also, the woofer response was smooth and flat, without a glitch in the upper part of its range. When the two curves were spliced together, the response was within  $\pm 3$  dB from 35 to 6000 Hz and rose at higher frequencies. Of course, the shape of the high-frequency curve would vary considerably with different settings of the level controls.

The reasons for using two different woofers are not obvious, since the measured frequency response from each was the same, although the larger cone delivered about 2 dB more output. The output of the woofer reached a maximum between 60 and 80 Hz, falling at a rate of 24 dB/octave below 60 Hz and at about 6 dB/octave above 80 Hz.

The rated impedance of the speaker system is 4 ohms, a fact that was con-

firmed by our tests. It measured 4 ohms at 2 Hz and in the 100-Hz region, with a bass resonance rise to 15 ohms at 50 Hz. The impedance was in the 10-to-12-ohm range at all frequencies above a few hundred hertz.

**User Comment.** For most of our listening tests, the speaker systems were on tilt stands supplied by Speakerlab. This raised the cabinets about 8" (20.3 cm) above floor level and tilted them back to provide better coverage for the typical seated listener.

In our live-versus-recorded test, the Speakerlab S7 was highly accurate in the upper midrange and at high frequencies. We observed some added warmth in the lower midrange. It did not show up on the response curve, however, and may have been associated with the room's characteristics.

The S7's 4-ohm speaker impedance gives one a sense of higher speaker effi-

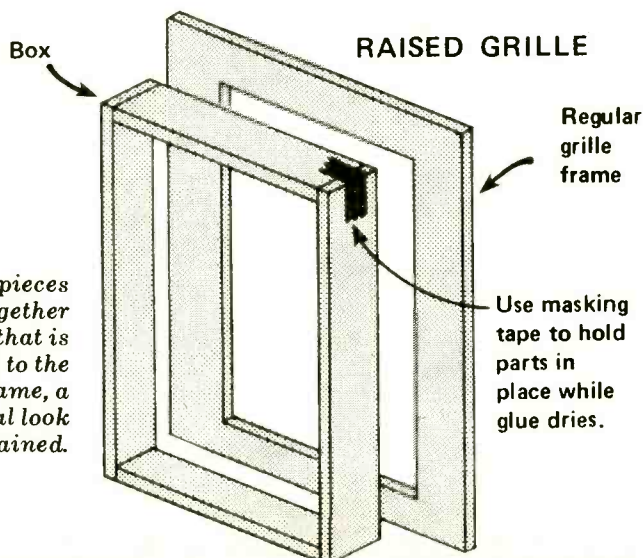
ciency as compared to equivalent 8-ohm speakers since it draws more power at a given volume-control setting. Note, however, that one cannot safely use two sets of speaker systems when using 4-ohm ones, even if the remotes are 8-ohm types, as most amplifiers will not be able to handle it. For obtaining maximum power from one set of speakers, however, the 4-ohm types are ideal.

All in all, this is a very fine speaker system. We found it to be equally suited to all kinds of music. Since its balance must be set by ear, the end result naturally depends on the builder's ability to set up both balance controls properly. (Instructions are provided with the kit.)

Assembling this kit was an interesting job. The instruction manual was clearly written and illustrated, and most informative. It took us about two hours to complete each speaker system, excluding waiting time for glue drying. Not having any screws to which to secure the speaker elements eliminated the possibility of damaging the cone by mistakenly moving the driver above it owing to the always surprising heavy weight of the element. But, even if this or any other damage is done, the manufacturer will send a new part, no questions asked. And if you happen to be the unhandiest person around and cannot complete the kit, Speakerlab will finish it for you at no charge (customer pays freight). If you should need help with the kit, there's a toll-free number where you can obtain fast, free assistance.

For those who want to make their own enclosures, speakers and the crossover can be purchased separately for \$191 each channel.

For more information, write Speakerlab, 5500 35th Ave., N.E., Seattle, WA 98105.



*By using four pieces of wood glued together to form a box that is then glued to the regular frame, a three-dimensional look for grille is obtained.*

# Why you should buy a digital multimeter from the leader in digital multimeters.

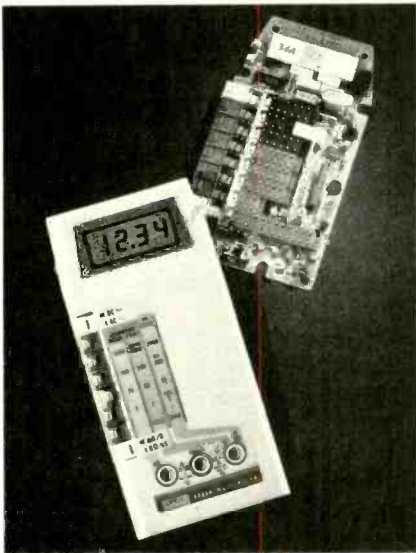
If you're shopping for your first multimeter, or moving up to digital from analog, there are a few things you should know.

First, look at more than price. You'll find, for instance, that the new Fluke 8020A DMM offers features you won't find on other DMMs at any price. And it's only \$169.\*

Second, quality pays. Fluke is recognized as the leading maker of multimeters (among other things) with a 30-year heritage of quality, excellence and value that pays off for you in the 8020A.

Third, don't under-buy. You may think that a precision 3½-digit digital multimeter is too much instrument for you right now. But considering our rapidly changing technology, you're going to need digital *yesterday*.

## If you're just beginning, go digital.



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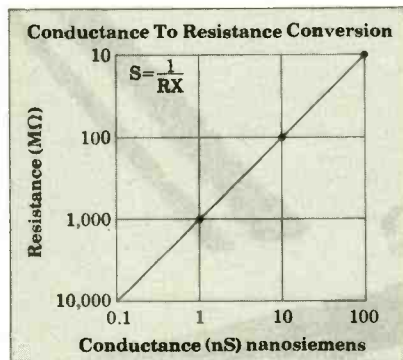
Also, the 8020A's digital performance means things like 26 ranges and seven functions. And the tougher your home projects get, the more you need the 8020A's full-range versatility and accuracy. The 8020A has it; analog meters don't.

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# 1/2-Octave Real Time Audio Analyzer

BY BOB JONES AND RICHARD MARSH

*Used with a mike and oscilloscope, it displays system output to permit accurate matching to room acoustics.*

## PART 1

IT'S COMMON knowledge that an equalizer can shape a sound system's frequency response. But adjusting multiple equalizer bands for flat audio response in a room is a challenge. This project, an audio Real Time Analyzer, provides a solution to the problem. It generates a graphic representation of the system's output with sufficient detail (20 half-octave bands) to allow quick, accurate matching to room acoustics when used with a calibrated microphone and a dc-coupled oscilloscope.

Furthermore, the RTA can be used to check the frequency response of such components as preamps, power amplifiers, etc. The RTA can also function as a sound pressure meter, as a noise analyzer (energy per frequency band), and as an aid in the design of speaker systems and crossovers.

A block diagram of the RTA is shown in Fig. 1. Input signals are selected by *S1* from MIC or AUX sources. Microphone signals are boosted to line level by a preamp with a gain of 200. A buffer am-

plifier then passes the MIC or AUX signal to twenty half-octave active bandpass filters. Each filter passes only that portion of the input signal within its passband. These filtered ac components are then rectified by diodes (one for each filter) and smoothed by RC combinations. The resulting dc levels, proportional to the amount of energy within each passband, are scanned sequentially by a 24-channel multiplexer. Finally, the multiplexed signal is buffered and presented at the RTA output.

At this point, dc levels can be applied to the vertical amplifier of the oscilloscope. Variations in vertical deflection from one band to the next will linearly reflect differences between dc levels, and hence between the energies contained in the filter passbands. However, in audio work, voltage variations are usually expressed in decibels. A logarithmic converter has therefore been incorporated into the RTA, allowing direct readout of signal levels in dB from the CRT trace. The multiplexing and display func-

tions of the RTA are carried on so quickly that all bands are shown simultaneously or in "real time."

**Circuit Details.** The input stage of the Analyzer is shown schematically in Fig. 2. A balanced differential amplifier, *IC1*, allows the use of long lines and low-impedance microphones due to its good common mode rejection characteristics. This amplifier has a voltage gain of 200, determined by *R2* and *R4*, and boosts microphone input signals to line level. External frequency compensation for the op amp is provided by *R6* and *C1*. Capacitor *C2* prevents any dc level at the output of *IC1* from reaching microphone level control *R7*.

Signals from either the microphone preamp or a source connected to the AUX input are selected by *S1* and applied to buffer amplifier *IC2*. Frequency compensation is provided by *C3*. The low-impedance output of *IC2* drives the parallel inputs of the half-octave filters.

Each active filter employs one IC (*IC3*

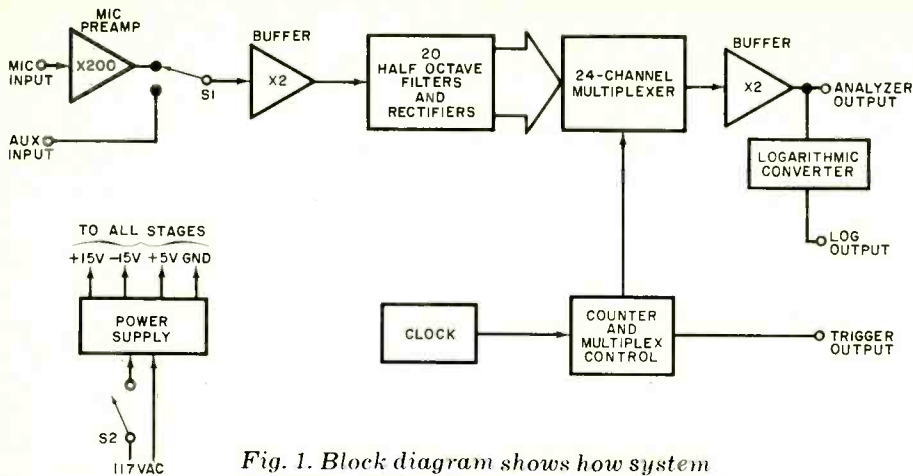


Fig. 1. Block diagram shows how system operates. All bands are shown in real time.

### PARTS LIST

C1, C106, C118 through C165—0.01- $\mu$ F, 50-V disc ceramic capacitor  
 C2, C4—15- $\mu$ F, 10-V tantalum capacitor  
 C3, C45 through C64—20-pF, 5%, 500-V silver mica capacitor  
 C5 through C44—See text and Table I. Close tolerances are essential.  
 C65 through C104—1- $\mu$ F, 50-V ceramic capacitor  
 C105—1.5- $\mu$ F, 50-V ceramic capacitor  
 C107—500- $\mu$ F, 50-V electrolytic capacitor  
 C108, C109—50 $\mu$ F, 50-V electrolytic capacitor  
 C110, C111—10- $\mu$ F, 20-V tantalum capacitor  
 C112—50- $\mu$ F, 10-V tantalum capacitor  
 C113 through C117—See Part II  
 D1 through D20—1N4148 switching diode  
 D21 through D24—1N4003, HEP R0052 or equivalent  
 F1—1-ampere slow-blow 3A6 fuse  
 IC1—LM725CH operational amplifier  
 IC2, IC3 through IC22—LM301AH operational amplifier  
 IC23—NE555 timer  
 IC24, IC26—SN7490 decade counter  
 IC25—SN7404 hex inverter  
 IC27—9301 (Fairchild, or equiv.) BCD-to-decimal decoder\*  
 IC28 through IC30—AM3705D (National Semiconductor, or equiv.) PMOS eight-channel multiplexer\*\*  
 IC31—LM741CH operational amplifier  
 IC32—MC7815CP or HEP C6114P +15-volt voltage regulator  
 IC33—MC7805 or HEP C6110P +5-volt voltage regulator  
 IC34—MC7915CP or HEP C6123P -15-volt voltage regulator  
 J1—Microphone connector (Canon XLR-3-13 or equivalent)  
 J2 through J4—BNC connector  
 LED1—20-mA LED (TIL32 or equivalent)  
 The following resistors are 1/8-watt, 1% tolerance, metal-film components.  
 R1 through R3—1000 ohms

R4, R5—200,000 ohms  
 R35 through R74—See text and Table I. The following resistors are 1/4-watt, 5% tolerance carbon components.  
 R6—47 ohms  
 R9, R12, R14, R95 through R114, R138, —10,000 ohms  
 R10, R11—100,000 ohms  
 R13—5000 ohms  
 R115 through R134—3.3 Megohms  
 R135—330 ohms  
 R136—560 ohms  
 R137—20,000 ohms  
 R139—300 ohms  
 R7—10,000-ohm, single-turn Cermet potentiometer\*  
 R8—100,000-ohm, single-turn Cermet potentiometer\*  
 R15 through R34—50,000-ohm, 20-turn, Helitrim Cermet potentiometer (Beckman 66X or equivalent)\*  
 R75 through R94—100,000-ohm, single-turn miniature Cermet trimmer potentiometer (Beckman 91W or equivalent)\*  
 S1—Dpdt miniature toggle switch  
 S2—Spst miniature toggle switch  
 T1—Triad F91-X universal transformer or equivalent 40-volt center-tapped transformer.\*  
 Misc.—IC sockets or Molex Soldercons, printed circuit boards, heat sinks, line cord, fuseholder, pc board spacers, suitable enclosure, knobs, coaxial cable, hookup wire, machine and self-tapping hardware, solder, etc.  
 Note: The following is available from Southwest Technical Products Corp; 219 W. Rhapsody, San Antonio, TX 78216: set of three etched and drilled pc boards for \$19.00  
 \*Available through distributors such as Allied Radio or Newark Electronics.  
 \*\*Consult a National Semiconductor local distributor or sales representative.

Q. When properly adjusted, the bandwidth of each filter is exactly one-half octave. With filter center frequencies spaced one-half octave apart, the skirts of the filter response curves will cross over 12 to 18 dB down. This is satisfactory for most audio work.

To achieve the value of Q necessary for narrow bandwidth, the resistors and capacitors in the series and parallel legs of each filter must have close tolerances. Resistors should have tolerances no greater than 1%, and capacitors no greater than 3%. Band-to-band variations in filter gain can be trimmed by LEVEL ADJUST potentiometers R75 through R94. Each filter output is rectified and filtered into a proportional dc voltage by D1 through D20, C85 through C104, R95 through R114 and R115 through R134. A long time constant is employed in the RC filter to average low-frequency components and reduce display bounce.

The digitally controlled multiplex system requires a reference time base or clock. In this project, IC23, a free-running 555 IC timer, generates the necessary clock pulses (Fig. 4). Duty cycle and frequency are determined by R135, R136, and C105. Too high a frequency causes excessive display bounce with a varying input such as random noise. Too low a clock frequency results in display flicker which is hard on the eyes. A clock rate of 2000 Hz was chosen to avoid both undesirable effects.

Clock pulses are applied to IC24, a 7490 decade counter wired to count from 0 to 7, then reset to 0 on the eighth clock pulse. Therefore, a total of eight different output states on three data lines (2<sup>0</sup>, 2<sup>1</sup>, 2<sup>2</sup>) are available. These outputs allow selection of any one of eight FET gates in a 3705 PMOS IC multiplexer. All required decoding circuitry is on the 3705 chip. Of course, twenty channels are needed, not just eight. This is why IC26 and IC27 (7490 and 9301, respectively) are employed. The multiplex circuit is shown in Fig. 5. Each 3705 (three required for 24-channel capacity) has an enable line (E). This allows sequential multiplexer activation.

Decade counter IC26 (7490) is wired to count from 0 to 2, and then reset to 0 on the next pulse from IC25F. For the first seven clock pulses (refer to timing diagram Fig. 6), IC26 has a 0 output. This is decoded by IC27, a 9301 BCD-to-decimal decoder, as a select line one (MPX1 Select) command. Accordingly, multiplexer IC28 is activated. The rectified outputs of the first eight filters are

(continued on page 50)

through IC22) in a Wein-bridge circuit, as shown in Fig. 3. The parallel legs of the filters are formed by R35 through R54 and C5 through C24, and the series legs by R55 through R74 and C25 through C44. The values of these com-

ponents are chosen according to the formula for the center frequency of the filter passband:  $f_c = 1/(2\pi RC)$ . Note that each RC pair (series and parallel) has the same time constant. Potentiometers R15 through R34 control filter gain and

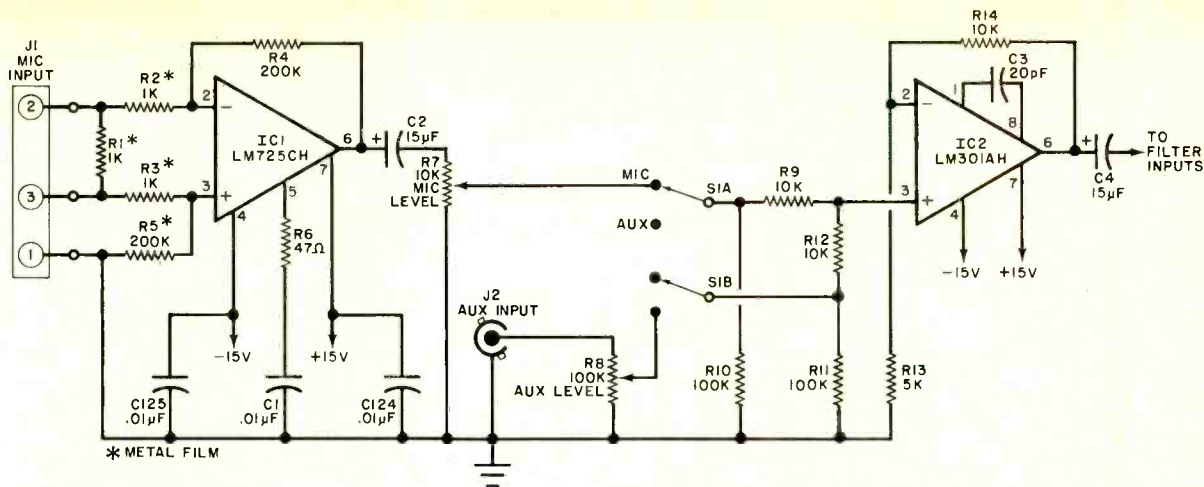


Fig. 2. Input stage includes a balanced differential amplifier, IC1, and buffer, IC2.

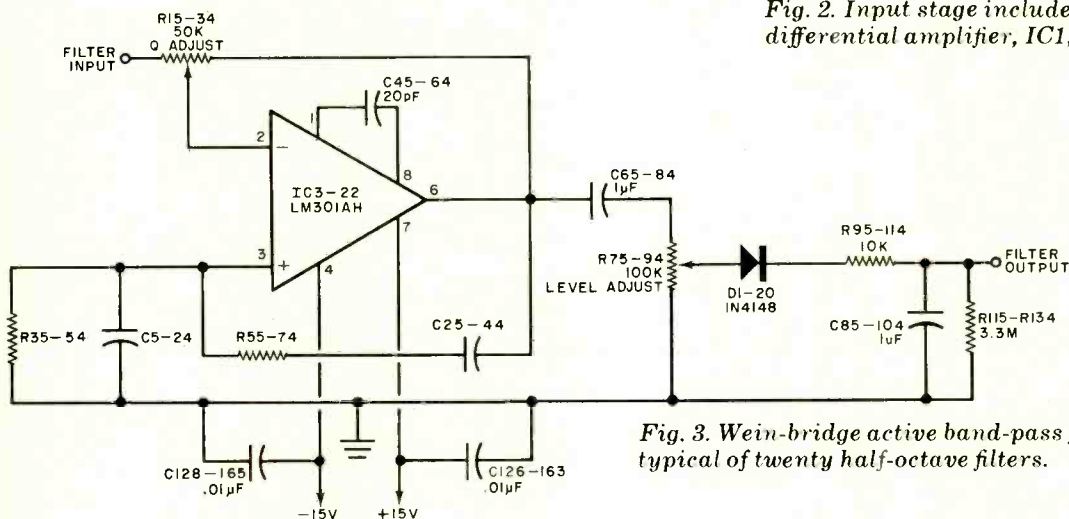


Fig. 3. Wein-bridge active band-pass filter, typical of twenty half-octave filters.

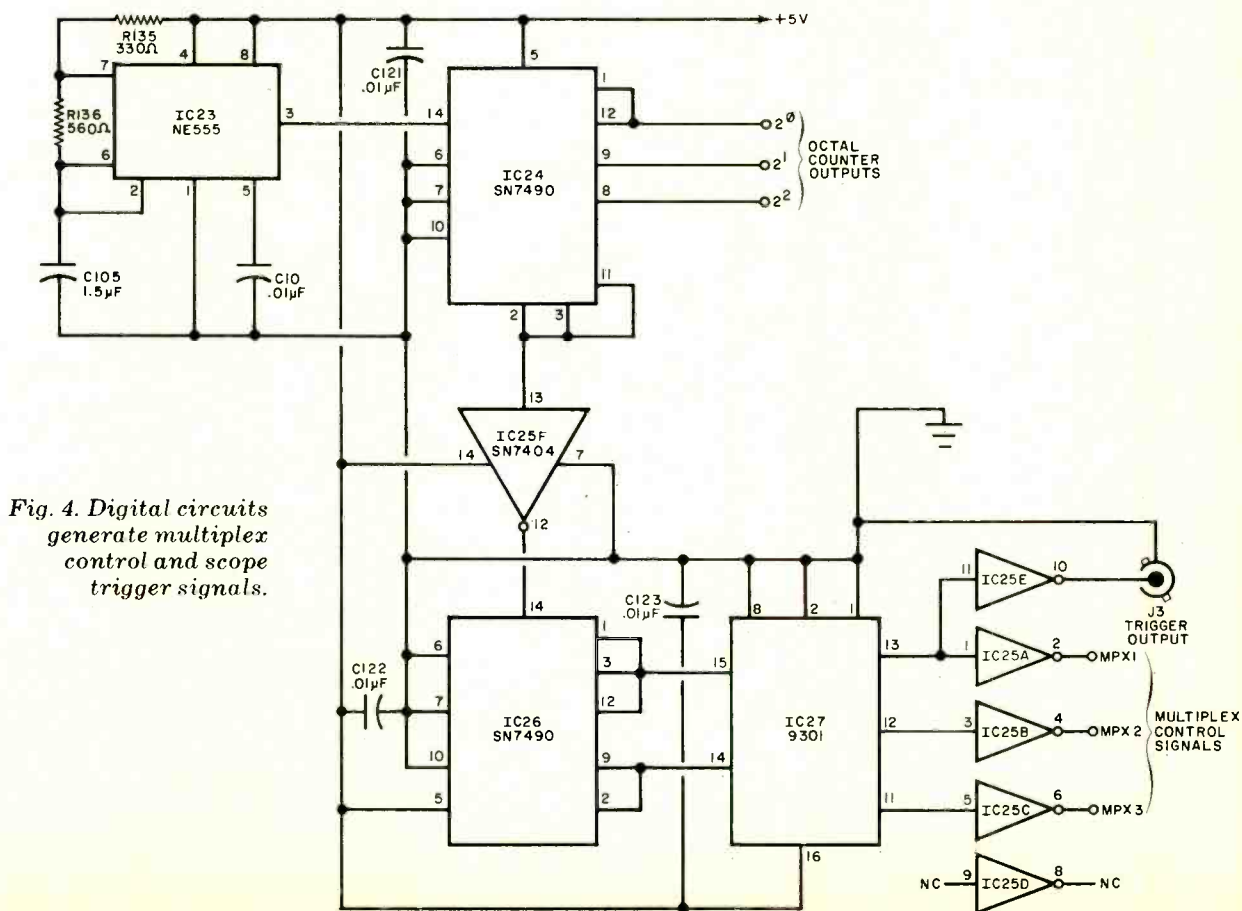


Fig. 4. Digital circuits generate multiplex control and scope trigger signals.

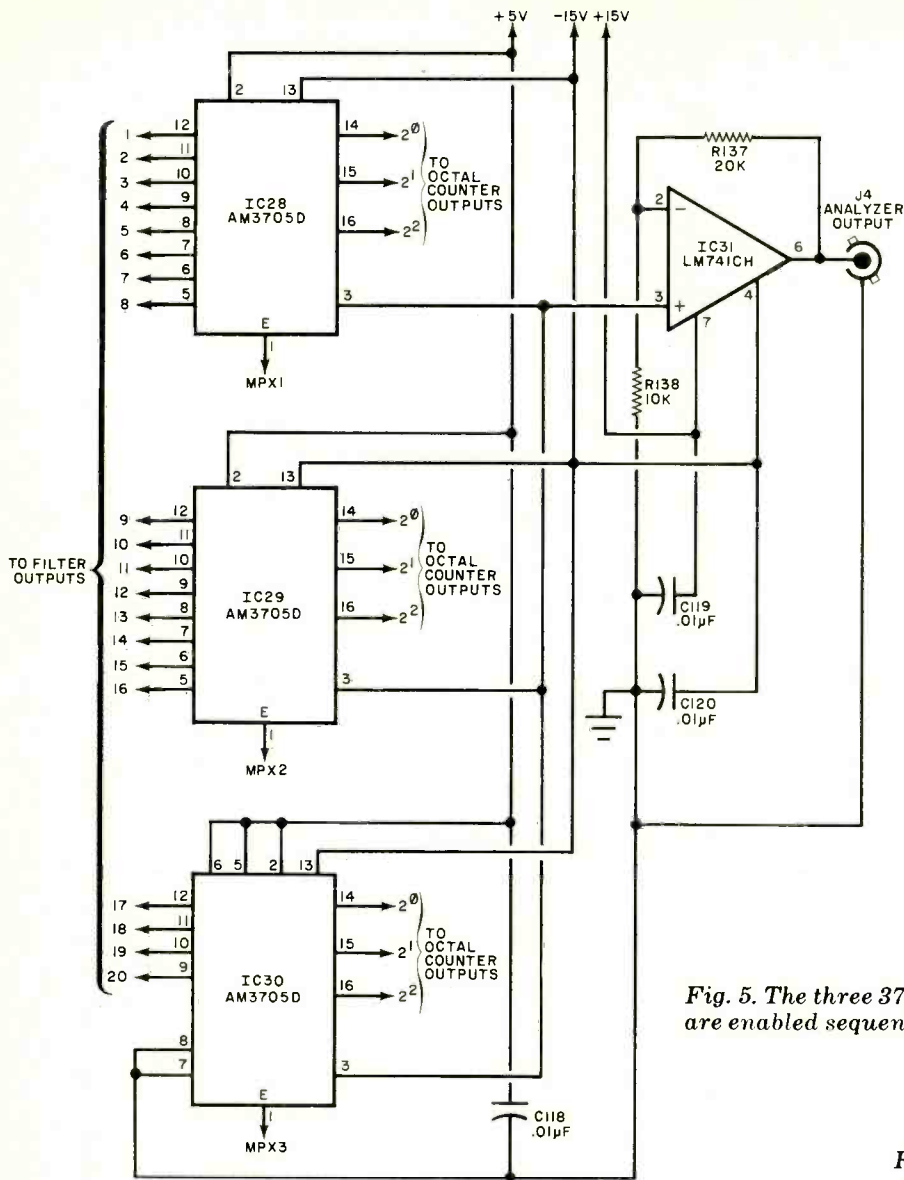


Fig. 5. The three 3705 multiplexer IC's are enabled sequentially.

scanned and sequentially passed to output buffer amplifier IC31, a 741 op amp with a voltage gain of two. On the eighth clock pulse, IC24 will revert to a 0 output, IC26 will increment to 1, causing MPX2 Select to go high and activating IC29. Thus, the outputs of filters 9 through 16 are scanned and passed to IC31. On the sixteenth clock pulse, IC24 causes IC26 to increment to 2, and IC27 issues an MPX3 Select command which enables IC30. Accordingly, the rectified outputs of filters 17 through 20 are scanned and passed to the buffer. At clock pulses 21 and 22, a ground (0 volt) is sent to the scope for base line reference. At clock pulses 23 and 24, IC30 sends +5 volts (boosted by IC31 to 10 volts) to the scope for maximum level reference. (Input signal levels should be adjusted to fall within these extremes.) At clock pulse 24, IC24 and IC26 reset themselves to zero, MPX1 Select again goes high and the process is repeated. Also, a positive-going transition at clock pulse 24 is used for scope triggering.

The power supply for the Analyzer is shown schematically in Fig. 7. Transformer T1 (40 V CT) and diodes D21 through D24 form a bridge rectifier. Ca-

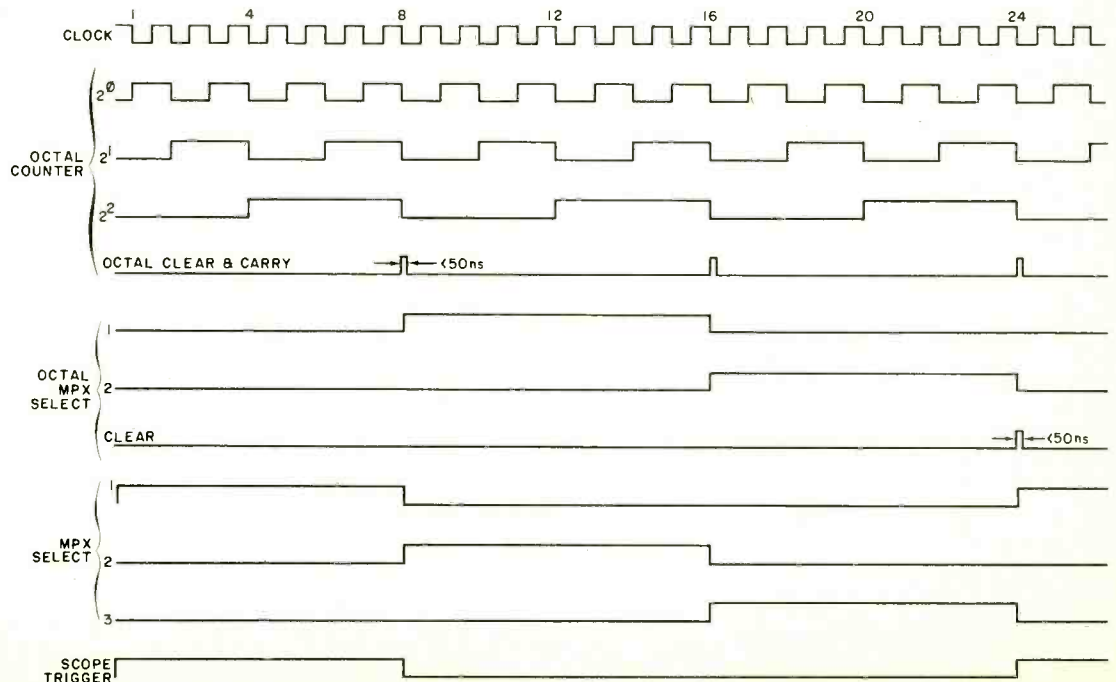


Fig. 6. The timing diagram below shows the clock waveform (top) and the events that occur at various clock pulses.

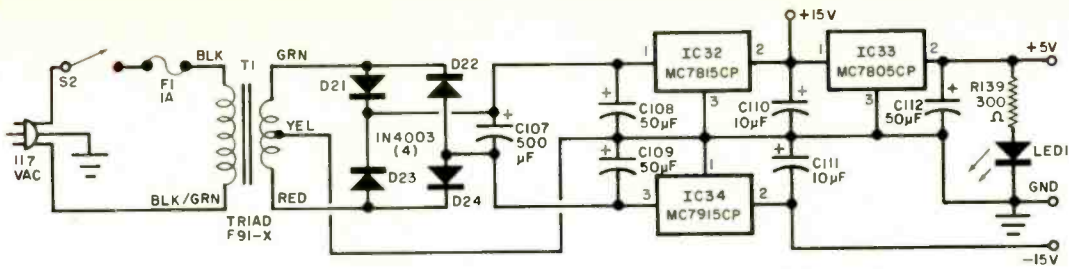


Fig. 7. Schematic of power supply circuit shows bridge rectifier and voltage regulators.

TABLE I—FILTER VALUES

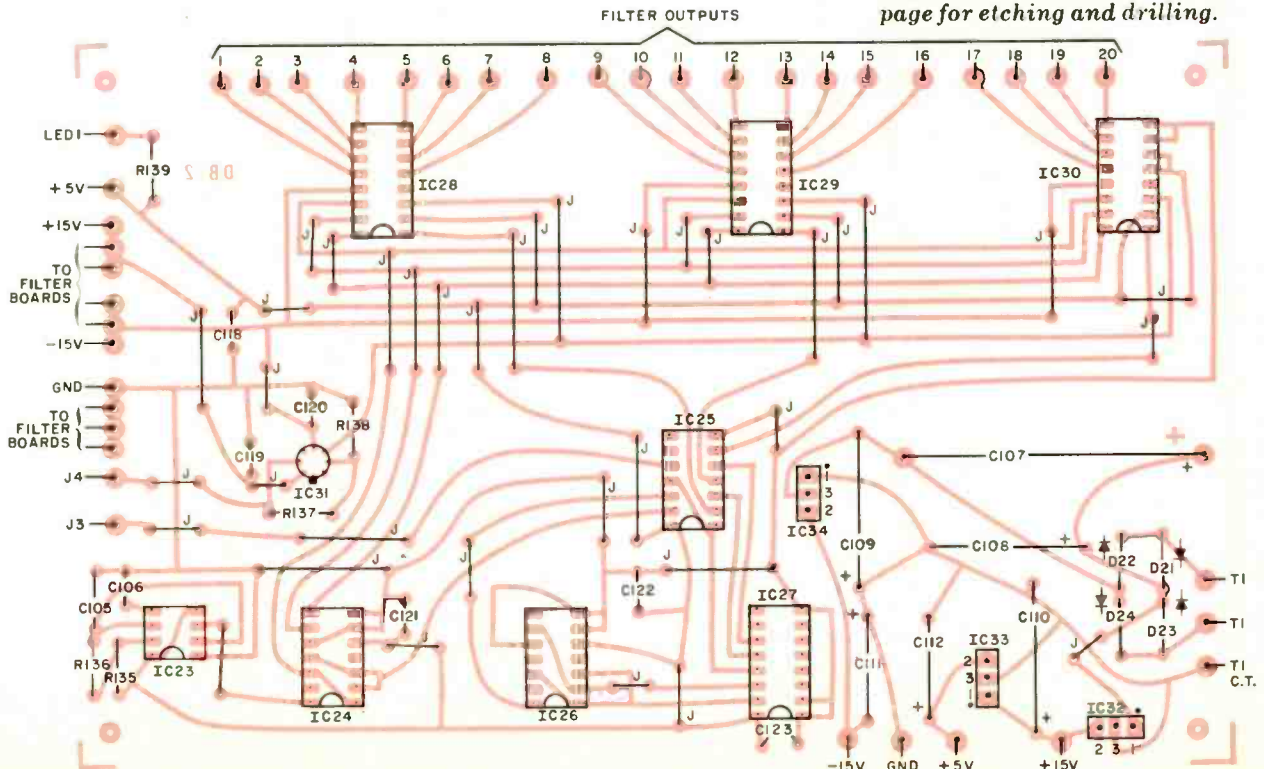
Filter	Center Frequency $f_c$ (Hz)	Resistors (ohms)	Capacitors ( $\mu$ F)
1	22.4	R35, R55—68, 100	C5, C25—0.1
2	31.5	R36, R35—75,000	C6, C26—0.068
3	45	R37, R57—51,100	C7, C27—0.068
4	63	R38, R58—38,300	C9, C29—0.047
5	90	R39, R59—38,300	C9, C29—0.047
6	125	R40, R60—26,100	C10, C30—0.047
7	180	R41, R61—26,100	C11, C31—0.033
8	250	R42, R62—28,700	C12, C32—0.022
9	355	R43, R63—46,400	C13, C33—0.01
10	500	R44, R64—31,600	C14, C34—0.01
11	710	R45, R65—31,600	C15, C35—0.0068
12	1000	R46, R66—23,700	C16, C36—0.0068
13	1400	R47, R67—23,700	C17, C37—0.0047
14	2000	R48, R68—23,700	C18, C38—0.0033
15	2800	R49, R69—26,100	C19, C39—0.0022
16	4000	R50, R70—38,300	C20, C40—0.001
17	5600	R51, R71—28,700	C21, C41—0.001
18	8000	R52, R72—42,200	C22, C42—470pF
19	11200	R53, R73—31,600	C23, C43—470pF
20	16000	R54, R74—28,700	C24, C44—360pF

capacitors C107, C108, and C109 provide input ripple filtering to IC voltage regulators IC32, IC33, and IC34. Capacitors C110, C111, and C112 provide output filtering. Resistor R139 limits current to LED1, the front panel power indicator.

**Construction.** The RTA is most easily assembled on three printed circuit boards (four if the optional log converter is desired). Etching and drilling and component placement guides for the Digital and Power Supply Board, Filter Board 1, and Filter Board 2 are shown in Figs. 8, 9, and 10, respectively. (See Table I for RC values for each filter.)

Mount all components on the pc boards using the minimum heat and solder required for good connections. Pay close attention to the polarity and basing of electrolytic (aluminum and tantalum) capacitors, diodes, transistors, and integrated circuits. The use of IC sockets or

Fig. 8A. Parts placement guide for digital and power supply board. See next page for etching and drilling.



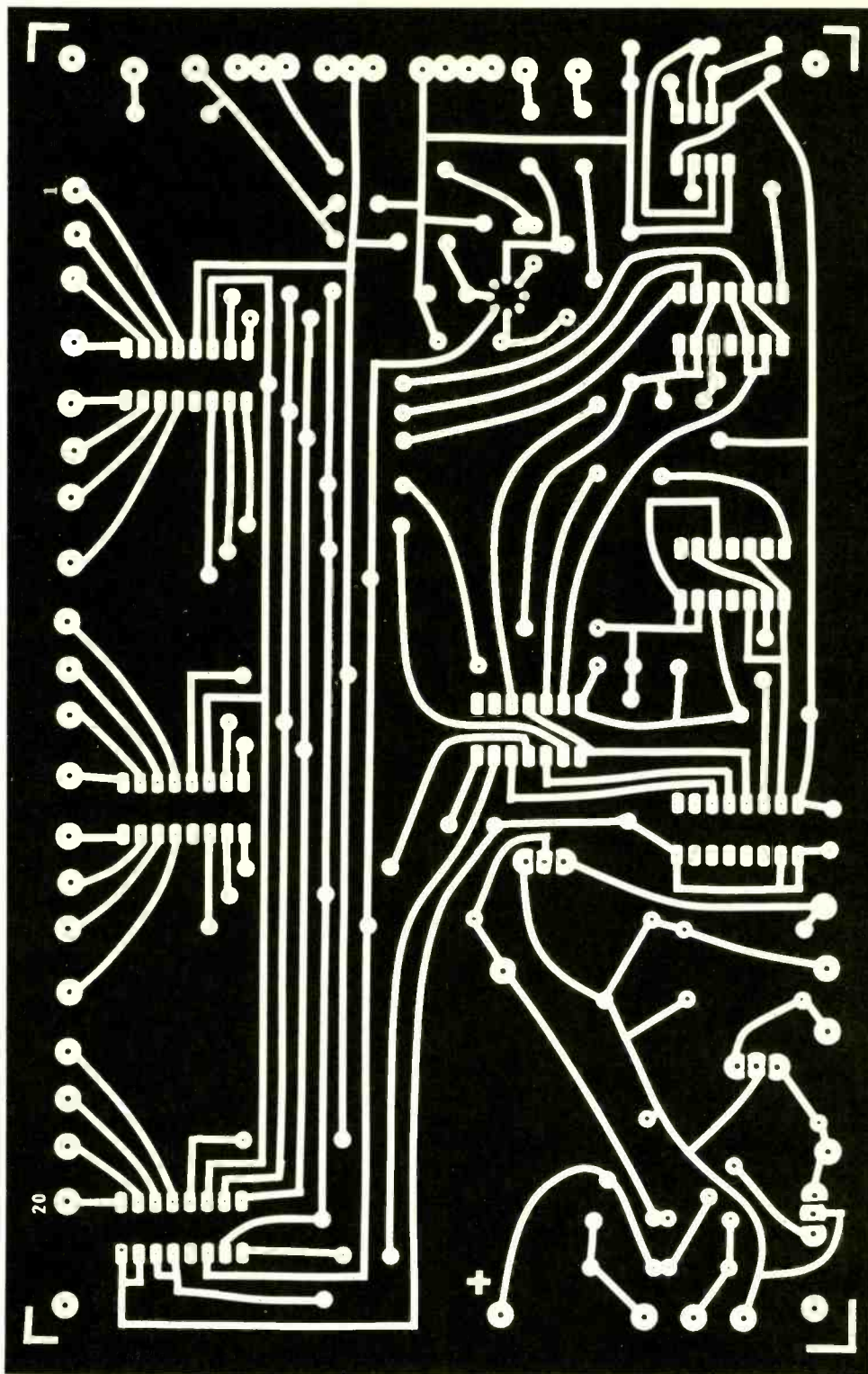
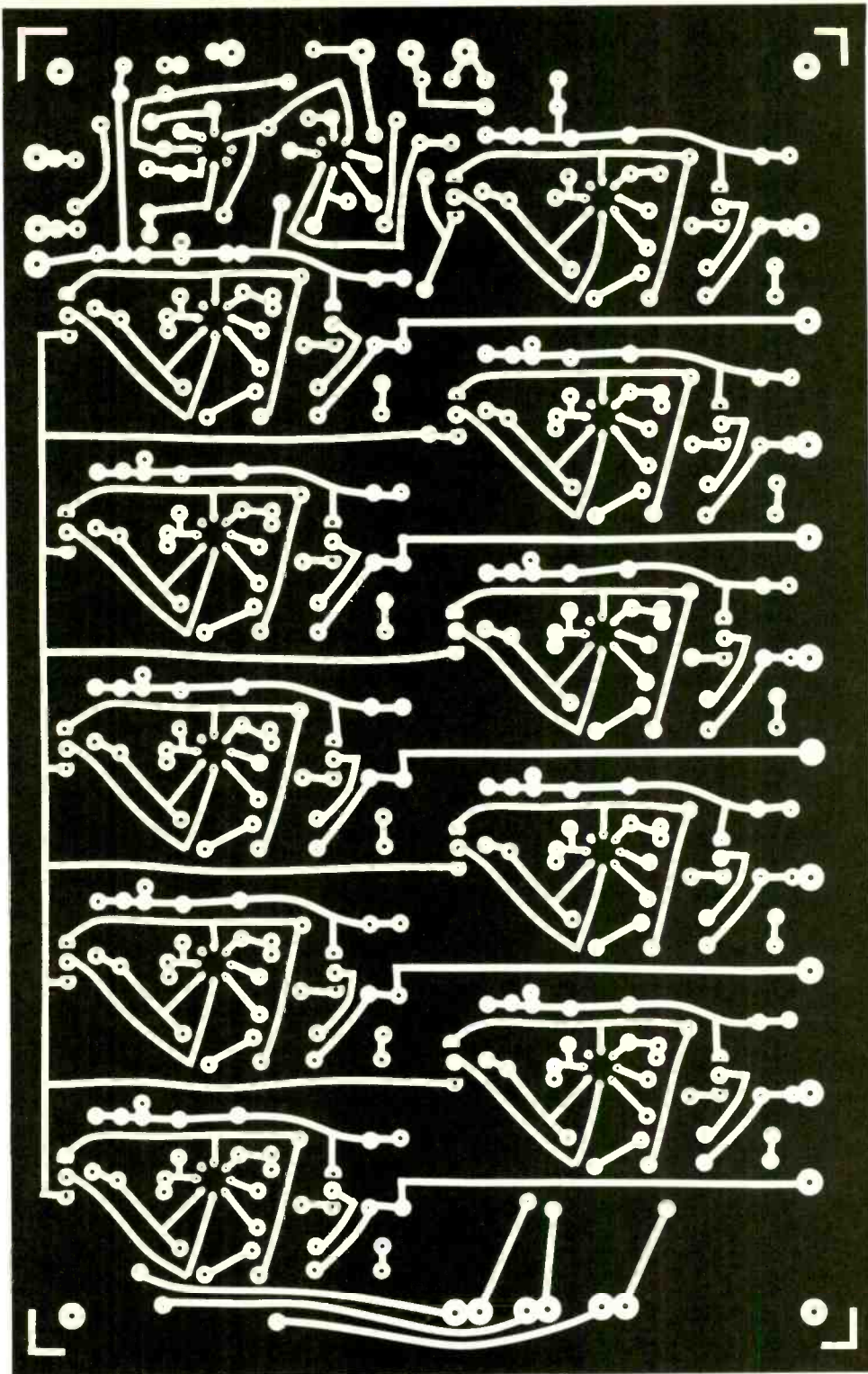


Fig. 8B. Etching and drilling guide for digital and power supply board.

Molex Soldercons for all IC's is recommended. All signal lines to and from the boards should be shielded (small-diameter coax is ideal). The power transformer should be mounted as far away from the boards as possible to minimize hum.

This transformer (T1) is a "universal" transformer, and not all of its color-coded leads are used. Cut short any unused



*Fig. 9A. Use this pc board for Figs. 9B and 10 on next page.*

leads and cover the ends with heat-shrink tubing. Also, be sure to use heat sinks on the voltage-regulator IC's.

In the authors' prototype, the pc boards (except the log converter) were stacked to conserve space. If you want to stack the boards, be sure to leave sufficient clearance for easy access to the LEVEL ADJUST and Q ADJUST potentiom-

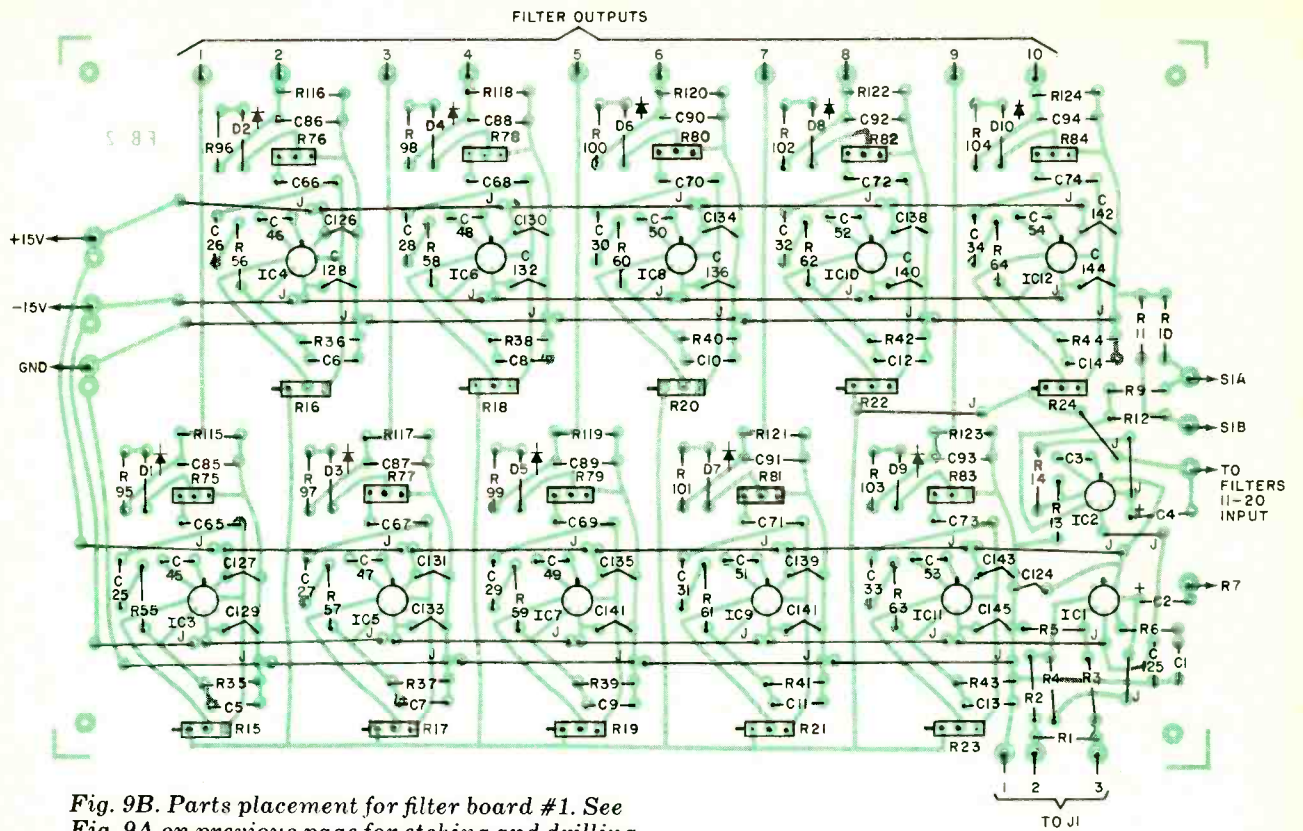


Fig. 9B. Parts placement for filter board #1. See Fig. 9A on previous page for etching and drilling.

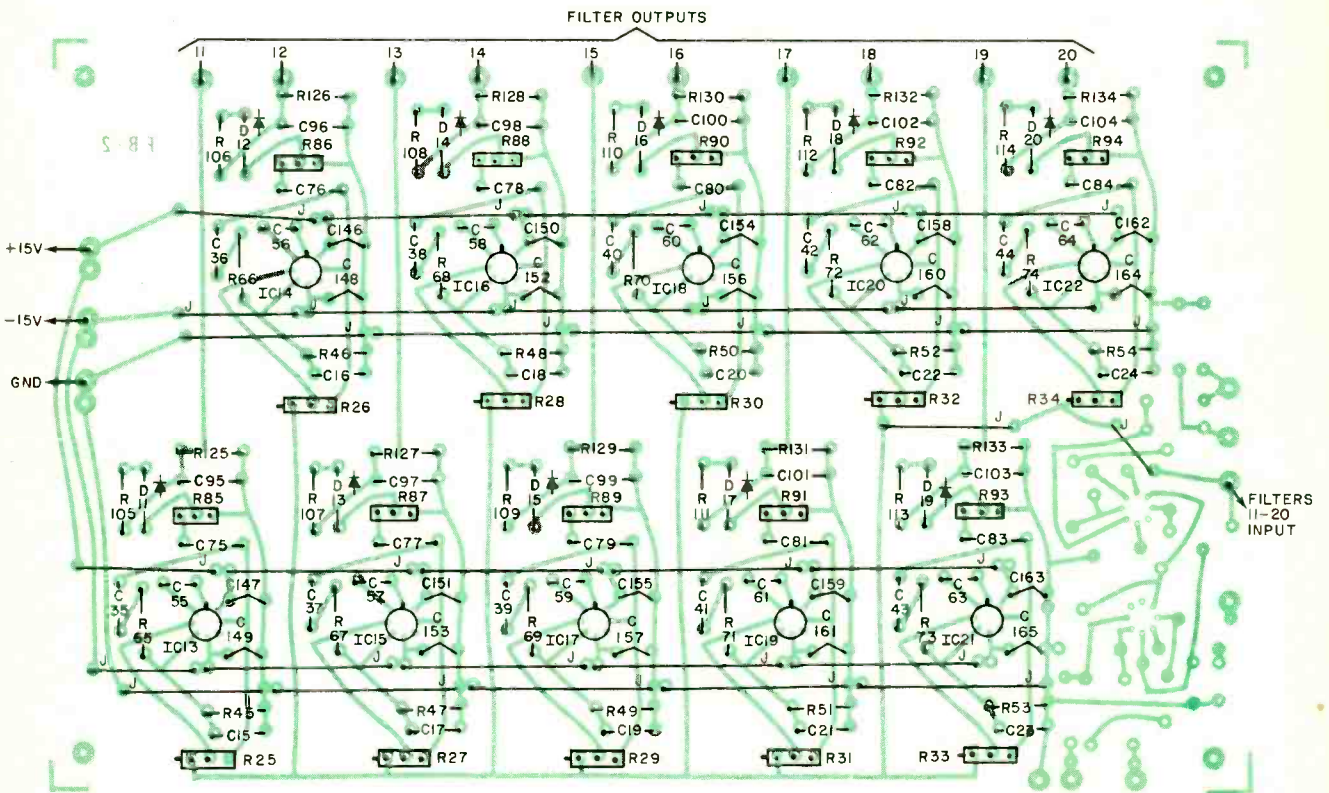


Fig. 10. Parts placement for filter board #2. See Fig. 9A for etching and drilling.

eters. These controls should be mounted on the filter boards so that all adjustment screws point toward power supply pads and away from input pads.

The prototype was enclosed in a 15" x

10" x 5" (38.1 x 25.4 x 12.7 cm) metal cabinet. Switches S1 and S2, LEVEL controls R7 and R8, jacks J1 through J5, and LED1 were mounted on the front panel. The fuseholder and line cord

strain relief were mounted on the rear.

Part II of this article will describe an optional log converter for direct readout of the scope trace in dB. Calibration and RTA use will also be covered. ◇



# BUILD A TRANSFORMERLESS DC-TO-DC VOLTAGE DOUBLER

*High-efficiency, high-current solid-state circuit doubles the input dc level.*

BY MARLOWE J. BUCHANAN

FOR MANY years, the only reasonable nonmechanical means of generating high dc potentials from low voltages in the medium-to-high-power range has been the oscillator-driven transformer. This type of converter has two major drawbacks—the average experimenter may not have the knowledge or the materials to design and build his own transformer/converters, and the power consumption is relatively high, making the converters inefficient at currents much below their ratings.

The capacitive voltage doubler described here is superior to normal converters in many applications. For example, it can be used to extend the range of a low-voltage power supply or to run a

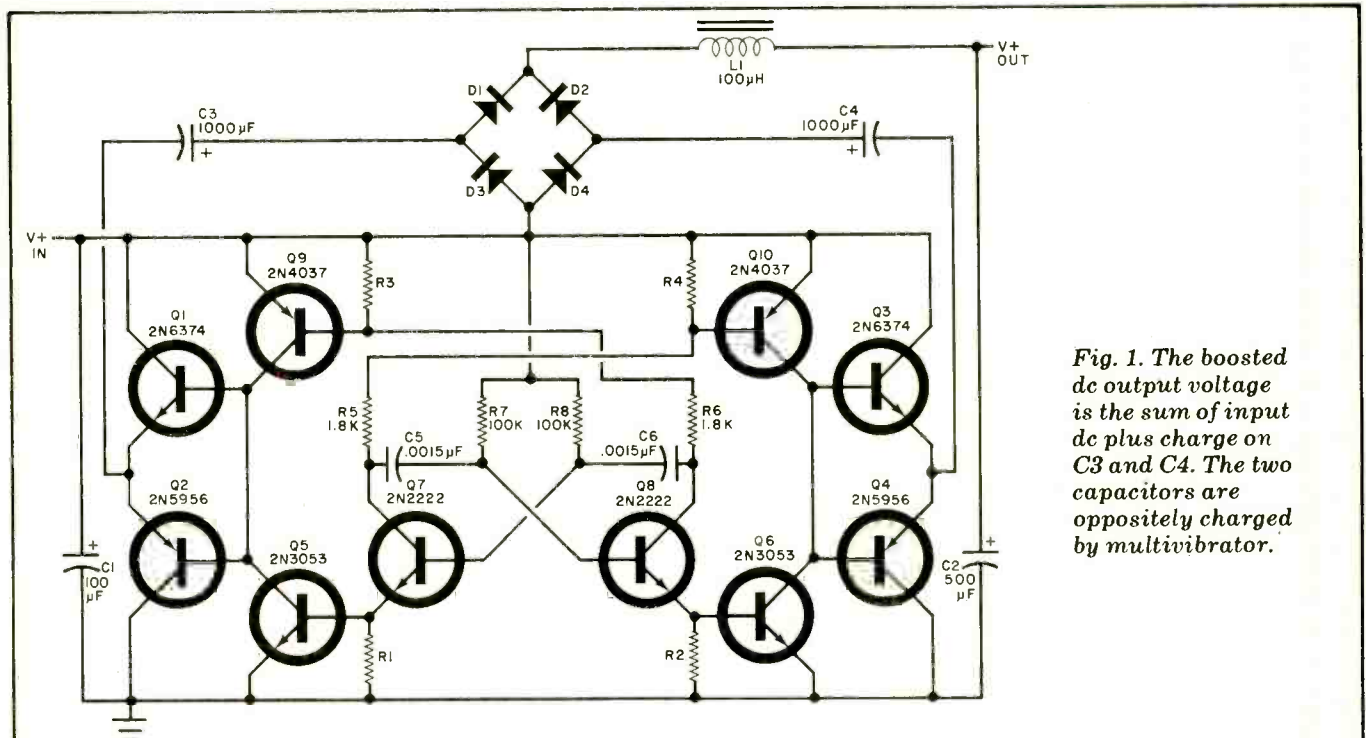
medium-power audio system in a vehicle. Capable of very high efficiencies, the converter can easily be adapted to the voltage and power needed.

**Circuit Operation.** Basically, the circuit shown in Fig. 1 acts as a set of high-speed electronic switches that alternately charge C3 and C4 to the supply voltage and then connect the capacitors in series with the supply and load. The output load in effect "sees" the sum of the voltages across C3 and C4 and the supply voltage. Since C3 and C4 are driven 180° out-of-phase, this is a true full-wave voltage doubler.

Transistors Q7 and Q8 and their associated components form a multivibra-

tor that has an operating frequency of roughly 6000 Hz with a 12-volt dc input supply. This oscillator produces two square waves that are 180° out-of-phase with each other and are used to drive Q5, Q6, Q9, and Q10. Resistors R1 through R4 are selected to limit base current to 3 mA. Drive transistor pairs Q5/Q9 and Q6/Q10 produce equal and opposite square waves that have extremely fast rise and fall times and are capable of sinking or sourcing a minimum of 100 mA to the output transistor pairs (Q1/Q2 and Q3/Q4).

When Q7 conducts, Q2, Q3, Q5, and Q10 are driven into saturation. Capacitor C3 charges through Q2 and D3, while C4 discharges through Q3, D2 and



*Fig. 1. The boosted dc output voltage is the sum of input dc plus charge on C3 and C4. The two capacitors are oppositely charged by multivibrator.*

## PARTS LIST

C1—100- $\mu$ F, 25-V electrolytic capacitor  
 C2—500- $\mu$ F, 50-V electrolytic capacitor  
 C3, C4—1000- $\mu$ F, 50-V electrolytic capacitor  
 C5, C6—0.0015- $\mu$ F, 50-V capacitor  
 D1 through D4—50-V, 6-A rectifier diode (or bridge)  
 L1—100- $\mu$ H, 4-A, 0.1-ohm dc resistance (or less) choke

Q1, Q3—2N6374 or similar transistor  
 Q2, Q4—2N5956 or similar transistor  
 Q5, Q6—2N3053 or similar transistor  
 Q7, Q8—2N2222 or similar transistor  
 Q9, Q10—2N4037 or similar transistor  
 Following resistors are 1/4 or 1/2 watt, 10%:  
 R1 through R4—For input of 6 volts, omit; for

9 V, use 1000 ohms; for 12 V, use 330 ohms; for 15 V, use 180 ohms; for 18 V, use 120 ohms; for 21 V, use 100 ohms; for 24 V, use 82 ohms.

R5, R6—1800 ohms

R7, R8—100,000 ohms

Misc.—10-watt heat sink, suitable enclosure, heavy-gauge wire, mounting hardware, etc.

## Empire's Blueprint For Better Listening

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Already your system sounds better.

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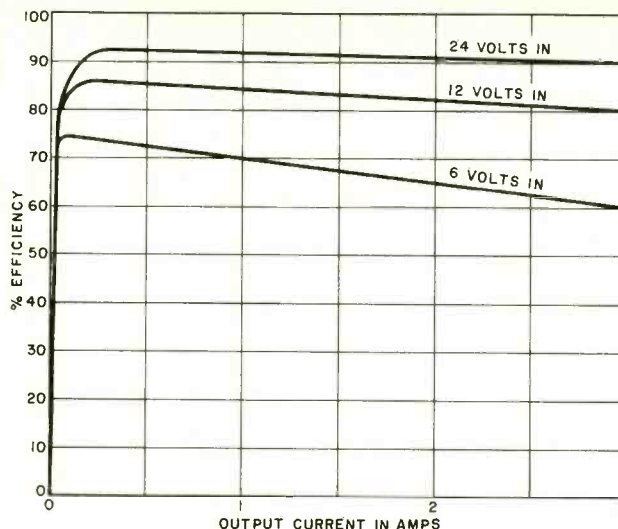


Fig. 2. With 12-volt power source, the efficiency remains above 80% even with full load. The higher the input voltage, the higher the efficiency.

the output load. When  $Q8$  conducts, the process reverses itself, with  $C3$  discharging through the output load,  $Q1$ , and  $D1$ , while  $C4$  charges through  $Q4$  and  $D4$ . Capacitor  $C1$  helps prevent high-frequency pulses from entering the supply, while  $L1$  and  $C2$  filter the output.

**Construction.** Since circuit operation is not critical, any convenient means of construction can be used to build the converter. However, for maximum efficiency and minimum ripple, the following should be observed:

Keep all leads, especially those to the output devices, as short as possible. Even the minor inductance of long wires can cause ripple in the output at the high switching frequency used in this voltage converter.

Use 12- or 14-gauge wire for power lines and making connections to output transistors  $Q1/Q2$  and  $Q3/Q4$ . If you elect to assemble the circuit on a printed circuit board, use at least  $\frac{1}{4}$ " (6.4-mm) wide copper traces to interconnect the output devices. These measures will eliminate resistive voltage losses.

Connect  $C1$  as close as possible to the emitter leads of  $Q5/Q6$  and  $Q9/Q10$  to minimize ripple feedback into the voltage source.

No heat sinking is required for outputs up to 1 ampere. At higher currents,  $Q1$  to  $Q4$  must be on a heat sink that has a thermal resistance of  $5^\circ\text{C}/\text{watt}$ .

**Use.** The major loss of efficiency in a capacitive voltage doubler is the inherent voltage drop across the diodes and output transistors. Hence, it is not possible to exactly double the supply voltage, the difference being 1.4 volts with no load to 4.8 volts with a 3-ampere load. Since these losses are a fixed function of the output current, overall efficiency

will increase dramatically with higher operating potentials, as shown in Fig. 2. Efficiencies in excess of 98% at several hundred watts can be achieved by a capacitive voltage doubler adapted for 100 volts input. These doublers also have very low ripple, typically less than 200 mV at a 3-ampere output.

The other loss of efficiency is the power consumed by the multivibrator and drive transistors. This is generally less than 150 mW at a 12-volt dc input, which accounts for the circuit's ability to achieve high efficiencies over 98% of its operating range. This sharply contrasts with the much lower efficiencies obtainable with transformer-based converters.

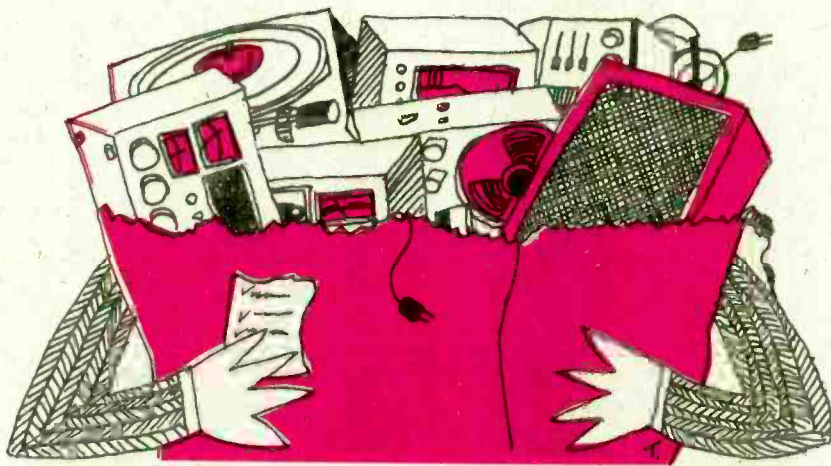
If the circuit shown in Fig. 1 does not satisfy your needs, there are a number of adaptations you may wish to try. For example, higher currents or potentials can be handled by substituting appropriately rated devices and slightly altering the multivibrator. Higher efficiencies can be obtained by substituting germanium power transistors for  $Q1$  through  $Q4$  and replacing the rectifiers with four suitable germanium power rectifiers (transistors with the base tied to the collector or emitter). For currents less than 100 mA,  $Q1$  through  $Q4$  can be omitted;  $C2$ ,  $C3$ ,  $C4$  need be rated at only 50  $\mu\text{F}$ ; and the rectifier diodes ( $D1$  through  $D4$ ) can be rated at 1 ampere each.

A voltage tripler can be made by adding two 1000- $\mu\text{F}$  capacitors and another bridge rectifier between ground and the common emitters of the output transistors. However, triplers work at lower efficiencies and with considerably reduced output current capability.

It is possible to use the output of one doubler as the input voltage source for another doubler. Two doublers connected in this manner provide about 36 volts output from a 12-volt battery.  $\diamond$

## Special Focus on AUDIO

- THE BASICS OF BUYING HI-FI COMPONENTS
- DYNAMIC NOISE REDUCTION SYSTEMS AND EXPANDERS
- MATCHING TAPES TO RECORDERS
- IC MULTIPLEX DECODER IMPROVES STEREO FM PERFORMANCE
- QUIZ OF AUDIO BASICS



## The Basics of Buying HI-FI COMPONENTS

**Y**OU can run down to your neighborhood appliance store, hand the clerk around \$99.95, and come away with a "home music system" that will deliver music received via AM or FM broadcasting and probably play records as well. Or, you can go to your favorite furniture shop and spend a few hundred dollars or more for a console cabinet containing unspecified electronic elements that will do the same thing. Finally, you can shop for individual audio components, spending anywhere from a few hundred dollars to many thousands of dollars and, again, end up with a home music system that reproduces radio broadcasts, records, and even tape recordings. These three divergent approaches to home music reproduction

have some things in common—but they are also poles apart in terms of the kind of sound you will hear.

Crammed inside the \$99.95 compact system and the one-piece console are circuits which pick up radio signals and translate them back to audio signals, circuits which amplify the minute signals picked up by a self-contained record player with its tonearm and cartridge, and even a pair of loudspeakers which translate all these signals back to audible sound. Audio electronics can be further broken down into the "tuner" or radio section, the "pre-amplifier" or control section, and the "power-amplifier" section which activates the loudspeakers. Even a tiny portable transistorized radio contains all these elements, but you

would hardly classify the sound you hear from such a portable as "high fidelity."

In order for a loudspeaker (or, a pair of loudspeakers in the case of stereo or four loudspeakers for quadrasonic sound) to reproduce music, its cone or diaphragm must vibrate, for sound is nothing more than rapid compressions or expansions of the air around us. When the air vibrates rapidly, we hear a high-pitched tone. Slower vibrations of air impinge upon our hearing mechanism to create the hearing sensation of a low-pitched note—or one of low frequency. But, whenever a pair of loudspeakers is mounted in the same cabinet as the delicate record-playing tonearm and pickup, the fairly violent vibrations of that speaker (needed to re-

produce sound) are also transmitted via the cabinet structure to the tone-arm and pickup, the fairly violent vibrations of that speaker (needed to reproduce sound) are also transmitted via the cabinet structure to the tone arm and its phono pickup stylus. If you try to turn up the volume to life-like levels, the vibrations generated by the speaker system can initiate a "vicious circle." They are re-amplified by the record player, reproduced as greater and greater vibrations from the speakers and so on, until the entire system takes off in an annoying "howl" which is called "acoustic feedback."

Interestingly, most all-in-one systems do not exhibit this phenomenon. The reason they don't is because the electronics built into such systems is generally restricted in its ability to reproduce all musical tones in their proper relative intensity. Since low-frequency tones (bass) involve more intense vibrations, the ability of the electronics of such systems to reproduce those tones is often severely restricted. In other words, you don't hear all the music contained in the actual record!

The first requisite of a true high-fidelity system is that it reproduce all musical tones faithfully. So it's imperative that loudspeakers are separated from the rest of the system—a condition easily achieved with separate components. Faithfulness of musical reproduction also means that sounds must not contain more tones than were present in the original program. In high-fidelity terms, that means low or negligible distortion. Distortion, broadly defined, includes any extraneous sounds such as harmonically related tones, electrically generated hum, or random noise or hiss. In short, the reproduced music should be an exact replica of the original performance as contained in the record or other program source. The minimal electronics, poor-quality record players, and undersized, un baffled loudspeakers contained in most all-in-one radio-phonographs and "compacts" are simply incapable of this kind of reproduction.

**Building-block Flexibility.** There are other distinct advantages in the component approach to high-fidelity sound. Over the brief history of high fidelity we have witnessed a progression from monophonic sound (in which all music is reproduced in one-dimensional form from a single loudspeaker), to two-dimensional stereophonic sound (in which two speakers are used to give the listener an added sense of spatial real-

ism), to 4-channel or quadraphonic sound (in which the listener gains true concert-hall ambience reproduced from four properly positioned loudspeakers). Owners of "compacts" or consoles found their equipment hopelessly obsolete as each of these advances gained acceptance. Owners of quality component systems, on the other hand, were able to update and add to their basic systems without any loss of their original investment.

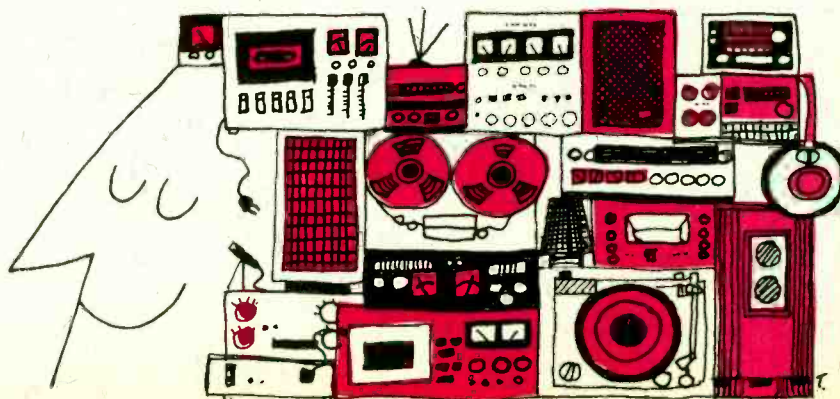
Clearly, this building-block approach to good sound makes sense economically. As a further example, suppose that your primary interest is in a good record-playing system. You might elect to purchase a system consisting of a good amplifier, a pair of speakers, and a separate turntable or record-playing system at the outset. Then, if taste and budget dictate, you can add a stereo FM/AM tuner at a later date, connecting it in seconds to the system you already enjoy. You might also wish to upgrade one component in a system while retaining the others, which is easily achievable with an audio component system. Finally, you might even want to add tape recording and playback facilities to your expanding system by purchasing a tape deck of the open-reel, cassette, or cartridge variety. All of these added program sources will utilize the basic amplifier electronics and speaker systems purchased initially. You may even want sound in other listening rooms (a bedroom, or a den). This can be provided by the addition of another pair of speakers which can be connected to most high-fidelity component amplifiers or receivers and switched in by means of suitable front-panel controls. Moreover, one can add an equalizer, noise-reduction system, or other accessory component to an audio component system in order to obtain more realistic sound.

**Electronic Options.** There are three

basic approaches to assembling the electronics of a hi-fi system. The most popular of these involves the purchase of a component called a receiver. This single unit will contain all the circuitry needed to pick up AM, FM, and stereo-FM radio signals, the necessary preamplifier and control circuits whereby program sources are selected and adjusted for proper listening, and the power amplifier section needed to drive the loudspeaker systems.

In the early days of hi-fi, all-in-one receivers were rather limited in their ability to deliver sufficient power to the loudspeakers. Today, you will find all-in-one receivers which boast power-output ratings higher than 100 watts per channel. Because all of the electronics is combined on a single chassis, the receiver represents the most economical approach to a hi-fi component system. A common power supply, a single front panel, a single cabinet enclosure and other parts-in-common result in savings that cannot be obtained from wholly separate components.

Nevertheless, a visit to your hi-fi dealer will reveal an array of separate amplifiers as well. So-called integrated amplifiers combine two of the three previously referred to electronic sections—the preamplifier-control portion and the power-amplifier section. We already mentioned a possible reason for choosing this option. You may want to forego FM and AM radio at the outset and concentrate on good record reproduction (or possibly tape). A tuner can always be purchased later and will interconnect easily with any integrated amplifier, even if your purchase is made many years from now. Furthermore, you will often find that an integrated amplifier has additional control refinements and perhaps more signal input facilities than an all-in-one receiver—another possible reason for its selection as the basic component of a system. You may also



be able to purchase a more powerful integrated amplifier for the same amount of money that would be required for a more moderately powered complete receiver unit.

A third option, offering perhaps the greatest flexibility of all (and generally the most costly), is to purchase a separate tuner, a separate preamplifier-control unit, and a separate *basic power amplifier*. This arrangement is not nearly as popular as the other two, and usually represents the choice of those audio enthusiasts who demand the ultimate in flexibility, superior performance specifications (lowest distortion and very-high-power-output capability), and other operating features not found either in complete receivers or integrated amplifiers.

Irrespective of which of these three types of component systems you choose to assemble, you'll want to familiarize yourself with the more important technical performance specifications listed in manufacturers' advertising brochures. Tuner, preamplifier, and amplifier specifications mean the same thing whether they are used to describe those individual sections in a complete receiver, an integrated amplifier, a separate tuner, a separate preamplifier-control unit, or a basic power amplifier.

What about 4-channel sound? Multiple-channel sound is certainly not new. As early as the 1930's, moviegoers thrilled to the multi-channel Walt Disney production of "Fantasia," in which listeners were surrounded by music reproduced over as many as six separate speaker systems. For many years, recording studios have used multiple tape tracks to record individual instrumentalists and vocalists under optimum studio conditions. These tape "tracks" were then "mixed down" to two-channel "stereophonic" final products in the form of stereo records. Only in 1970 did 4-channel sound reach the home music listener—first as 4-channel tapes and later in a variety of disc formats.

Musically, there are two distinct approaches to 4-channel sound. The "classical" approach involves the reproduction of the ambience of the concert hall itself. Any concertgoer will readily admit that much of the sound he or she hears at a live concert is reflected from the walls and ceiling of the hall itself, rather than from the performers on stage. It is this ambient quality which distinguishes the live performance from its recorded and reproduced equivalent in a home listening room of restricted dimensions. By recording two additional channels, using microphones at the rear

of the concert hall and reproducing these channels over similarly positioned speakers behind the listener, it is possible to create a sense of vast space in the home listening environment which is not achievable with conventional two-channel reproduction systems.

Given the extra pair of channels, it is also possible to assign different instruments or soloists to specific channels so that the listener finds himself in the center of the "performance" when playing back recordings. This alternate recording approach to quadraphonic sound is particularly effective when applied to modern pop and rock music, affording the listener a sense of involvement not otherwise attainable.

Recording four channels on tape is relatively simple. Both 8-track cartridges and open-reel tapes have multitrack capability. Cassettes do not.

In the case of phonograph records, there are two basic systems. One called "matrixing," is a process of combining or encoding the four original program channels into two complex audio programs. These two "encoded" channels can then be applied to the record groove much like a stereo program. Suitable decoder circuits, often built into a four-channel amplifier or receiver, "decode" the two channels into four separate signals approximating those which were recorded at the beginning of the process.

The two most popular matrix techniques currently in use in the United States are the SQ system, developed by CBS and the QS system developed by Sansui. Both are capable of excellent 4-channel reproduction and each can be further enhanced by the addition of circuits called "4-channel logic" which increase apparent separation between channels. In addition to matrix records, there are also so-called discrete or CD-4 records which actually contain four separate programs in the single record groove. Because of the very high frequencies contained in these CD-4 discs (developed jointly by RCA and the Japan Victor Company of Japan), a new cartridge or phono pickup is required. Moreover, a turntable used for playing CD-4 records should have low-capacitance phono cables for best results.

A 4-channel home music system is necessarily more costly than a stereo system of equal power and performance capabilities. Any 4-channel system requires four separate loudspeakers as well as four amplifiers (the latter often combined in one unit).

Before deciding whether to buy 2- or 4-channel equipment, listen to each type

of system in a properly equipped demonstration room at your audio dealer. Bear in mind that, whether you elect to buy 4-channel or stereo, the important criteria of low distortion, good frequency response, and adequate power output apply to each type of system. If your budget is limited, you might be better off starting with a good stereo component system rather than settling for an inferior quadraphonic system. Separately available decoders, demodulators, and extra amplifiers and speakers can be added to any existing stereo sound system at any time in the future.

**Hi-Fi Shopping Tips.** Shopping for a hi-fi component system can be fun—or it can be a frustrating experience. There are four general sources of supply. (1) You can visit an audio specialist dealer who sells nothing but high-fidelity component equipment. (2) You can shop in a branch of one of the many electronic-supply stores that sell other specialized electronic equipment in addition to hi-fi, but generally have listening rooms set aside for hi-fi component selection. (3) You can order components from a variety of mail-order or catalogue houses (some of whom also have retail stores in many cities), or (4) you can visit a "discount" establishment which has a variety of merchandise available in sealed factory cartons but provides no facilities for equipment auditioning. Your choice of supplier will generally depend upon how much (or how little) personalized service you require.

The first two categories of retail establishments generally offer the most service. If you are starting from "scratch," it is essential that you be able to listen to the components you plan to buy. As a matter of fact, the first components you should select are your loudspeakers, since there is the greatest variation in sound amongst the hundreds of speaker models currently available. Zeroing in on the loudspeakers that sound best to you also puts you in a better position to decide on how powerful an amplifier or receiver you will need, since some speakers require far more power than others to deliver a given loudness level.

Generally, the well-equipped audio dealer who offers auditioning facilities and technically trained sales personnel will offer less of a discount than the "mail order" or "warehouse" type of retailer, since his overhead costs are higher. In return for the somewhat higher price you pay, you will obtain the aforementioned advantages that may or may not be important to you. ◇

# Dynamic Noise Reduction Systems and Expanders

BY WILLIAM S. GORDON

**T**HE QUEST for noise reduction in high-fidelity equipment has challenged audio engineers for decades. As far back as 1947, H. H. Scott introduced a "Dynaural Noise Suppressor," to deal with the noise problem; and the Dolby noise-reduction system (professional version) was demonstrated in the mid-sixties. The age of noise suppression was really ushered in for serious audiophiles, however, when the Dolby NR system was incorporated into cassette decks in the late sixties.

Since then, a great deal has been done to make noise reduction a realistically inexpensive and practical means of obtaining the maximum enjoyment out of hi-fi equipment. In this article, we will examine a host of noise-reducing systems that have come onto the consumer market and describe how the different schemes work.

**Two Categories.** Noise-reduction systems can be grouped into two categories: Those that rely on preprocessed (encoded) signals and those that operate on "raw" (unprocessed) signals. Examples of the first category are the Dolby A and B systems, JVC's Automatic Noise Reduction System (ANRS), and the dbx system. In the latter category are Phase Linear's "Autocorrelator," Philips' Dynamic Noise Limiter (DNL), and Burwen's noise-reduction system.

The devices that encode the signal before recording or transmission first pass the signal through an encoder and then through a decoder. In essence, these "two-pass" systems are noise-preventive devices because they do nothing to remove noise already in the program but attempt to prevent it from creeping in between the encoder and decoder. The unencoded "single-pass" systems attempt to remove noise already in the program.

Two-pass processors generally employ complementary signal compressors and expanders, called companders. During processing, the dynamic range of the signal is compressed so that a two-fold increase in the input signal causes

less than a two-fold increase in the output. The actual input/output characteristic depends on the compression ratio used. For example, a 3:2 ratio causes a 2-dB output increase for every 3-dB increase in the level of the input signal. This means that a 60-dB dynamic range can be compressed into an output signal with only a 40-dB range.

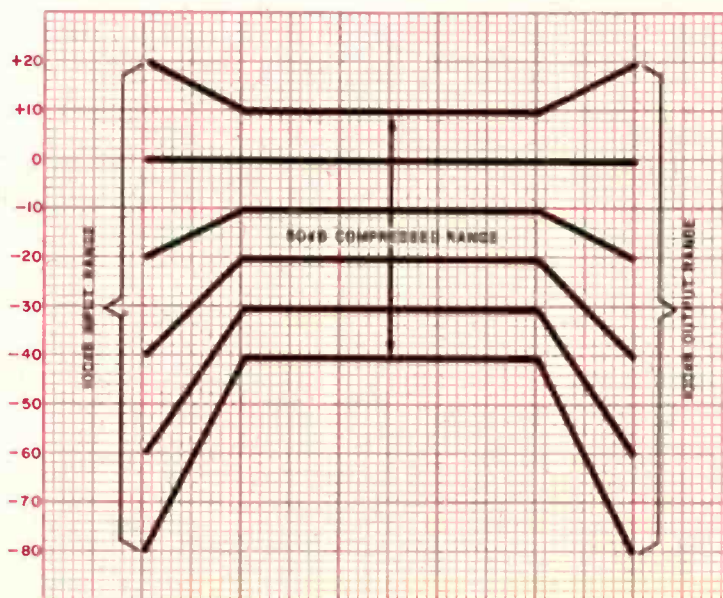
Compression is important because the dynamic range of many program sources exceeds the range of modern state-of-the-art hi-fi equipment, especially tape recorders and FM tuners. A symphony orchestra can have an 80-dB dynamic range, but a recorder might have a range of only 55 or 60 dB. By using a 2:1 compression ratio, the entire 80-dB orchestra range can be compressed down to 40 dB, which is well within the average recorder's capabilities to handle.

The signal-to-noise ratio (S/N) can give you an idea of the capabilities of a piece of equipment. The maximum level a device can handle is determined by the point at which distortion reaches an unacceptable level (generally 3% THD in consumer equipment and 1% in pro-

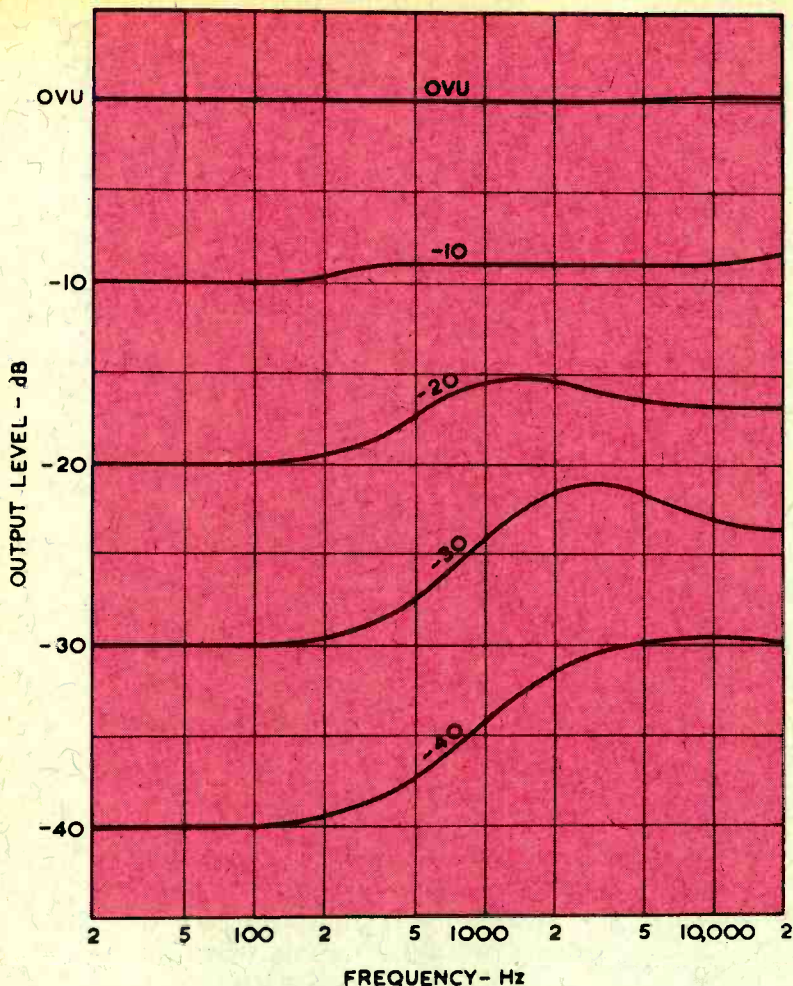
fessional equipment). The minimum level that can be handled is determined by the "noise floor." Signals that are lower in level than the residual noise of the equipment are lost in the hiss and hash at the noise floor.

With sufficient compression, a wide dynamic range program can be squeezed into the limited range available in a tape recorder. This assures that the program peaks will not be too high to handle, while keeping the minimal signals above the noise floor.

A compressed signal must be expanded to restore its original dynamic range. An expander is the mirror image of a compressor. In it, a two-fold increase in program level at the input results in a greater than two-fold increase in the expander's output signal. To restore the original dynamics of the signal in the above example, a 2:3 expansion ratio would be used. Hence, the 40-dB compressed signal would be expanded back up to its original 60-dB dynamic range. This opens up the top of the range and simultaneously pushes down the noise floor. The net effect appears as a reduction in the residual noise, so



The 2:1 linear compander characteristic of the dbx system illustrates how dynamic range is compressed and then restored.



*Dolby encoding characteristics show output level changes in decibels versus frequency over entire 20-to-20,000-Hz range.*

the system qualifies as a "noise-reduction" system.

**How Companders Work.** Compressors and expanders are basically amplifiers whose gain is varied by a voltage. (Such a device is known as a voltage-controlled amplifier, or vca.) They also include detectors that measure the signal level and produce the voltage that controls the gain of the amplifiers.

The time constants of the detector circuits must be chosen very carefully. If they are too short, the detector responds very rapidly and follows the low-frequency signals. The vca's gain "chases" the low-frequency signals, increasing distortion and modulating the rest of the signal with a low-frequency tone. A very long time constant causes the detector to respond very slowly to the average signal level. Sudden transients get through before the gain of the vca can be reduced. The transient will not be compressed and will cause the system to overload. Since the transient is detected, the signal for the vca to reduce its gain will be delayed. Then, an audibly discrete inter-

val later, the vca's gain reduces where no reduction is required and a "dropout" will be heard in the program.

Another audible flaw in wideband, widerange companders is "breathing." When the input signal disappears or is greatly reduced in level, the gain of the compressor increases and boosts the level of any noise present in the signal. When the music level increases, the level of the noise decreases, and when the music level decreases, the noise floor comes up. As the system operates under these conditions, it sounds like it is "breathing." Note that this is not noise introduced by the recorder between the compressor and expander (which is reduced by compander action) but noise in the signal prior to compression.

**Enter the Dolby System.** The Dolby noise-reduction system was originally designed to combat the problems inherent in companders. The professional Dolby A system divides the frequency spectrum into four bands, each of which is processed separately. This was done so that an increase in midband energy

would not reduce the level of the lows and highs. Where there might be a lot of midband energy but little high-frequency content, the processor reduces the midband level to avoid overloading the recorder. At the same time, it keeps the gain at the high end up so that the highs are not pushed down near the noise floor. This is important because psychoacoustic tests reveal that low-frequency signals do not mask high-frequency noise, nor do high-frequency signals mask low-frequency noise. (Masking psychoacoustically makes one less aware of noise when a strong signal is present than when it is absent. Masking of noise is effective only in the frequency range of the signal; hence, Dolby's use of the four-band approach to the problem.)

The Dolby system employs the processor only on low-level signals, which are boosted above the noise floor, while high-level signals emerge unchanged. The lower the level of the signal, the greater the boost. Hence, the processor is used only when signal levels approach the noise floor. The action of the system is less noticeable to the listener and overcomes the objections of previous full-range companders.

The final improvement in the Dolby system is that the attack time of the compressor is variable. If the signal level increases dramatically, the attack time is very fast to minimize the time the system is overloaded. For less severe increases in level, the attack automatically slows down to minimize low-frequency distortion and modulation of the music by low-frequency tones.

Having become the standard of the professional recording industry, the Dolby A system was later simplified and became the Dolby B system familiar to consumer products. The B system reduces cost by processing signals in only the band where high-frequency hiss resides. To make it more effective, the processor's upper frequency cutoff is made to automatically vary with signal level. As the level drops, the system processes a larger bite of the upper-frequency band. Since hiss is the major source of audible noise in hi-fi tape recording, the system is quite effective.

Since only low-level signals are processed by the Dolby A and B system and in the consumer B version only a portion of the audible band is processed, there is a limit to how much noise reduction can be achieved. In the case of the B system, this is approximately 10 dB. And since the processor does not operate over the entire dynamic range of the

signal, the signal must be standardized and matched for the decoder to properly track the encoder. Hence, the reference level, the so-called "Dolby Level," must be maintained to calibrate the chain.

It is the signal itself that "tells" the decoder where and how much expansion to use. If the level into the decoder is too low, the expansion will begin at too high a level. This will upset the original balance of the program. Similarly, if the input to the decoder is too high, expansion will not occur soon enough.

JVC followed Dolby's lead with its ANRS device, which functions in a manner quite similar to the operation of the Dolby B system. In fact, Dolby B tapes can be decoded by the ANRS circuit with quite good results.

**The dbx System.** The foremost competitor of the Dolby system is the noise reduction system developed by dbx Inc. This is a "classical" compander in that it operates over the entire dynamic range of the music. However, it has improvements over previous companders that make its action virtually inaudible.

The dbx system is a linear 2:1 compander that compresses the 80-dB dynamic range of the symphony orchestra down to a mere 40 dB. On the decoding end, the 40-dB range is expanded back up to 80 dB, pushing down the noise that was introduced by the tape-recording process to an inaudible level.

Since the dbx system operates linearly over the full dynamic range, matching of signal levels is not particularly important. Any 1-dB rise in input results in a 2-dB rise at the output of the expander. There is no "threshold" below which the system operates as there is in the Dolby B system. (Note, however, that any irregularities in recorder frequency response or any amplitude perturbations, such as dropouts, that are introduced will be magnified by a ratio of 2:1.)

One way dbx avoids the problems of classical companders is that it employs an rms detector to drive the vca, rather than the usual peak or average detector used by previous companders. The rms detector measures the power of the signal and is unaffected by the phase distortion introduced in the taping process. Peak or averaging detectors, on the other hand, are affected by phase shifts.

Another solution is the use of variable attack times that quickly respond to large changes in level and slowly respond to small changes. Both attack and release times vary with the signal level and are optimized to simulate the time response of the human ear.

The final solution is the use of high-frequency preemphasis before compression with complementary de-emphasis after expansion. This helps to reduce the effect of breathing by a factor of 12 dB.

The S/N improvement of the dbx system is in the range of 40 dB, which contrasts sharply with the 10-dB improvement provided by the Dolby B system. Although the Dolby system has a huge head start in the recording industry, there may soon come a time when the system developed by dbx will replace it as the standard one in use.

**Single-Pass Systems.** So far, our commentary has focused on two-pass systems designed to reduce noise only during the recording (or transmitting) process. Such systems do not reduce the noise already in the program. A great deal of work has been done to remove the noise already in the program, and the result is the single-pass system.

Two of these new systems are the Philips DNL and Burwen DNF that are both dynamic low-pass filters. The Philips system was developed specifically to reduce noise in unencoded cassette recordings. (It is not widely available in the U.S.) The Burwen system is more flexible and can be used for tapes and discs. Both systems consist of low-pass filters whose cutoff frequencies are automatically controlled by the program level. When there is a lot of high-frequency program energy, the filter "opens up" to let it through. Then when the high-frequency program energy is small, the cutoff frequency of the filter shifts downward to cut out the highs and the hiss. In essence, if there is enough high-frequency program energy to mask the hiss, the bandwidth of the DNF opens up to 30,000 Hz. But if the highs are missing and, hence, are unavailable to mask the hiss, the bandwidth narrows. In the absence of any signal, the Burwen DNF system starts to roll off above 500 hertz.

The constants of the detector circuit that senses the program level are critical. The filter must open up rapidly to let a transient through and should close down rapidly to prevent a burst of noise from following a brief transient or record tick. However, too fast a response tends to be audible. Consequently, the attack and release times are made variable according to the magnitude of the signal change. Depending on the program material and the control settings, the newest Burwen system provides from 5 to 14 dB of noise reduction. Since it is a

single-pass system, it operates on any program source.

The Phase Linear "Autocorrelator" is more complex than the dynamic noise filters. It actually attempts to distinguish between music and noise by electronic means. Noise is typically random in nature and contains many frequency components that are not related to each other, which makes it incoherent or uncorrelated. Music, on the other hand, contains mathematically related tones and is coherent, with a high correlation factor. The Autocorrelator consists of band-pass filters and a circuit that analyzes the signal for its degree of correlation. If it determines that the signal is music, it passes it through and those filters that correspond to the harmonics of the signal are activated to pass the overtone structure. If the signal is determined to be noise, the filters close down. It is obvious that this is a more sophisticated approach to noise elimination than the dynamic noise filter.

Another sophisticated type of noise-reducing device is SAE's Model 5000 pop and click filter. The premise used here is that clicks and pops are characterized by a rapid rise and decay, while music should exhibit a more gradual decay. Once a click or pop has been detected, that section of the program is gated out and the previous program section is recalled and inserted in its place. Since the click or pop is very short in duration (on the order of 1 ms), this substitution goes undetected by the ear.

Most of the time, the Model 5000 remains completely passive. A threshold control establishes the sensitivity of the detection circuit. This is necessary because different records may exhibit slightly different characteristics.

**Conclusion.** So far, noise-reduction systems have provided some impressive results. The effort to develop better systems is still going strong, but what the future has in store is difficult to predict. As things now stand, the most dramatic steps have been taken to reduce noise. Most of what is left is the refinement of the systems we now have and the addition of a few more decibels of noise reduction.

One or more of the noise-reducing devices we have mentioned certainly has a place in every high-quality hi-fi system. In fact, we can expect to see these devices incorporated into higher-quality hi-fi amplifiers and receivers in the future, just as all high-fidelity cassette decks now have noise-reduction systems built into them. ◇



# Matching Tapes to Recorders

BY LEN FELDMAN

**W**HETHER you own a new open-reel tape deck or a super-performing stereo cassette deck, you'll have to decide which type of tape to use to get the best possible performance. If cassettes are what you need, you can buy a 60-minute (C-60) cassette tape for as little as 99¢ or you can spend up to \$5.00 for the same amount of recording time. In the case of open-reel tapes, an 1800-ft (550-m) reel may cost less than \$6.00 or you may spend more than twice that amount for the same tape length. Which kind of tape you buy will depend on the type of recording you intend to do and the kind of tape deck you own.

For open-reel tape, selection involves physical considerations almost as much as electrical performance or fidelity. Broadly speaking, the two basic "grades" of tape are "standard and "high-energy," each of which requires a different bias setting on your machine. Lower priced standard tapes often have more residual noise and somewhat poorer frequency response than "premium" tapes, though they may be suitable for noncritical recording applications.

Generally, 1-mil-thick tape, with its 1800-ft capacity on a 7-in. (17.8-cm) reel, offers the best compromise between tape storage bulk and playback quality. Almost all open-reel tapes use ferric-oxide particle coatings even though there are still some differences between the products of different manufacturers. Mechanical differences in reel construction and accuracy of tape splitting and dimensions and uniformity of coatings account for the wide differences in prices.

In contrast to open-reel tape recording, the quality of recording obtained with a cassette deck is more critically dependent on the compatibility (or lack of it) between the tape and the machine with which it is used. A growing number of tape deck manufacturers make specific recommendations of tapes that work best with their products. However, even these suggestions require an understanding of the kind of recording to be made and the nature of different tape formulations.

**Correct Bias.** A high-frequency bias signal must be added to the program signal to be recorded to reduce the dis-

tortion normally caused by the nonlinear transfer characteristic of magnetic tape. However, not all tape formulations require the same amount of bias for best results. Normally, ferric-oxide coated tapes require less bias than do chromium-dioxide ( $\text{CrO}_2$ ) tapes. Several new formulations that combine ferric-oxide particles with other elements such as cobalt (in a single-compound layer) also require the high bias settings of  $\text{CrO}_2$ .

In cassette tape testing, most manufacturers determine the correct reference bias for a given tape by recording a fairly high frequency (usually around 6300 Hz) onto the tape while observing playback output as bias is gradually increased. At some bias setting, the output reaches a peak, after which a further increase causes the output level to drop off. The reference bias for the tape is set at the point where the output level has dropped off by about 2.5 dB beyond peak. Usually, a standard reference tape is tested in this way, and its optimum bias point is identified as the "0 dB" reference bias. Then, the tape under investigation is compared with the 0-dB reference bias specified in dB.

In Fig. 1 are shown the results of this test when performed on a well-known, low-noise, ferric-oxide tape. The optimum bias has been established at a -1-dB setting, relative to the standard

0-dB bias point. In Fig. 2, the same test was performed on a  $\text{CrO}_2$  cassette; and the optimum point for bias was +2 dB (with reference to the standard 0-dB bias point of the reference tape). This means that the  $\text{CrO}_2$  tape requires a bias setting that is 3 dB higher than that for the low-noise, ferric-oxide sample.

For any practical tape, the bias strength that results in the highest output at middle and low frequencies is greater than the ideal for high frequencies. Conversely, if the bias is adjusted to favor the highs, the middle and low frequencies suffer in terms of realizable output. Whatever bias point is selected, some degradation of signal-to-noise (S/N) ratio and overload distortion will occur in some part of the audio frequency spectrum. While increased bias tends to reduce distortion, no one setting can guarantee overall distortion reduction by the maximum amount at all frequencies. Thus, bias settings are always a compromise, and the best tape permits the most favorable compromise.

To demonstrate the effect of overbiasing and underbiasing, we recorded a continuously sweeping series of frequencies (20 to 20,000 Hz) on a strip of ferric-oxide tape at a fairly high recording level. The results are shown in Figs. 3 (underbiasing) and 4 (overbiasing). Note in Fig. 3 that high-frequency re-



Fig. 1. Determining the bias level for a sample low-noise tape.

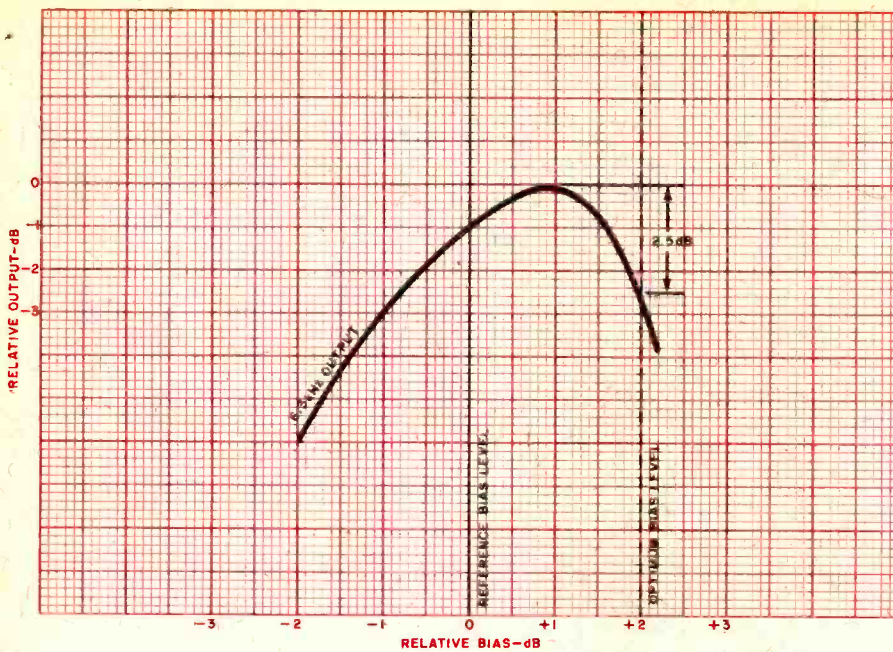


Fig. 2. Determining the bias level for a sample of CrO<sub>2</sub> tape.

sponse obtained in the underbiased condition is excellent. In fact, there is even a slight rise in response above 10,000 Hz before the response rolls off in the 20,000-Hz region. In Fig. 4, however, the response begins to fall off gradually above 1000 or 2000 Hz and really takes a giant dip beyond 10,000 Hz. Each vertical division in the photo equals 10 dB of amplitude.

From the results shown in Figs. 3. and 4, one might conclude that the best performance from any tape is obtained with underbiasing. However, the curves do not reveal what happens to harmonic distortion if a given tape's bias is set too low. In Fig. 5, the spectrum analyzer was used once more to examine the distortion and noise components of a reproduced 1000-Hz signal, as recorded on the underbiased deck. The large spike at the center represents the desired fundamental output (1000 Hz), while the spikes to the right, notably at 3000 and 5000 Hz, are components of third- and fifth-harmonic distortion. The third-harmonic component is only about 33 dB below the fundamental or about 2.2% of the signal content. The random spikes represent residual tape noise as reproduced during playback of the 1000-Hz recorded signal.

Figure 6 shows what happens to a 1000-Hz signal in the overbias condition that resulted in the frequency response of Fig. 4. The third-harmonic distortion component has gone down to about 44 dB below the fundamental. This corresponds to distortion of about 0.6% but there is little if any evidence of fifth-har-

monic contribution, and the general random noise content is much lower.

**Equalization.** Once the proper bias for a given tape has been selected, it is still possible to tailor the frequency-response capabilities of that tape by a process called equalization. Up to a certain frequency, if a recording is made on magnetic tape, the playback system "reads" that signal with a rising amplitude characteristic as the frequencies are increased. Since we want a "flat" frequency response, a rolloff in response is built into the playback electronics so that the net response, hopefully, will be flat.

Playback equalization in a tape deck is generally standardized and fixed to obtain reasonably flat playback results from any tape recorded on one tape deck and played back on another.

Recording equalization, however, is variable and is designed to match the particular tape you use and generally involves a specified amount of treble "boost" added to the record electronics to compensate for the high-frequency rolloff that occurs above a given high frequency. As with bias, record equalization is often adjustable by means of a switch on the deck's control panel. Most equalization switches have only two or three positions that generally approximate the right playback conditions for many of the tapes on the market.

In recent years, manufacturers of cassettes have tried to make tapes that give best results when used with the most commonly available equalization set-

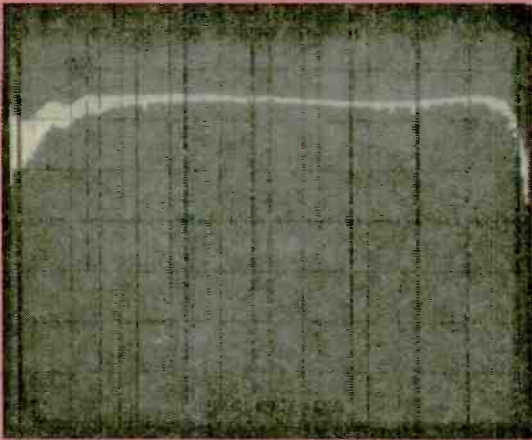
tings of most machines. The two most popular settings of equalization are 70 and 120  $\mu$ s, the figures representing the time constant provided by the resistor-capacitor combination that gives the required 6-dB/octave response slope. The 120- $\mu$ s equalization setting begins to boost high frequencies during recording at a lower turnover point than does the 70- $\mu$ s setting that has been standardized for CrO<sub>2</sub> tapes and some of the more exotic ferric-cobalt tapes.

Let us see what happens to the response if the wrong setting is used for a given tape during the recording process. For one series of tests, a ferric-cobalt tape requiring the 70- $\mu$ s equalization was used. After adjusting the bias for optimum, the proper equalization switch position was set and a frequency response check was run. The result (the lower trace in Fig. 7) shows a good, flat response curve, similar to that shown in Fig. 3, but with somewhat greater rolloff at the high end because of the correctly adjusted bias. Without altering the bias setting, the run was repeated with the 120- $\mu$ s equalization setting. The result is the upper trace in Fig. 7. Overboosting during recording resulted in an overemphasized rising high-end response during playback.

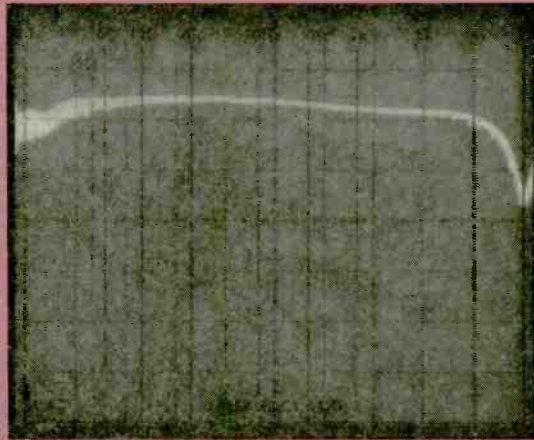
Next, a low-noise ferric-oxide tape was tried. It normally requires the 120- $\mu$ s equalization characteristic. With this equalization and the correct bias setting, we obtained the upper trace in Fig. 8. The response is nice and flat to well beyond 15,000 Hz. In a second sweep, the equalization switch was set to 70  $\mu$ s; and, as can be seen in the lower trace, the response during playback rolled off severely, starting at about 2000 Hz.

**Characteristics.** Here are details on other key specifications.

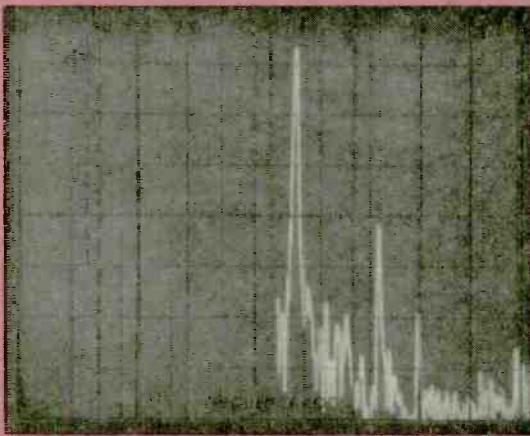
**Sensitivity** of a given tape is the decibel difference between the output and input levels when an input 20 dB below the reference level (0 dB) is recorded on a tape. If the recorder used for this test has been biased properly, equalized flat and input/output adjusted to be equal for a standard reference tape (a German DIN standard, known as Bezugsband 4.75/3.81 tape is often used as the standard), the data obtained is the sensitivity of the tape under test relative to the reference tape. For cassette tapes, 333- and 12,500-Hz tones are used for sensitivity tests. Typical results obtained for standard and high-output tapes are plotted against bias settings in Fig. 9. As can be seen at the "optimum bias" inter-



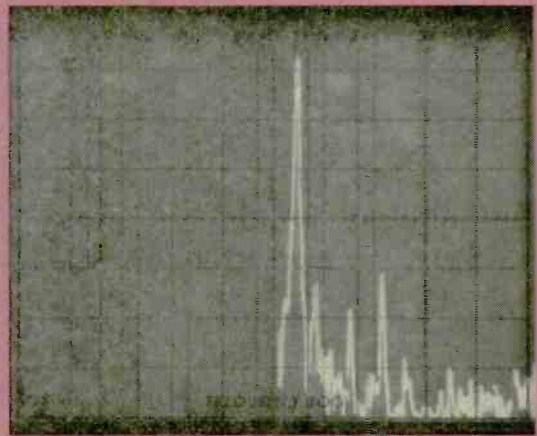
**Fig. 3.** Too little bias may improve a tape's high-end response but degrade other performance characteristics.



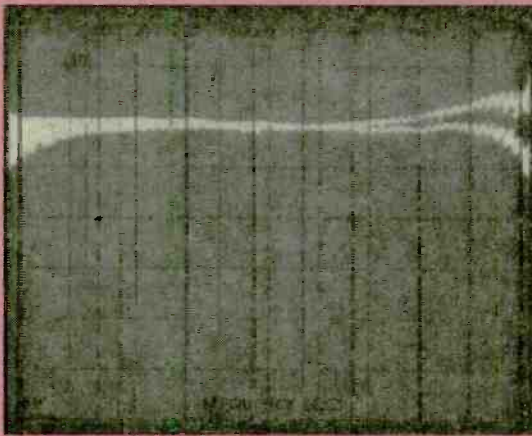
**Fig. 4.** Overbiasing causes high-frequency roll-off in tape playback as shown here.



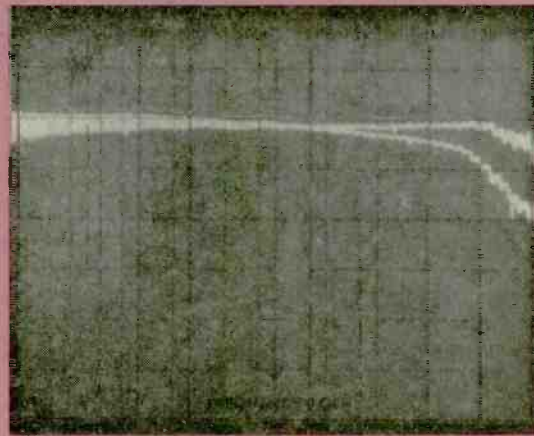
**Fig. 5.** Under-biased tape sample reproduces 1-kHz signal with high third-order harmonic distortion.



**Fig. 6.** Increased bias lowers third-order harmonic distortion content for this 1-kHz recorded test signal.



**Fig. 7.** Upper trace, with rising high-end response during playback occurs when sweep frequencies are recorded onto tape requiring CrO<sub>2</sub> equalization with switch set to "standard" position. Lower sweep was plotted using correct setting.



**Fig. 8.** When CrO<sub>2</sub> equalization setting is used with standard ferric-oxide tape, response at high end has severe rolloff (lower trace). Upper trace shows response obtained with correctly set equalization switch for this tape.

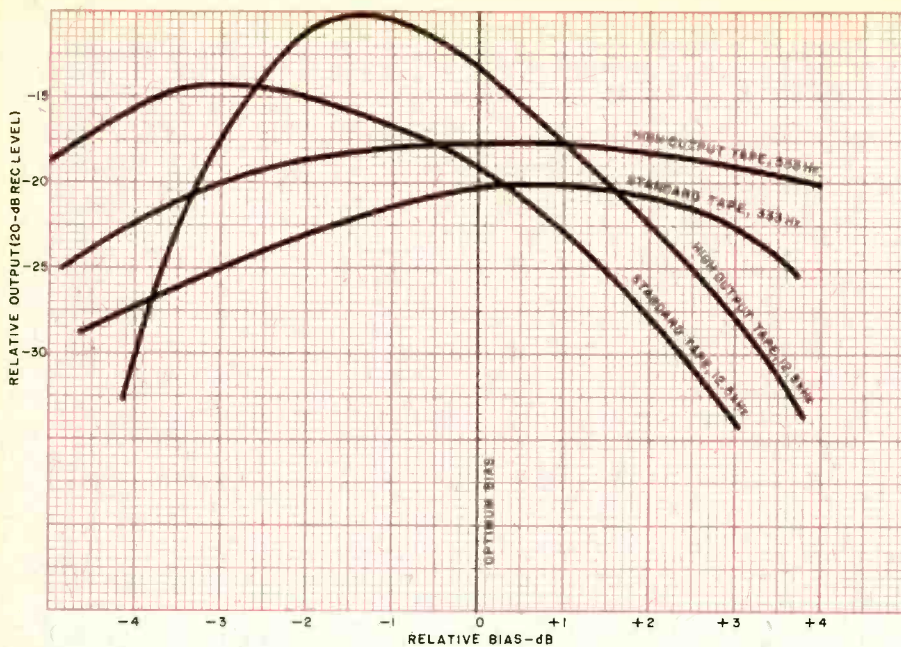


Fig. 9. Relative output sensitivities of standard and high-output tapes.

section, the high-output tape is more sensitive than the standard tape by nearly 2 dB at middle frequencies and by 6 dB at 12,500 Hz. This means that the higher-output tape affords a few extra decibels of dynamic range above the noise threshold.

**Maximum modulation level** is the recorded output level of a given tape that exhibits 3% third-order harmonic distortion. It is sometimes plotted as a function of bias level. In Fig. 10, are plotted the maximum output levels of two different tapes that have widely differing maximum output-level characteristics. The frequency used for maximum output lev-

el in cassettes is usually 333 or 1000 Hz. Some tape manufacturers also specify maximum output at a high frequency; in the case of cassette tapes, a 12,500-Hz signal is usually used for these tests.

**Biased tape noise** is also often specified by tape makers. This is the level of residual tape noise (referred to a specific reference level) when it has been recorded with bias signal only and with the bias signal weighted or modified by the use of a standard noise-weighting network. The biased tape-noise level for the two tapes tested in connection with maximum output level is also shown in Fig. 10. The difference between the noise

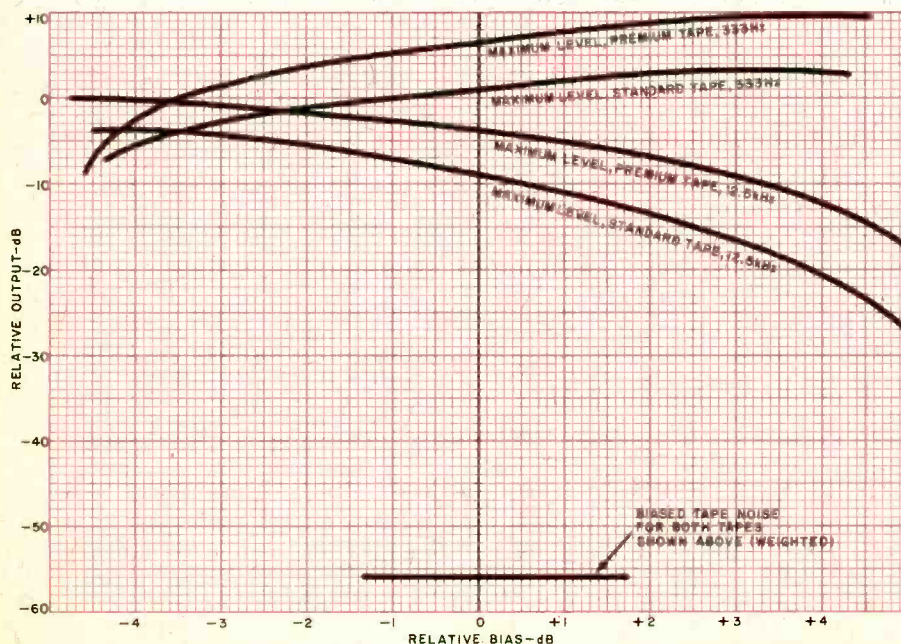


Fig. 10. Maximum output levels and biased tape noise for two types of tape.

level and the maximum modulation constitutes the maximum dynamic range of each tape.

**Tape Is Different.** As we have seen, tape cannot be looked upon in the same way that we consider other program sources in high fidelity, such as phonograph discs or FM signals. All discs are recorded with the same equalization and, therefore, only one fixed setting of playback equalization (RIAA) is required in preamplifier circuits. There are, of course, differences in disc quality that result from the use of different grades of vinyl from which discs are pressed. However, these differences are minor when compared with the differences that exist among the many grades of cassette tapes available.

Radio FM signals also employ a form of equalization known as "preemphasis," which has long been standardized in this country. Hence, all tuners provide correct deemphasis for FM reception, and difference in program quality depends on signal strength and the overall quality of a tuner or receiver.

In our discussion of the electrical properties of cassette tapes, we haven't stressed mechanical properties. These include: accuracy of tolerances maintained in the cassette housing (which can affect smoothness of tape travel); uniformity of magnetic coating and smoothness of the coated surface (both of which, if poor, can cause dropouts or momentary lapses of reproduced sound); tensile strength of the plastic base material itself (poor tensile strength can lead to tearing or stretching after repeated use); friction-reducing techniques used to insure smooth, uniform tape motion within the cassette housing; etc.

All of these qualities, in some measure, determine the price of a cassette and its usefulness for recording applications. Obviously, if all you want to record are baby's first words or a business conference, response to beyond 15,000 Hz is of little importance. (Though mechanical reliability of the cassette itself may be of as great importance as if you were recording a once-in-a-lifetime live concert over FM.) On the other hand, if you want the finest results from your cassette deck (or even from your open-reel machine), it pays to research the question of which tape is best for you. It is important to choose the brand and type whose formulation in relation to the switch setting available on your tape deck has the right "compromises" for your needs. ◇

# IC Multiplex Decoder Improves Stereo FM Performance

**T**ODAY'S state-of-the-art audio components yield levels of performance unattainable a few years ago. However, most of us can't update our sound systems as frequently as technological advances are made. This project—an add-on phase-locked-loop multiplex decoder—will allow the user to improve the stereo FM demodulation of an existing receiver or tuner for about \$25. Only a few hours of assembly and alignment time is required. The PLL decoder will not only improve channel separation and lower distortion levels, but will also select deemphasis time constants for standard and Dolby-FM broadcasts.

**About the Circuit.** The heart of the PLL multiplex demodulator is the LM1800A, an IC manufactured by Na-

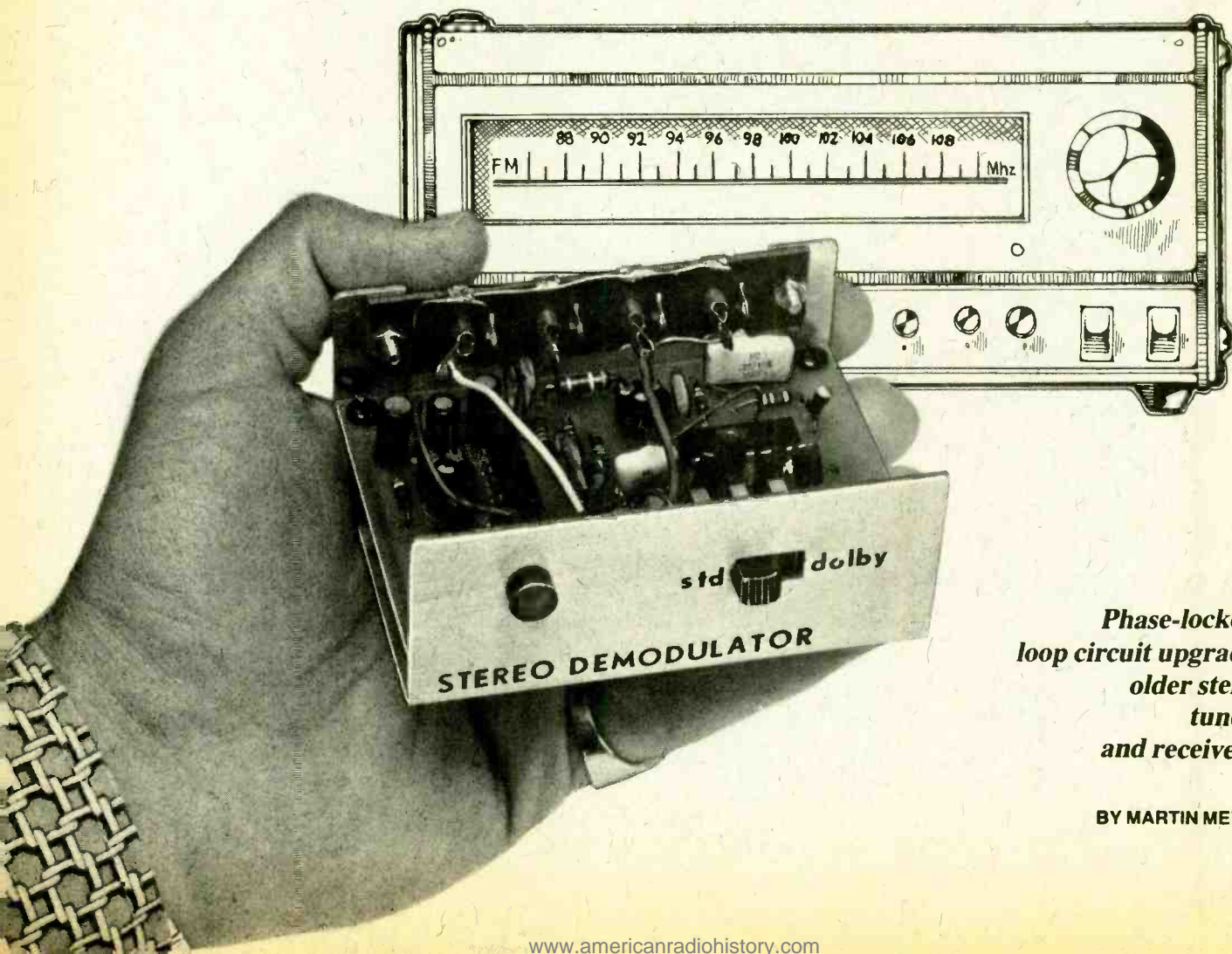
tional Semiconductor. A block diagram of the LM1800A is shown in Fig. 1. The phase-locked loop comprises a voltage controlled oscillator (vco), frequency dividers, phase detectors, low-pass filtering and an error amplifier. Also included are a voltage regulator allowing operation from 12-to-24-volt supplies, automatic stereo monaural switching, and use of a stereo indicator lamp.

In the absence of an input signal, no error signal is generated and the vco oscillates at a frequency designated as  $f_0$ . When a composite FM signal is applied to the input, the loop phase detector generates an error signal which is filtered and amplified. This amplified error voltage shifts the oscillating frequency of the vco to exactly 76 kHz. Filtering performed at the phase detector and error

amplifier prevents modulation of the vco by the input signal.

The vco input frequency is divided by two, resulting in a 38-kHz carrier used in the synchronous demodulation of the composite signal. Passing the 38-kHz signal simultaneously through a pair of  $\pm 2$  counters produces two 19-kHz signals which are applied to the IC's two phase detectors. If the 19-kHz pilot signal drops below the level at which a satisfactory stereo signal can be recovered, an electronic switch causes the IC to produce a monaural output.

The schematic diagram of the complete multiplex detector is shown in Fig. 2. Input signals are capacitively coupled by C5 to level control R5. Capacitor C4 passes the composite FM input to the base of Q1, which amplifies it to a level



*Phase-locked-loop circuit upgrades older stereo tuners and receivers.*

BY MARTIN MEYER

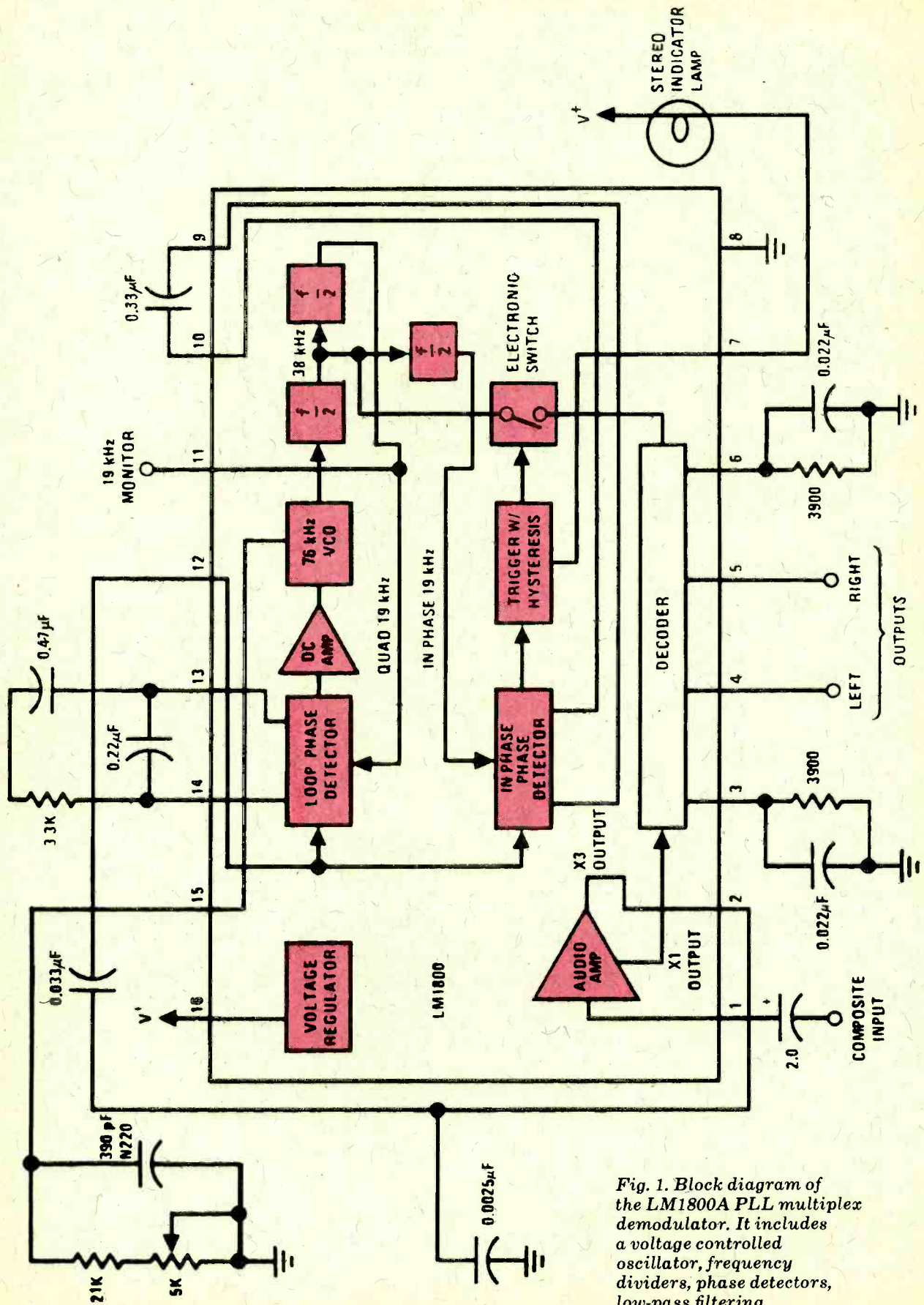
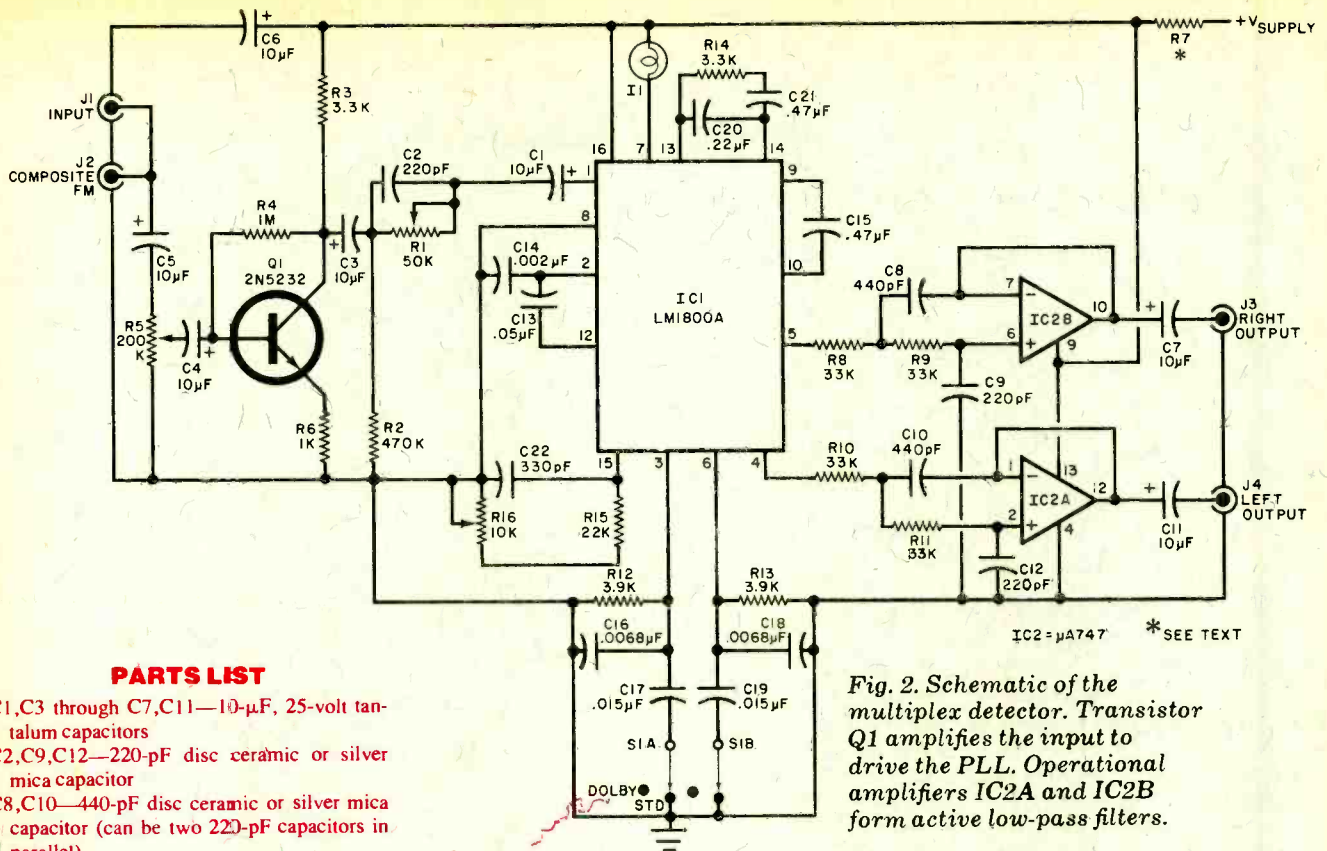


Fig. 1. Block diagram of the LM1800A PLL multiplex demodulator. It includes a voltage controlled oscillator, frequency dividers, phase detectors, low-pass filtering and error amplifier.



### PARTS LIST

- C1, C3 through C7, C11—10- $\mu$ F, 25-volt tantalum capacitors
  - C2, C9, C12—220-pF disc ceramic or silver mica capacitor
  - C8, C10—440-pF disc ceramic or silver mica capacitor (can be two 220-pF capacitors in parallel)
  - C13—0.05- $\mu$ F disc ceramic capacitor
  - C14—0.002- $\mu$ F disc ceramic capacitor
  - C15, C21—0.47- $\mu$ F Mylar capacitor
  - C16, C18—0.0068- $\mu$ F,  $\pm$  10% Mylar capacitor
  - C17, C19—0.015- $\mu$ F,  $\pm$  10% Mylar capacitor
  - C20—0.22- $\mu$ F Mylar capacitor
  - C22—330-pF disc ceramic or silver mica capacitor
  - I1—12-V, 35-mA pilot light
  - IC1—LM1800A PLL multiplex decoder
  - IC2—747 dual operational amplifier
  - J1 through J4—RCA phono jacks
  - Q1—2N5232 npn silicon transistor
- The following are linear-taper, pc trimmer potentiometers:
- R1—50,000 ohms
  - R5—200,000 ohms
  - R16—10,000 ohms
- The following are 10% tolerance, 1/4-watt carbon-composition fixed resistors:
- R2—470,000 ohms
  - R3, R14—3300 ohms
  - R4—1 Megohm
  - R6—1000 ohms
  - R7—See text.
  - R8 through R11—33,000 ohms
  - R12, R13—3900 ohms
  - R15—22,000 ohms
- S1—Dpdt slide or toggle switch
- Misc.—Printed circuit board, suitable enclosure, hookup wire, shielded cable, pilot light jewel, hardware, solder, etc.
- Note—The following are available from Neronics Research and Development, Ltd., 333 Litchfield Road, New Milford, CT 06776: complete kit including all components, pc board, screened enclosure, less audio cables, \$24.95; complete kit as above but less screened enclosure, \$19.95. U.S. residents add \$1.50 postage and handling; Canadians add \$3.00. For receiver connection info, send schematic, SAS envelope and \$1 (free if purchasing kit). Connecticut residents add 7% sales tax.

Fig. 2. Schematic of the multiplex detector. Transistor Q1 amplifies the input to drive the PLL. Operational amplifiers IC2A and IC2B form active low-pass filters.

that will properly drive the phase-locked loop. The parallel combination  $C2R1$  provides compensation for high-frequency rolloff in the tuner's i-f and detector stages. Resistors  $R12$  and  $R13$  and capacitors  $C16$  through  $C19$  provide deemphasis for multiplex decoder  $IC1$ . When  $S1$  is in the STD position, the standard 75- $\mu$ s FM deemphasis characteristic appears. Placing  $S1$  in the DOLBY position changes the deemphasis to 25  $\mu$ s, which corresponds to the reduced preemphasis used in Dolby-encoded broadcasts.

Operational amplifiers  $IC2A$ ,  $IC2B$ , and their associated components form active low-pass filters with 16,000-Hz cutoff frequencies and 12-dB/octave slopes. These filters attenuate any 38-kHz carrier and 67-kHz SCA components which would otherwise appear at the left and right audio outputs. If allowed to pass, these signals could cause beats and whistles when program material is recorded on tape. Indicator  $I1$  glows in the presence of stereo pilot carrier. Jack  $J2$  is wired in parallel with input jack  $J1$ , providing access to the composite FM signal for such accessories as 4-channel and SCA demodulators.

**Construction.** Printed circuit guides for the project are shown in Fig. 3. Mount all components on the board, paying close attention to pin basing and

polarities of semiconductors and electrolytic capacitors. Power can be tapped from any +12- to +24-volt dc source. The tuner's i-f stage or existing multiplex decoder is usually powered by a +15- to +20-volt supply which can be utilized for this purpose. Select the value of  $R7$  in kilohms according to the equation:

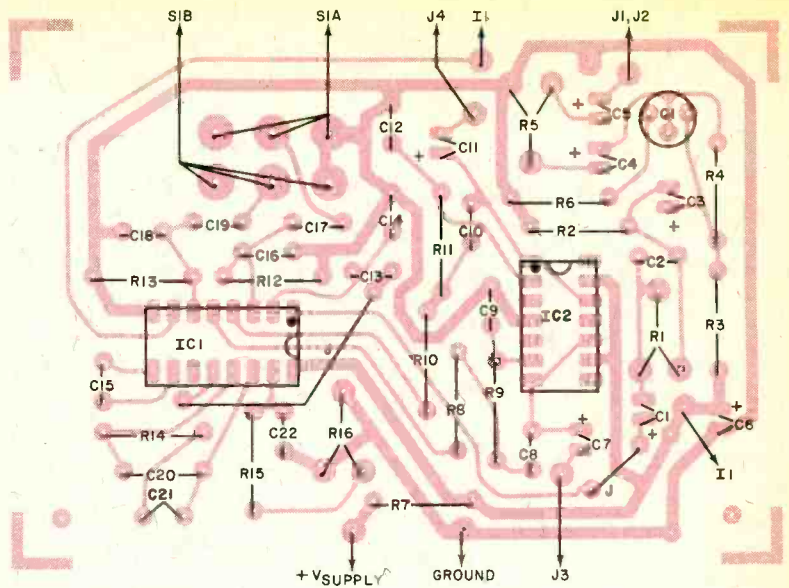
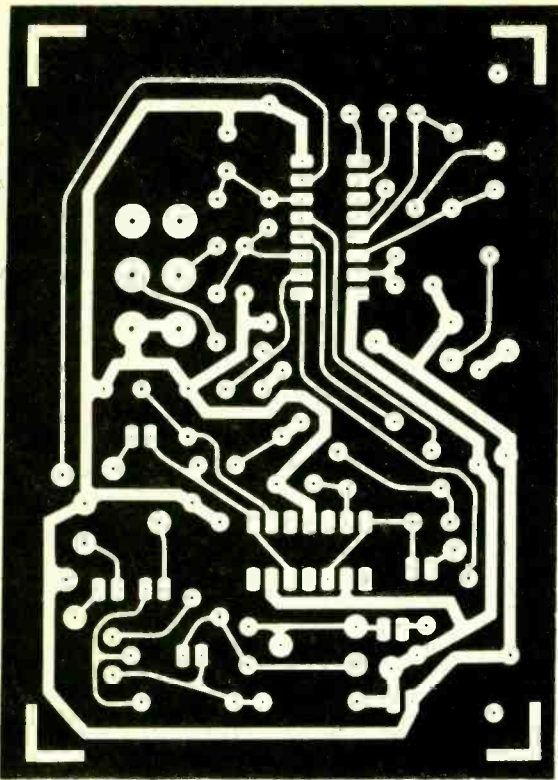
$$R7 = (V_{\text{supply}} - 12) / 55$$

A one-watt carbon composition resistor will have adequate heat dissipation capability for this application.

The tuning lamp used in the author's prototype (and supplied with the kit) draws 35 mA at 12 volts. If you substitute another incandescent lamp or a LED and current limiting resistor, modify the equation for the value of  $R7$ . Replace the 55 mA in the denominator with the sum of 20 mA (the current required by the PLL and active filters) and the

TABLE I  
LM1800A SPECIFICATIONS

Stereo Separation—100 Hz:	40 dB
1000 Hz:	45 dB
10,000 Hz:	45 dB
SCA Rejection:	50 dB
Total Harmonic Distortion:	0.2 %
Ultrasonic Frequency Rejection:	45 dB



**Fig. 3.** Etching and drilling guide for multiplex decoder is shown at left. Component placement guide is above.

current required by the indicator. For example, if a LED and resistor drawing 20 mA are used, the denominator would be 40 mA.

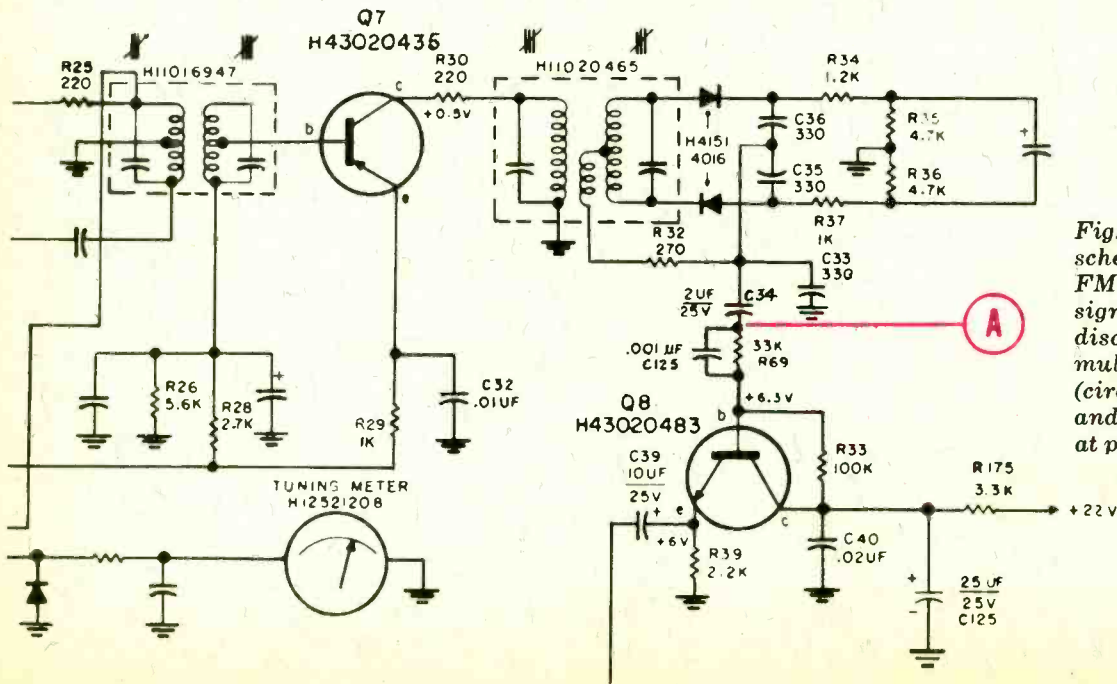
The project can be mounted in the tuner cabinet or housed in a separate enclosure. If it is placed in the tuner cabinet, mount S1 on the rear panel of the tuner and connect it to the pc board via low-capacitance shielded cable such as RG-59-U. The same type of cable should also be used to conduct the composite FM signal from the detector output to the input of the multiplex decoder.

If your tuner or receiver has a "composite FM" or "FM detector" output jack, the required signal is available there. If not, you will have to locate the FM detector and tap the signal at that point. The partial schematic of a typical FM receiver is shown in Fig. 4. The composite signal is obtained by disconnecting the existing multiplex decoder and tapping the signal at point A.

The left and right audio outputs are available at jacks J3 and J4. If you are using the project in place of the multiplex decoder in a tuner, you can either use

these jacks in place of those in the tuner, assuming the decoder is mounted externally. If it is mounted internally, you can disconnect the outputs of the existing multiplex decoder from the output jacks on the tuner's rear panel and connect the outputs of the decoder's active filters.

Similarly, if you have a receiver and are mounting the project in an external enclosure, you can connect the decoder's outputs to the tape monitor circuit. Mounting the decoder inside the receiver cabinet suggests an internal connection. Remove the output leads at the ex-



**Fig. 4.** Partial schematic of typical FM receiver. Composite signal is obtained by disconnecting existing multiplex decoder (circuit below C34) and tapping signal at point A.



isting multiplex decoder running to the appropriate lugs on the receiver's MODE switch. Then connect them to the decoder's active filter outputs.

**Alignment.** When properly aligned, the project will provide performance as outlined in Table I—assuming no degradation in the tuner's i-f and FM detector. Two typical receivers were used with the PLL decoder. Results are shown in Table II. The alignment procedure about to be described requires no test instruments, but will yield good results. The author was able to improve the stereo separation only 2 dB when instrument alignment was performed with an expensive FM stereo generator.

Rotate potentiometers *R1* and *R16* to the midpoint of wiper travel, and *R5* for maximum signal drive at the base of *Q1*. Turn on your receiver and tune in a station broadcasting in stereo. Indicator *I1* should glow. If not, adjust *R16* until it does. Then turn *R16* fully clockwise. If *I1* still glows, adjust *R5* until the indicator just goes out. Slowly rotate *R16* counter-

	Sony STR-6060FW		Harman Kardon SR900	
	Before	After	Before	After
Stereo Separation—100Hz:	20 dB	32 dB	25 dB	30 dB
	28 dB	42 dB	32 dB	42 dB
	18 dB	30 dB	25 dB	33 dB
Total Harmonic Distortion (1000 Hz):	0.5%	0.3%	0.6%	0.25%

clockwise until the lamp begins to glow. Note the position of the control. (It may be necessary to adjust *R5* slightly.)

Next, turn *R16* fully counterclockwise, adjusting *R5* again if necessary to extinguish the lamp. Slowly rotate *R16* clockwise until the lamp glows, noting the position of the control. Set *R16* midway between the two positions noted. Adjust *R5* until the lamp goes dark, then slowly turn it until the lamp just starts to glow. Advance the wiper of *R5* another 10°. This will properly tailor the input level to decoder *IC1*.

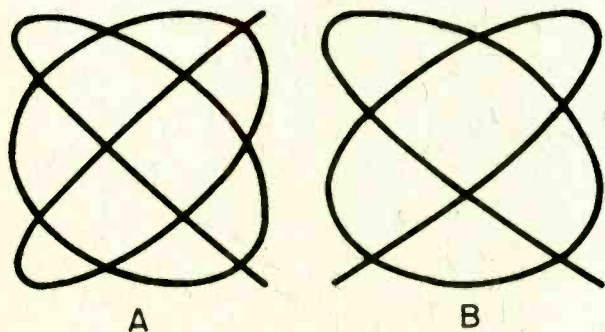
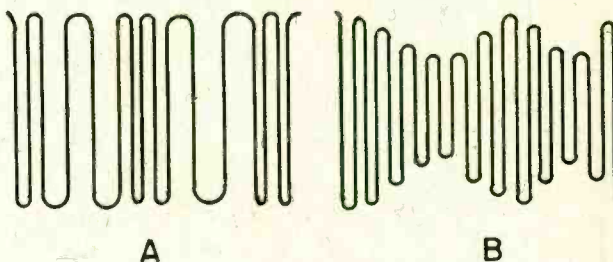
Potentiometer *R1* is included in the circuit for adjustment if test equipment or

a cooperative FM broadcast engineer is available. Since all stations must conduct tests and certify the quality of their signals once a year, you can easily check out adjustments. Call several local stations and ask when they will perform the tests. If it is late at night, the engineer might turn off a channel for 30 seconds or so. While only one channel is being transmitted, adjust *R1* for maximum separation at any mid-band frequency. Note, however, the setting of *R1* will not have a critical effect on the performance of the decoder and can simply be left midway between the two adjustment extremes. ◇

# Quiz of Audio Basics

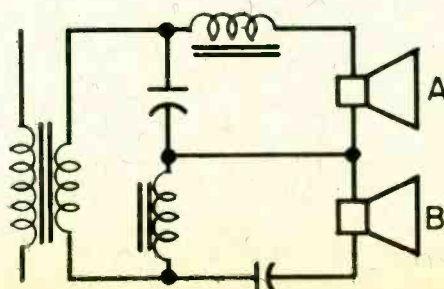
BY ROBERT P. BALIN

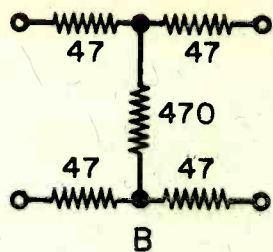
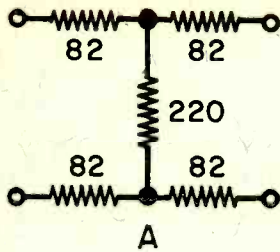
1 Which of these audio waveforms indicates the use of tremolo and which is vibrato?



2 If the vertical frequency used to produce these Lissajous patterns is 1000 Hz, which has a horizontal frequency of 1200 Hz and which is 1250 Hz?

3 With this crossover network, which speaker is the woofer and which the tweeter?

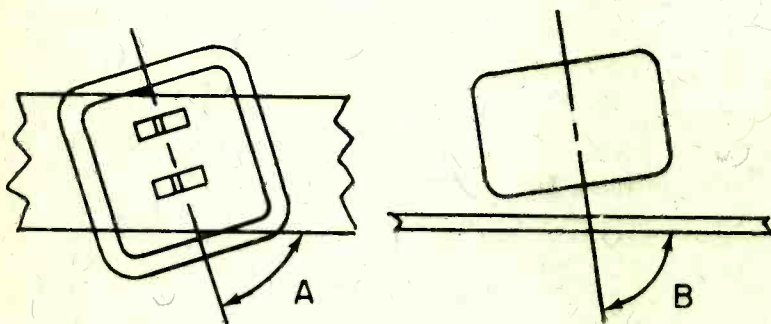




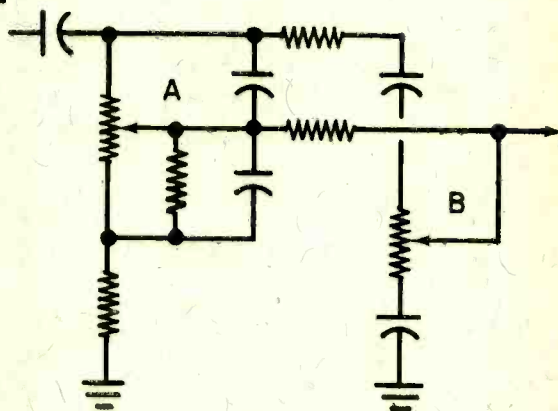
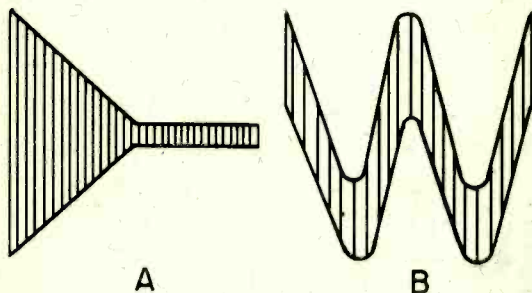
4 Of these 300-ohm attenuator pads, which produces a 6-dB signal voltage loss and which a 12-dB loss?



5 Which of these square-wave audio test signals indicates low-frequency attenuation and which high-frequency?

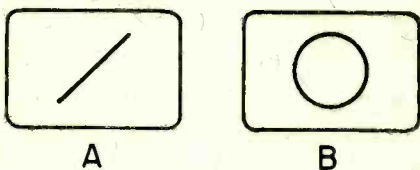


6 Which tape-head condition produces an azimuth error and which a zenith error?



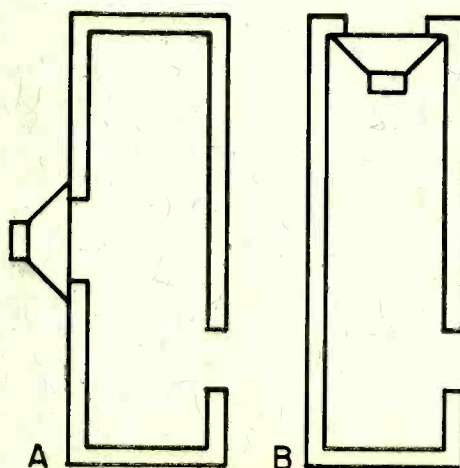
7 In this phono-amplifier tone control circuit, which pot is for treble and which is for bass?

8 Which audio test signal has been affected by intermodulation and which by overmodulation?



9 Which scope pattern indicates that two audio sine waves are in phase and which that they are 90° out of phase?

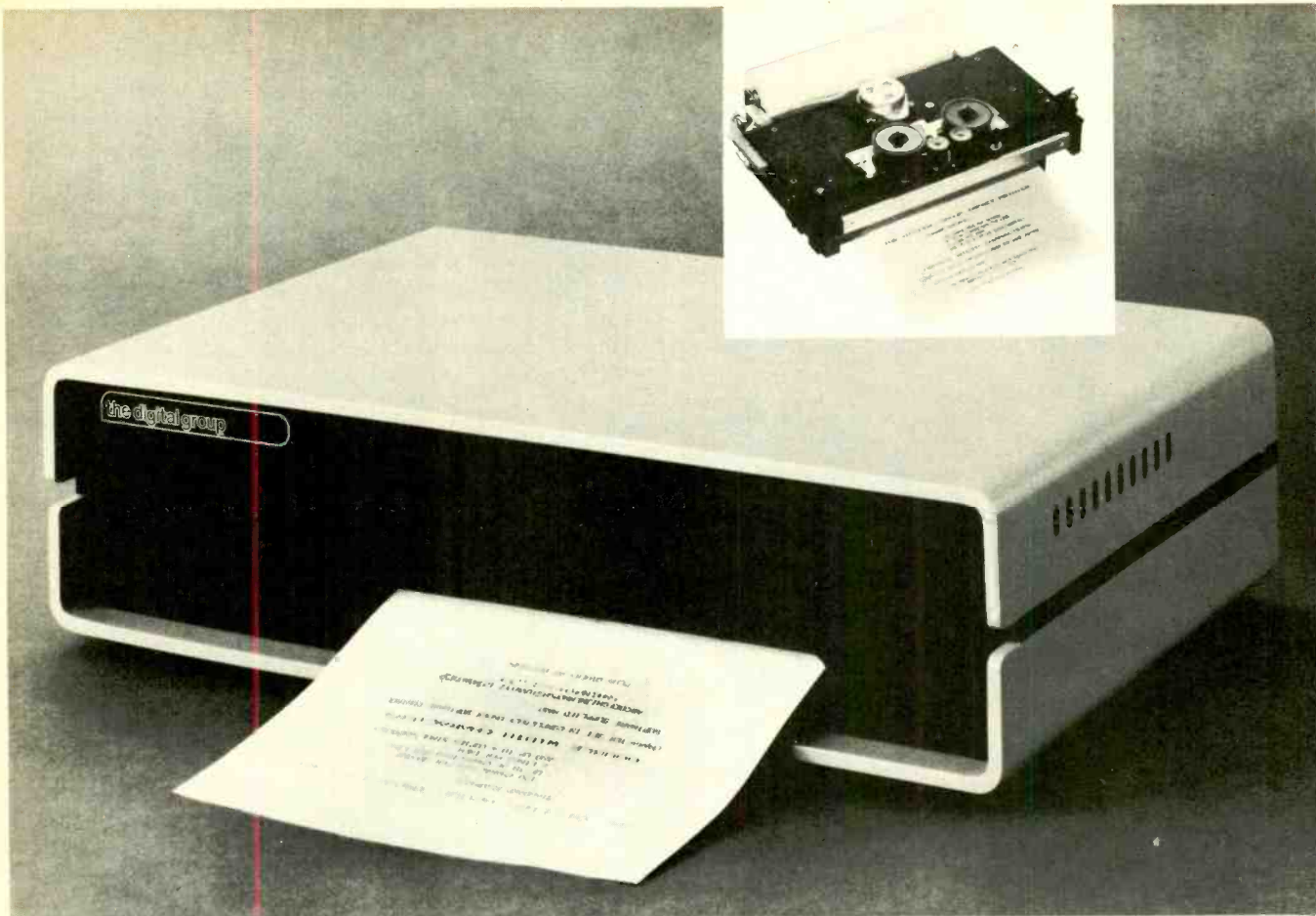
10 Which speaker baffle is known as a resonant column and which as an air coupler?



8. Intermodulation, B; over, A.  
9. In phase, A; 90° out, B.  
10. Column, B; coupler, A.

4. 6-dB, B; 12 dB, A.  
5. Low-frequency, A; high, B.  
6. Azimuth, A; Zenith, B.  
7. Treble, B; bass, A.

1. Tremolo, B; vibrator A.  
2. 1200 Hz, A; 1250 Hz, B.  
3. Woofer, A; tweeter, B.



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# FIRST WEST COAST COMPUTER FAIRE BY TOM MUNNECKE

**S**AN FRANCISCO was the setting last April for the First West Coast Computer Faire, which may become the Woodstock of the personal computing movement. Almost 13,000 people attended the 165 exhibits, 107 lectures, 17 home-brew demonstrations and two banquets.

The crowd was as kaleidoscopic as one would expect in San Francisco. Among them were a blind man seeking braille production equipment and voice synthesizers; Berkeley pamphleteers warning of government restrictions against home computers; artists looking for a new medium for artistic ex-

pression; and a father looking for aids for his deaf child.

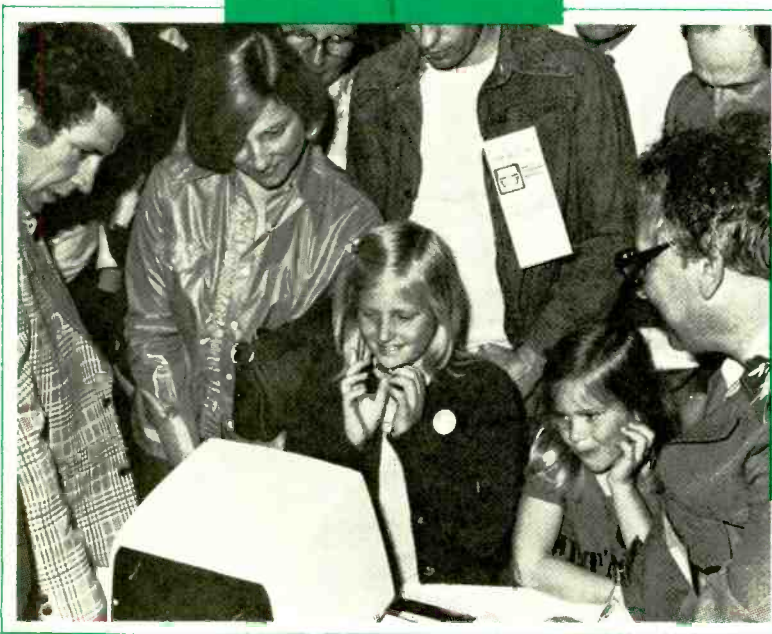
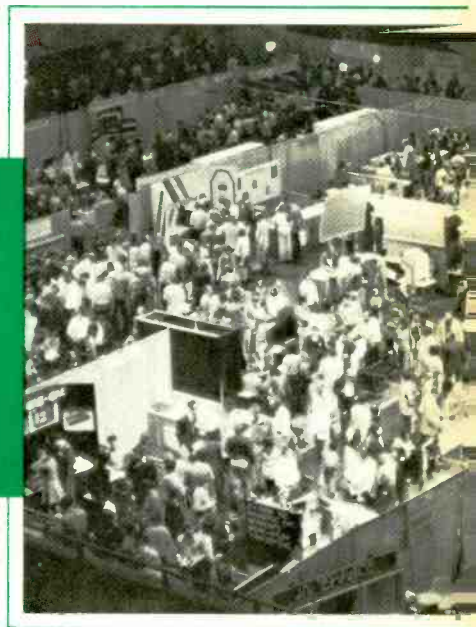
Banquet speakers told of the coming revolution in home computing. Ted Nelson predicted that the "cybecrud" coming out of the large computers would be counteracted by the masses of personal computers. What used to be a topic for science fiction writers has come true, with the help of MPU's.

There were 37 conference sessions, covering everything from "Tutorials for the Computer Novice" to "Heretical Proposals." Commercial exhibitors had on display all their latest products, including electronic music synthesizers, speech

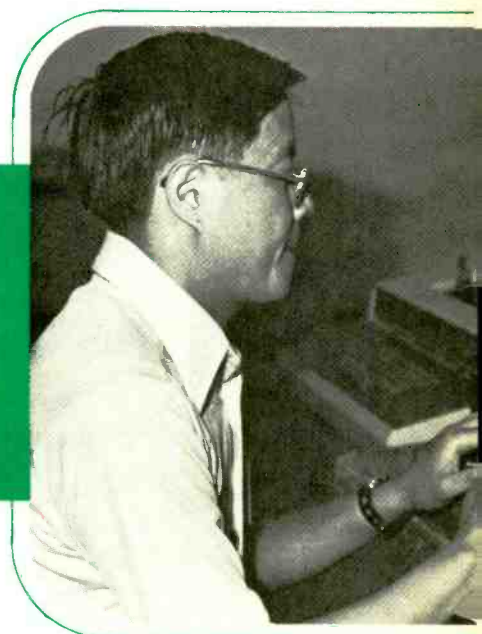
1



2



4



**1** Prototype of Commodore's PET 2001, an "appliance-type" computer based on the 6502 MPU. Computer provides built-in BASIC, a graphics or character-oriented CRT, cassette storage, and 4k of RAM in a factory-assembled unit.

**2** A portion of the exhibit hall, where 165 vendors displayed their wares to 12,750 people. The crowd and the size of the exhibition made it almost impossible to see all of the interesting computers on display.

**3** Dr. Franz Frederick, Lafayette, Indiana, shows his "turtle" to Michael Rubinstein. Built in three weeks from surplus parts, it is controlled by a homebrew 6800 system to draw pictures while moving about the floor.

synthesizers and recognizers, and 64k memory boards.

A new class of computers emerged at the Faire—the so-called appliance computer. Meant to be purchased much as one would buy a television receiver or stereo tuner, these computers are complete systems that require no assembly. Apple Computers, Inc., showed the Apple II, a 10-lb (4.5-kg) microcomputer with keyboard, color-TV and audio cassette interfaces, game paddle, and BASIC built-in for \$1300. Commodore International had a working prototype of its PET 2001 computer, which has a CRT, keyboard, cassette drive, IEEE 488 interface, and built-in BASIC; price goal is the \$500-\$600 range. Commodore sees the personal computing market as a

merger of the electronic games and calculator markets and expects the same dramatic decline in prices as more of the semiconductor manufacturers join in the competition.

There was a general air of amazement at both the number and sophistication of the products offered by the vendors. Since the January, 1975 POPULAR ELECTRONICS article introducing the Altair 8800 microcomputer, a dozen new companies have emerged to offer Altair-compatible mainframes; memory boards have increased 16 times in capacity; an array of compatible peripherals is being offered; and a whole new generation of computers has emerged. And all those people came to San Francisco to see it happen. ◇



3



5



6

**4** Angela and Joanna Frelesnik, of Santa Clara, react to the PET's showing of their lunar landing module's crash on the moon. MOS Technology 6502 architect Chuck Peddle is shown looking on at left.

**5** Dennis Wong, from Mountain View, shows his computer-based payroll system for small businesses. System consists of a Processor Tech. SQL microcomputer, a North Star Floppy Disk, and Memorex printer, all for less than \$3000.

**6** Rich Gold's "Mr. Computer" is based on a KIM-1 and 200-byte program. Its coded messages (via LED displays in its mouth) are interpreted by Rich in storybook form. He plans to add video graphics and electronic music output.



# BUILD Cabonga

## PART 2

*How to use various accessories to achieve greater flexibility.*

BY JAMES BARBARELLO

**L**AST MONTH, we described the circuitry and construction of the Cabonga electronic percussion synthesizer. Now here are four accessories—the Snare Drum Adapter, the Auto Trigger, the Sound Modifier, and the Combiner/Power Pack. Methods of interconnecting them with each other and the Cabonga will be shown. The result of these patches will be a flexible and expandable percussion synthesizer system.

The Cabonga has two jacks which, until now, you have not used. They are marked EXTERNAL TRIGGER and EXTERNAL POWER. The EXTERNAL TRIGGER jack will be used with the Auto Trigger and the Snare. The EXTERNAL POWER jack will accept  $\pm 9$  volts from the Combiner/Power Pack. Actually, all Cabonga system components could be powered by 9-volt batteries. Cost, however, makes this an unattractive proposition in a multi-component system.

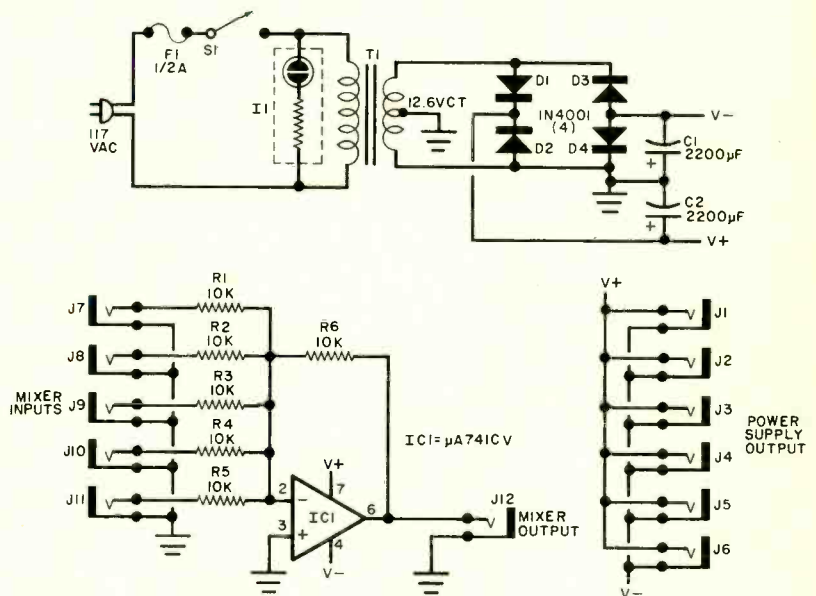
**The Combiner/Power Pack** will not only provide  $\pm 9$  volts dc (if 117 volts ac is available), but also includes a unity-gain active mixer. This mixer will sum up to five input signals and present them at a low-impedance output. In practice, all Cabonga components will operate with supplies ranging from  $\pm 8$  to  $\pm 15$  volts dc. Accordingly, the Combiner/Power Pack does not include such features as voltage regulation, foldback current limiting, etc. If you're a purist, you can add them; but you will probably not be able to *hear* any difference.

The schematic of the Combiner/Power Pack is shown in Fig. 6. A full-wave bridge composed of  $D1$  through  $D4$  rectifies ac from  $T1$ , a 12.6-volt, 1.2-ampere center-tapped transformer. Pulsating dc produced by the bridge is filtered by

electrolytic capacitors  $C1$  and  $C2$ . The  $\pm 9$ -volt output of the power supply is routed to jacks  $J1$  through  $J6$  and to  $IC1$ , the unity-gain summing amplifier.

Etching and drilling and parts placement guides are shown in Fig. 7. Be sure to observe polarities and pin basing

of semiconductors and electrolytic capacitors. The Combiner/Power Pack should be housed in an enclosure measuring about  $9\frac{1}{4} \times 4 \times 2\frac{1}{2}$  ( $23.5 \times 10.2 \times 6.4$  cm). The top and bottom of each wall should be rabbeted to provide a  $\frac{3}{8}$ " (9.5-mm) deep  $\times \frac{1}{4}$ " (6.4-cm)



### COMBINER/POWER PACK PARTS LIST

- $C1, C2$ —2200- $\mu$ F, 16-V electrolytic capacitor
- $D1$  through  $D4$ —1N4001 silicon diode
- $F1$ — $\frac{1}{2}$ -ampere fuse
- $I1$ —120-V ac neon pilot lamp assembly (Radio Shack 272-703 or equivalent)
- $IC1$ — $\mu$ A 741CV operational amplifier
- $J1$  through  $J6$ —Miniature phone jack
- $J7$  through  $J12$ —Standard phone jack
- $R1$  through  $R6$ —10,000-ohm,  $\frac{1}{4}$ -watt, 10% carbon composition resistor
- $S1$ —SPST switch
- $T1$ —12.6-V, 1.2-A transformer
- Misc.—Printed circuit board, ac line cord, etc. See photo p. 80 for kit prices.

*Fig. 6. Schematic of Combiner/Power Pack. The former is a full-wave rectifier with filters.*

### BILL OF MATERIALS

- 1—Piece  $\frac{1}{32}$ " aluminum  $8\frac{3}{8} \times 2-15/16$ "
- 1—Piece  $\frac{1}{16}$ " phenolic stock  $1\frac{3}{4} \times 1\frac{1}{4}$ "
- 2—Pieces  $\frac{3}{4}$ " pine or plywood  $9\frac{1}{2} \times 2\frac{1}{2}$ "
- 2—Pieces  $\frac{3}{4}$ " pine or plywood  $3-1/16 \times 2\frac{1}{2}$ "
- 1—Piece  $\frac{1}{4}$ " plywood  $8-7/16 \times 3$ "
- 1—Piece  $\frac{1}{8}$ " rubber matting  $8-7/16 \times 3$ "
- 1—Piece black vinyl  $28 \times 5$ "
- 10—No. 4  $\times \frac{1}{2}$ " sheet metal screws
- 1— $\frac{3}{8}$ " grommet
- Misc.—Contact cement, etc.

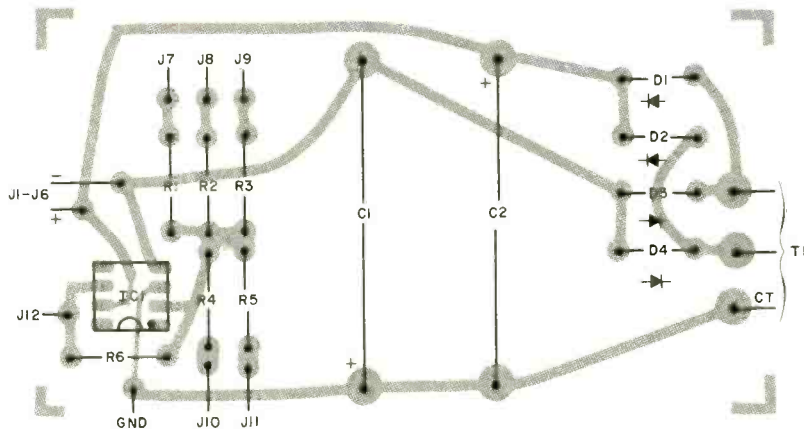
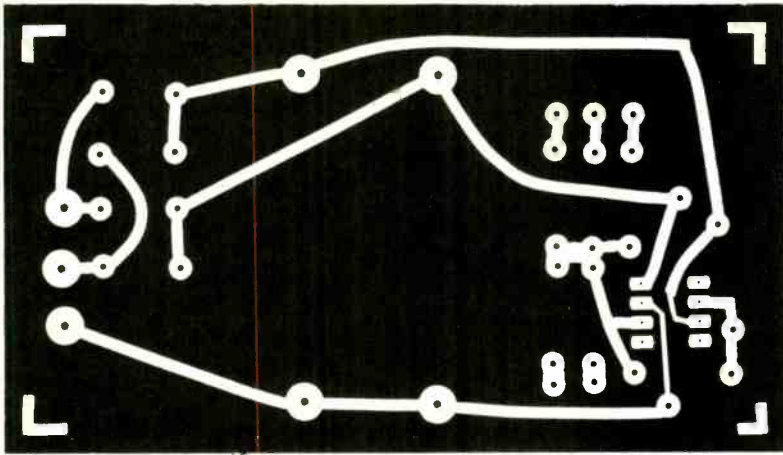


Fig. 7. Guides for Combiner/Power Pack board.

"shelf" on which to mount the top and bottom plates. This will enable the plates to be flush with the top and bottom of the walls. Round all top and bottom edges of the walls with sandpaper.

Form a top plate from an 8 $\frac{3}{8}$ "  $\times$  2-15/16" (21.3-  $\times$  7.5-cm) piece of 1/32" (0.8-mm) aluminum stock. Holes should be drilled for the mixer input and output and power output jacks, for the line cord, power switch and pilot light. The power output jacks, as well as the EXTERNAL POWER jacks on the Cabonga components, must be isolated from the aluminum top plates. This is because the "ground" portions of the jacks are at -9 volts. Isolation can be ensured by drilling the holes for the jacks with 7/16" (1.1-cm) bits. The jacks should be mounted on a 1 $\frac{3}{4}$ "  $\times$  1 $\frac{1}{4}$ " (4.4-  $\times$  3.2-cm) piece of 1/16" (1.6-mm) phenolic.

An 8-7/16"  $\times$  3" (21.4-  $\times$  7.6-cm) piece of 1/4" (6.4-mm) plywood forms the bottom plate. If you wish, you can fashion a sheet of ribbed rubber runner to the outer surface of the bottom plate with contact cement. The runner will provide an antiskid surface for the Combiner/Power Pack. The case can be covered with a 28"  $\times$  5" (71.1-  $\times$  12.7-cm) piece of black vinyl. Secure the vinyl to the case with contact cement by wrapping it around the perimeter. At each

corner, slit the vinyl and trim it as necessary. Carefully fold the vinyl over the top and bottom edges and into the rabbets.

Wire the jacks, switch, etc., according to the schematic diagram. When all connections have been made, secure *T1* and the pc board to the bottom plate, and the top and bottom plates to the case. Make one patch cord from a convenient length of shielded audio cable, terminating its ends with miniature phone plugs and prepare one patch cord terminated with standard phone plugs for each Cabonga. Also make one terminated with miniature phone plugs and one terminated with subminiature phone plugs for each Auto Trigger or Snare.

To test the Combiner/Power Pack, plug one power patch cord (terminated with miniature phone plugs) into a power output jack. Then connect the line cord

to a wall socket and close *S1*. Indicator *I1* should glow. Attach the negative probe of a voltmeter to the barrel of the miniature phone plug, and the positive probe to the plug tip. The meter should read 17 to 20 volts dc. If you read only half of this voltage or zero volts, turn off the Combiner/Power Pack and disassemble the enclosure. Check your wiring for shorts. When the reading is correct, attach the negative probe to the aluminum top plate and the positive probe to the plug tip. A reading of 8.5 to 10 volts dc should be obtained.

Turn off the power by opening *S1*. Then remove the patch cord from the power plug. As the plug barrel comes out of the jack, it momentarily touches both terminals of the jack and shorts them together. The Combiner/Power Pack's supply can take a direct short for a second or two without damage to its components. As a rule, however, you should turn off the power before making any power patch cord changes.

Connect a Cabonga to the power supply and mixer circuits to verify that both are functioning correctly. Successively try each power and mixer input jack to be sure they are correctly wired.

**The Modifier.** Most often, the damped sinusoidal output of the Cabonga is the signal you will use. But there will be times when a certain amount of clipping is needed. For example, the peaks of the Cabonga output should be clipped somewhat to get a "crisp" sound like that of a good bongo. This also produces a better sounding tom-tom.

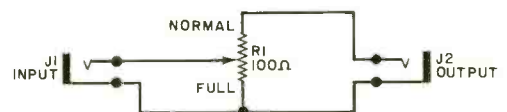
The schematic diagram of the Modifier is shown in Fig. 8. The circuit is simply a 100-ohm potentiometer. It presents a variable load of from 0 to 100 ohms to the output stage of the Cabonga. As the load resistance decreases below the value required for "crispness," various sound effects can be obtained. Although the load resistance as seen by the Cabonga varies, the Combiner/Power Pack input sees a constant 100-ohm signal voltage source.

The Modifier, as well as the Auto Trig-

Fig. 8. Modifier is simple potentiometer circuit shown here.

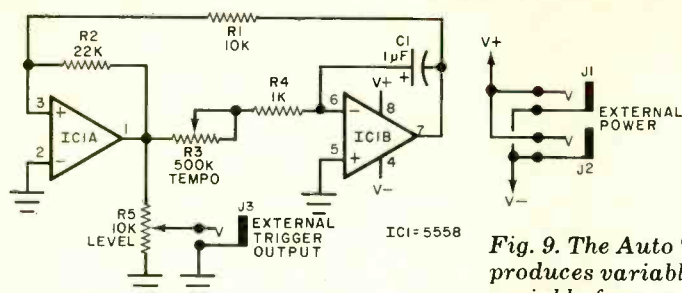
**MODIFIER PARTS LIST**

J1, J2—Standard phone jacks  
R1—100-ohm, linear-taper potentiometer  
Note—See photo p. 80 for kit price.



**BILL OF MATERIALS**

Same as for Auto Trigger, less phenolic stock and one 3/4" diameter knob.



### AUTO TRIGGER PARTS LIST

- C1—1- $\mu$ F, 16-volt electrolytic capacitor
- IC1—5558 dual operational amplifier
- J1, J2—Miniature phone jack
- J3—Subminiature phone jack
- R1—10,000-ohm, 1/4-watt, 10% carbon composition resistor
- R2—22,000 ohm, 1/4-watt, 10% carbon composition resistor
- R3—500,000-ohm, audio-taper potentiometer
- R4—1000-ohm, 1/4-watt, 10% carbon composition resistor
- R5—10,000-ohm, linear-taper potentiometer

Misc.—Printed circuit board, hookup wire, etc. See photo p. 80 for kit prices.

### BILL OF MATERIALS

- 1—Piece 1/32" aluminum 4" x 2"
- 2—Pieces 3/4" pine or plywood 5-1/16" x 2"
- 2—Pieces 3/4" pine or plywood 2-1/16" x 2"
- 1—Piece 1/8" rubber matting 4-3/4" x 2-3/4"
- 1—Piece 1/16" phenolic stock 1 1/2" x 1/2"
- 1—Piece black vinyl 16 1/2" x 3 1/2"
- 4—No. 4 x 1/2" sheet metal screws
- 2—3/4" diameter knobs

Fig. 9. The Auto Trigger produces variable-level, variable-frequency square waves.

ger and Snare, should be housed in enclosures measuring about 5 1/4" x 3 1/8" x 2" (13.4 x 7.9 x 5.1 cm). The enclosures should be constructed from the same materials as used for the Cabonga itself and the Combiner/Power Pack, rabbetted, and finished with black vinyl and rubber matting. Top plates can be made from 4" x 2" (10.2- x 5.1-cm) pieces of 1/32" (0.8-mm) aluminum stock. Two standard phone jacks and the 100-ohm potentiometer are mounted on the Modifier top plate. Wire them as per Fig. 8.

To test the Modifier, patch the output of the Cabonga to input jack J1, and the output of the Modifier (J2) to the mixer input of the Combiner/Power Pack. Place R1 in its NORMAL position. Play the Cabonga and slowly rotate R1 toward its FULL position. You will notice that the sound becomes "crisp." As the control is rotated further, the sound will become more and more distorted and lower in volume. At the extremity of wiper travel, the output will be a steady oscillation if your potentiometer's minimum resistance closely approaches zero ohm. (This will not damage the Cabonga output state.)

**The Auto Trigger.** Before we discuss the Auto Trigger, let's review how the Cabonga has been triggered until now. When the head is struck, switch S1 closes and applies a pulse to the active filter, resulting in a damped sinusoidal output. The amplitude of the trigger pulse determines the amplitude of the output signal. Jack J1 (EXTERNAL TRIGGER) is connected in parallel with S1 so

that an external pulse source can cause the generation of a percussive output.

The Auto Trigger is such a pulse source. It produces a variable level (0 to 9 volts), variable-frequency (0.5-to-400-Hz) square waves. Its circuit, shown schematically in Fig. 9, is not complicated. Only seven components are used. Operational amplifier IC1A, one half of a 5558 dual op amp IC, is used as a comparator. The other half, IC1B, is used as an integrator. When the comparator output changes states, a pulse is generated. This pulse is integrated by IC1B into a ramp whose slope depends on the amount of signal current supplied to the integrator, and thus on the values of R3 and R4. When the output of the integrator reaches one-half of the supply voltage, the comparator changes states again. The process then repeats itself.

Resistors R3 and R4, and capacitor C1 determine the frequency of oscillation. It can be varied over a wide range by adjusting TEMPO control R3. The upper limit of oscillation is governed by R4. Square waves appear at the output of IC1A and are coupled to J3 by LEVEL control R5. Power is derived from the Combiner/Power Pack and coupled to J1 or J2. An extra power jack is provided for patching to other accessories.

Etching and drilling and parts placement guides for a suitable schematic are shown in Fig. 10. Be sure to observe the polarity of C1 and the pin basing of IC1 when mounting them on the board. Construct an enclosure and top plate to the dimensions and style previously described. Note that jacks J1 and J2 must

be isolated from the aluminum top plate, which is at ground potential.

Connect a power patch cord between the Combiner/Power Pack and J1 or J2 of the Auto Trigger. Then connect a patch cord terminated with subminiature phone plugs between the Cabonga's EXTERNAL TRIGGER jack (J1) and the Auto Trigger output (J3). Turn the Auto Trigger's TEMPO and LEVEL controls fully clockwise. Then close the Combiner/Power Pack's power switch and monitor the mixer output. You will hear an output signal about once every two seconds. As the TEMPO control is rotated, the trigger rate will increase. Rotating the LEVEL control will vary the output signal's volume from minimum to maximum.

**The Snare Drum Adapter.** The snare sound is the most difficult to synthesize because a snare drum produces three different sounds simultaneously. As the drumstick strikes the top head, the sharp sound of the strike is heard. At the same time the sound of the drum itself (actually a medium-size tom-tom) is produced. The bottom head also vibrates and causes the snare wires touching it to move.

We can synthesize this complex sound by combining three different components: a high-level, short-duration pulse; an exponentially damped sine wave; and filtered noise. The damped sinusoid is already available at the Cabonga output. We can therefore use the Cabonga to trigger an accessory that

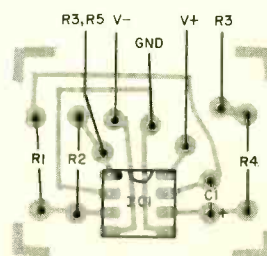
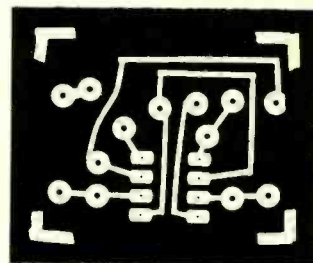


Fig. 10. Guides for Auto Trigger board.

will produce the other two components and mix them all together to produce a synthesized snare.

That is exactly what the Snare Drum



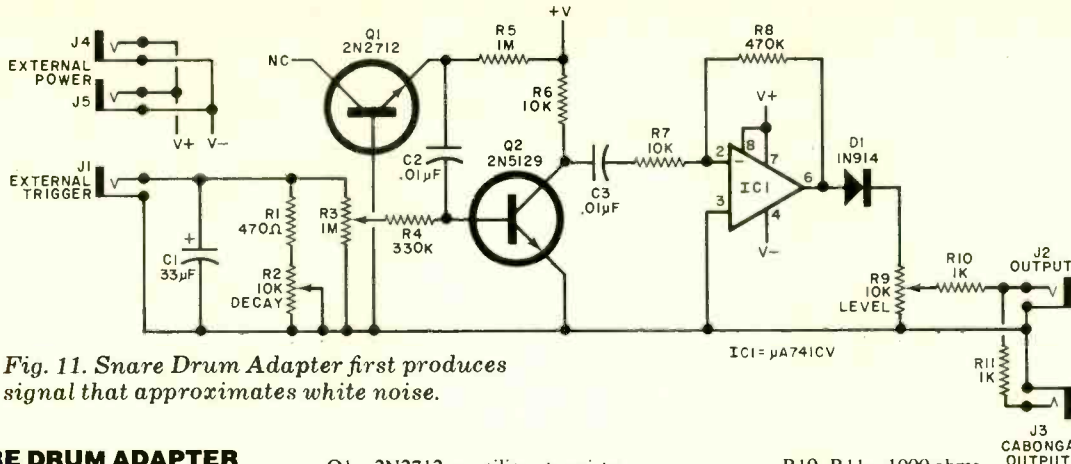


Fig. 11. Snare Drum Adapter first produces signal that approximates white noise.

### SNARE DRUM ADAPTER PARTS LIST

C1—33- $\mu$ F, 16-volt electrolytic capacitor  
 C2, C3—0.01- $\mu$ F disc ceramic capacitor  
 D1—1N914 or 1N4148 silicon diode  
 IC1— $\mu$ A 741CV operational amplifier  
 J1—Subminiature phone jack  
 J2, J3—Standard phone jack  
 J4, J5—Miniature phone jack

Q1—2N2712 npn silicon transistor  
 Q2—2N5129 npn silicon transistor  
 The following fixed resistors are 1/4-watt, 10% carbon composition components.  
 R1—470 ohms  
 R4—330,000 ohms  
 R5—1 megohm  
 R6, R7—10,000 ohms  
 R8—470,000 ohms

R10, R11—1000 ohms  
 R2, R9—10,000-ohm, linear-taper potentiometer  
 R3—1-megohm trimmer potentiometer  
 Misc.—Hookup wire, printed circuit board, etc. See photo p. 80 for kit prices.

### BILL OF MATERIALS

Same as for the Auto Trigger

Adapter does. It is shown schematically in Fig. 11. Noise generator *Q1* produces a continuous signal that approximates white noise. Capacitor *C2* couples this noise to the base of *Q2*.

When a voltage spike is applied to the Snare's EXTERNAL TRIGGER jack (*J1*), it charges *C1*. Such a spike is available when the Cabonga's trigger switch closes as the head is struck. Depending on the values of *R1* and *R2*, the voltage across *R3* decays exponentially with a time constant equal to the product of *C1* and (*R1*+*R2*). A portion of this voltage envelope (determined by the setting of *R3*) is also applied to the base of *Q2* via

*R4*. The voltage envelope causes *Q2* to conduct and pass the noise signal.

Transistor *Q2*'s output is filtered and capacitively coupled by *C3* to a high-gain amplifier. At the input to op amp *IC1*, the signal comprises a high-level spike and a very low-level noise component. Amplifying the signal by a factor of 47 (determined by the ratio *R8*/*R7*) produces a useful effect. The initial spike, whose amplitude is already approaching the positive supply voltage, is relatively unaltered while the noise component is amplified and equalized in level with the spike.

However, the high gain has an unde-

sirable side effect—it greatly accentuates the internal noise of the inexpensive op amp. To eliminate this noise, *D1* is placed in series with the op amp output. The diode will not pass signals below 0.7 volt, so the unwanted noise, which would sound like a low-level hiss, is eliminated but the desired signal is allowed to pass. In the process, we get a bonus—the noise is made to sound more realistic by clipping off its bottom half. Resistors *R10* and *R11* combine the Cabonga and Snare waveforms into a single output, available at output jack *J2*. Potentiometer *R9* serves as a LEVEL control for the snare signal.

Etching and drilling and component placement guides are shown in Fig. 12. Mount the components on the board, observing polarities and pin basing of the semiconductors and electrolytic capacitors. Construct an enclosure and top plate to the dimensions and style previously described. Note that jacks *J4* and *J5* must be isolated from the aluminum top plate, which is at ground potential. Trimmer potentiometer *R3* is installed on the pc board. The other potentiometers are mounted on the top plate.

Patch external power to *J4* or *J5*, and run patch cords from the Cabonga output and external trigger jacks to *J3* and *J1*, respectively. Interconnect the Snare

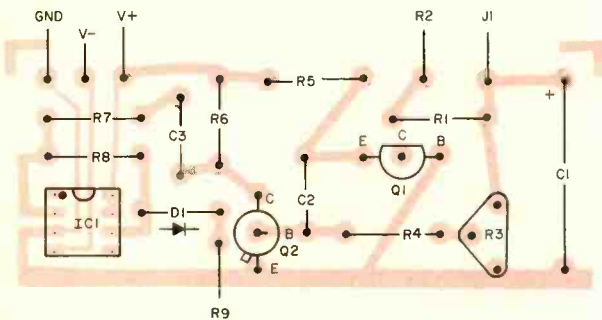


Fig. 12. Use the etching and drilling guide below and component placement at left to make Snare Drum Adapter board.

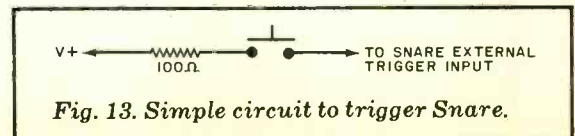
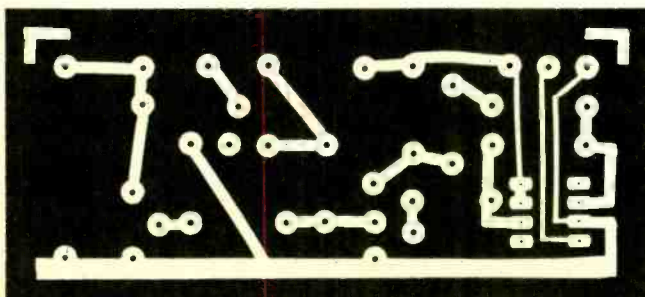
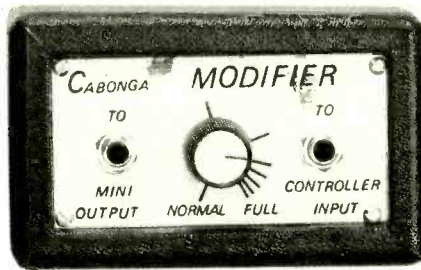


Fig. 13. Simple circuit to trigger Snare.



output (J2) to the Combiner/Power Pack's mixer input. Place the thumbwheel of R3 at the midpoint of its rotation. While striking the Cabonga drum head, adjust the setting of R3 in either direction until you obtain the most pleasing sound. As you strike the head, you will hear the sound of the strike, the tom-tom and the noise simultaneously. The relative loudness of the strike sound as compared to the noise is governed by R3, so you might have to make a compromise adjustment of the trimmer potentiometer. Adjust the output level to obtain a balanced snare sound.

Use the circuit shown in the Fig. 13 to trigger the Snare. It will result in a fair approximation of a cymbal. Then trigger the Snare with the Auto Trigger. For a different effect, prepare a patch cord from a single piece of stranded hookup wire. Solder the hookup wire to the tips of two subminiature phone plugs. Connect the patch cord to the Auto Trigger output and the Snare EXTERNAL TRIGGER input. Turn both Snare controls to maximum. By adjusting the Auto Trigger TEMPO and LEVEL controls, you can create such effects as the sound produced by a biplane.

**Using the Cabonga System.** The Cabonga and its accessories form an expandable synthesizer system. As with any electronic musical instrument, the best way to realize its full potential is to experiment. Here are some hints. It is always best to turn off the power before making any patch cord changes. As previously mentioned, this prevents inadvertent damage to the power supply diodes. It's the only restriction on use of the system that should be observed. Let your imagination dictate system configurations and patches.

*Cabonga accessories are shown here and below. Following are available from JAL Assoc., Box 107, Eatontown, NJ 07724: Combiner/P-P pc board at \$3.50, complete kit, \$27; Snare pc board, \$3.50, complete kit, \$16.95; Auto Trig. pc board, \$1.50, complete kit, \$12.95; Modifier complete kit, \$7.50. All postpaid. NJ residents add 5% sales tax.*

A three-head system is shown in Fig. 14. (You may prefer a fivehead system.) Cabonga 1 is set up as a snare, Cabonga 2 as a tom-tom and Cabonga 3 as an automated bass drum, resulting in an electronic drum set. Set the Modifier control to give a crisp tom-tom sound.

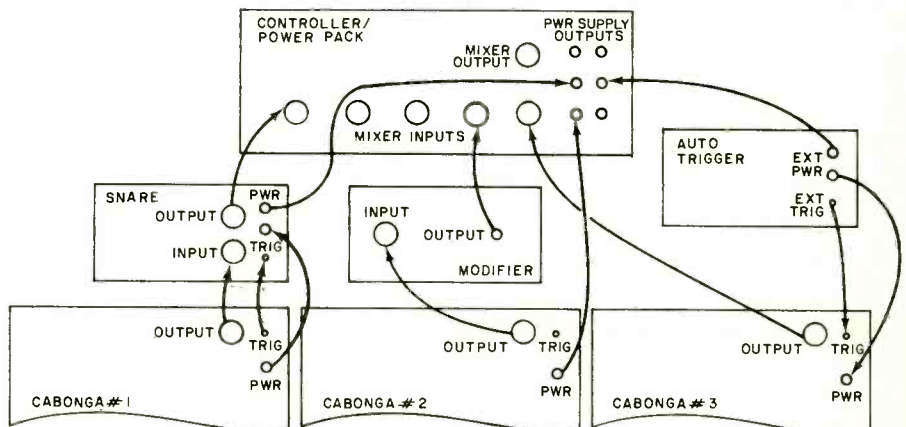
*The Controller and Power Pak is necessary to connect all the other units together.*



As mentioned in Part I of this article, the Cabongas can be interconnected via their EXTERNAL TRIGGER jacks. Tune two Cabongas an octave apart and interconnect them. You will note that the sound produced is much fuller than that from just one. Another possibility using four Cabongas is as follows. Tune two (A and B) as a Conga set and two (C and D) as a pair of Bongos. Interconnect A to

On the more practical side, you can use a number of Cabongas and Modifiers to make a fairly realistic steel drum set. The Modifier, as previously mentioned, is most useful when synthesizing a Bongo or tom-tom.

Those are some ideas to get you started. As you experiment more and more, you will probably create sounds that no one else has even thought of! ◇



*Fig. 14. This interconnection diagram shows how to set up a three-headed Cabonga system.*



# HOW TO CUSTOM DESIGN PLASTIC CASES FOR PROJECTS

BY JOHN HUFF

*An auto-clock case is used to describe cutting, bending, joining, etc.*

**Y**OUR electronic projects deserve to be housed in attractive and reasonably priced "custom designed" cases. As a modern hobbyist, you don't have to make do with utility boxes that do not complement your projects. Instead, you can design your own inexpensive and attractive plastic cases, thanks to the ready availability of acrylic plastic sheets and tubes.

Acrylic plastic is easier to work with than wood—and with the same tools used in woodworking. It can be cut, filed, sanded, glued, and even bent to permanently conform to a desired shape. Available under such brand names as Plexiglas, Lucite, and Safe-t Vue, it comes in crystal clear, color-tinted transparent, translucent, and opaque sheets in 1/16", 1/8", and 1/4" (1.6, 3.2, and 6.4 mm) thicknesses.

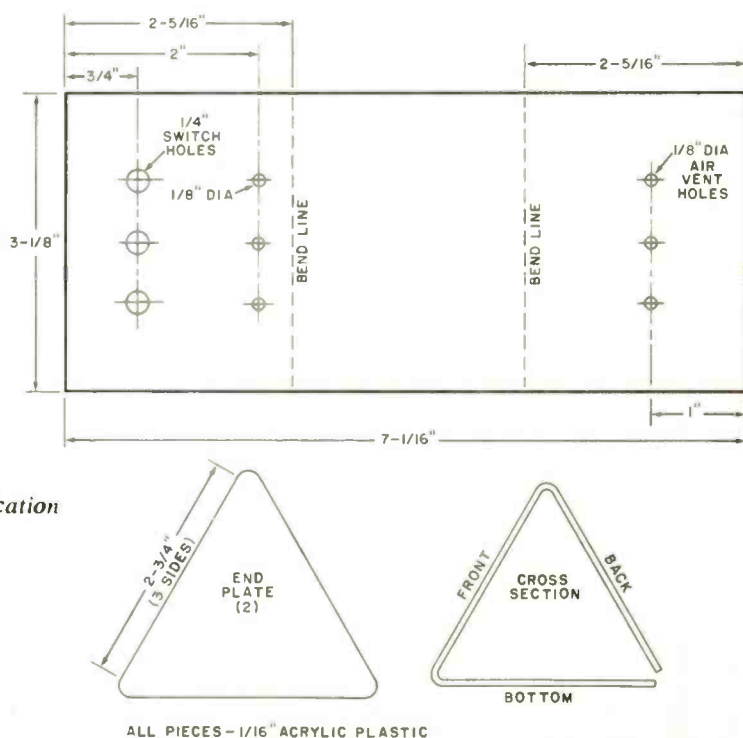
This article describes how to work with acrylic plastic to custom design and fabricate cases for your electronic projects. To illustrate the step-by-step procedure to use, we also include a digital Kar Klok project to assemble (see box). The Kar Klok is built around National Semiconductor's new MA1003 clock module, a printed circuit assembly containing a four-digit 0.3" (7.6-mm) high fluorescent display, time base, clock chip, and all necessary driving circuitry.

**Working With Acrylic.** Just about any brand of acrylic plastic can be used by the electronics hobbyist because all

have the same basic physical properties. However, some types of acrylic are easier to work with than are others. Most acrylic pieces made by the cast method can be cemented together with a solvent that actually dissolves the mating surfaces and forms a monolithic weld joint in minutes. More difficult to work with are the acrylics made by a continuous conveyor-belt process, which require a

thickened type of cement (airplane dope) that takes an hour or more to set. Needless to say, cast acrylic, such as Plexiglas G, is your best first choice. Ask for Plexiglas G (or similar cast-type acrylic) at your local hardware or hobby/craft store.

Acrylic sheets come with a special protective paper on both surfaces to prevent scratches. This paper makes an ex-



*Fig. 1. Fabrication details for the Kar Klok case.*

ALL PIECES—1/16" ACRYLIC PLASTIC

cellent surface for marking cutting lines and the centers of holes to be drilled.

The plastic can be cut with a saw or a special scribing tool. You can use a jigsaw, hacksaw, coping saw, or saber saw for cutting. However, scribing is easier if all you have to do is cut straight lines. Curved lines and circles still require cutting with a saw.

The fabrication details for the Kar Klok (see box) case are shown in Fig. 1. Mark all necessary lines and hole centers on the protective paper on the acrylic sheet.

The scribing tool, which sells for about \$2.00 wherever the plastic is sold, looks like a miniature harpoon. In use, the sharp point of the tool is guided along the cut line with moderate downward pressure, using a straight edge, as shown in Fig. 2. Once the line is scribed, the plastic is placed over the edge of a table, scribed line up and in direct alignment with the edge of the table, and struck sharply on the side overhanging the table. The snapping action yields a very straight, clean edge. The snapped edges must then be lightly smoothed with fine sandpaper before being cemented. Edges that are not to be cemented can be buffed to a crystal sheen with a drill-mounted muslin wheel and a special buffing compound (about \$3.00 for wheel and compound) or with fine steel wool and soap and water.

Cutting holes is done with ordinary drill bits, as shown in Fig. 3. It is important to note that during the drilling operation, the sheet of plastic must be firmly held or clamped to a piece of wood to prevent it from riding up the bit and cracking. Square and rectangular slots can be made by drilling a small hole and cutting with a coping saw.

Since the Kar Klok case pictured in the lead photo and dimensioned in Fig. 1 is triangular in shape, it is necessary to bend the acrylic plastic sheet to conform to this shape. The trick to making accurate bends is to use a bending jig and heat only those portions of the plastic that are to be bent. Do not heat the entire surface of the plastic.

Acrylic plastic bends at about 300° F (about 150° C). It bends best if the protective paper is peeled off before the heat is applied. You can heat the plastic along the bend line in several ways, the easiest of which is to use the specially made strip heater element that sells for about \$8.00 from the same dealers who handle the plastic. This heater element requires a simple wood strip that keeps it about 1/4" (6.4 mm) away from the plastic. Detailed instructions come with the element.

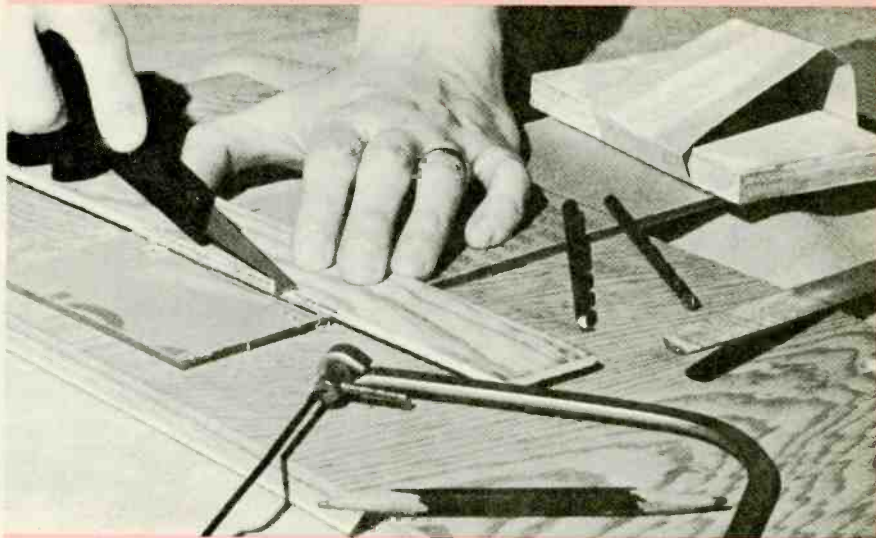


Fig. 2

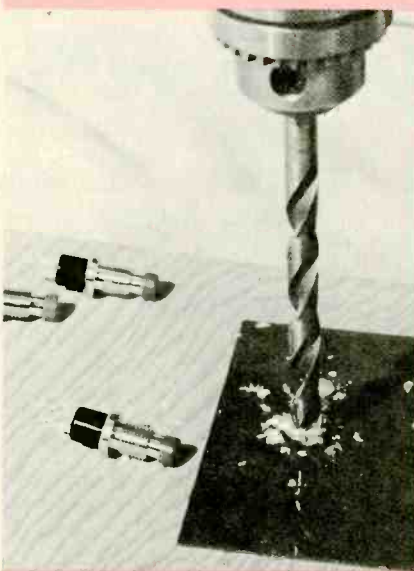


Fig. 3

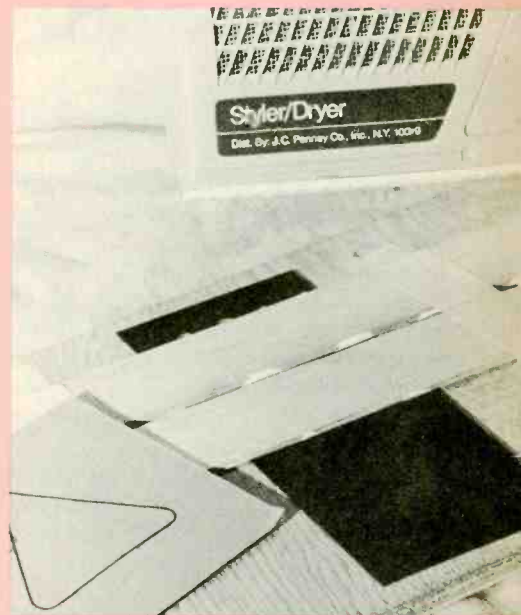


Fig. 4

**Fig. 2.** The acrylic scribing tool, obtainable wherever the plastic is sold, looks like a small harpoon and is used to scribe a line, following a straight edge, where the plastic is to be broken.

**Fig. 3** Acrylic is easily drilled by holding the plastic firmly to a wooden base. Here, holes are being drilled for pushbutton switches. Square and rectangular slots can be made by drilling a hole and cutting with a coping saw.

**Fig. 4.** Acrylic bends at about 300° F. Here strips of wood faced with cloth for protection, are placed on both sides of bend mark and heat is applied by a 1000-watt hair dryer.

**Fig. 5.** Heat for bending can also be obtained from a 500-watt photoflood bulb.

**Fig. 6.** Once the plastic has been heated, it can be bent using a jig as shown here. Note that the actual crosssection of the case has been drawn on the bottom of the jig. Jig corners are 4-inch nails.

**Fig. 7.** Acrylic solvent cement is easily applied and dries in minutes.

**Here one end of the clock case is being glued to the main frame.**

**Fig. 8.** If preferred, an acrylic cylinder can be used for the body of the clock with square end pieces as shown here.

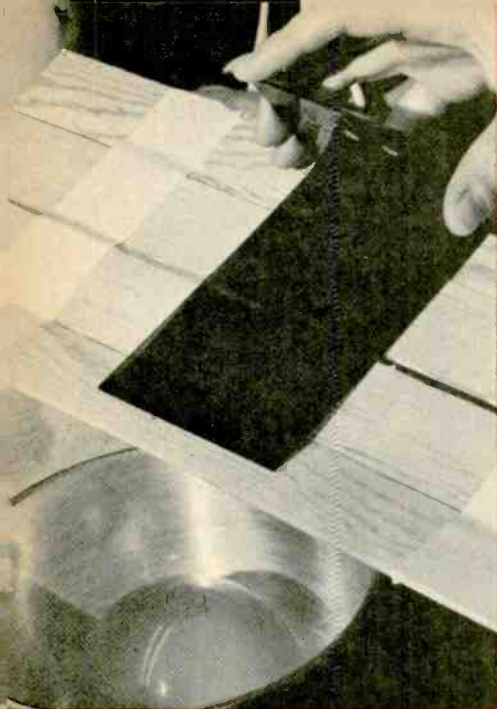


Fig. 5

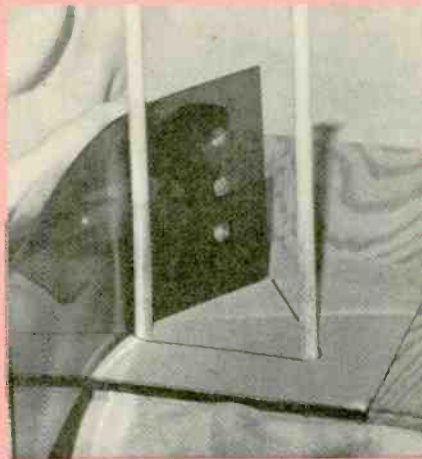
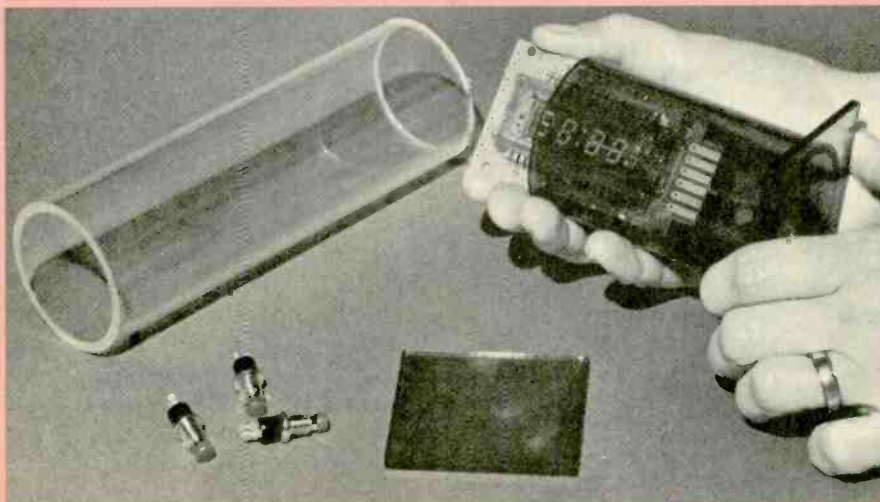


Fig. 6



Fig. 7

Fig. 8



Another bending technique is to place the plastic sheet on a flat surface, place a 1/4" thick strip of wood on both sides of the bend line (face the strips with soft cloth or cotton to prevent them from scratching the plastic), and use a blow-type hair dryer to heat along the line. Details are shown in Fig. 4. The hair dryer must be rated at a minimum of 1000 watts. How well it heats the plastic depends on the chemistry of the particular sheet of acrylic you use. Do not hold the dryer too close to the plastic or the air flow will be restricted and the heat fuse will blow.

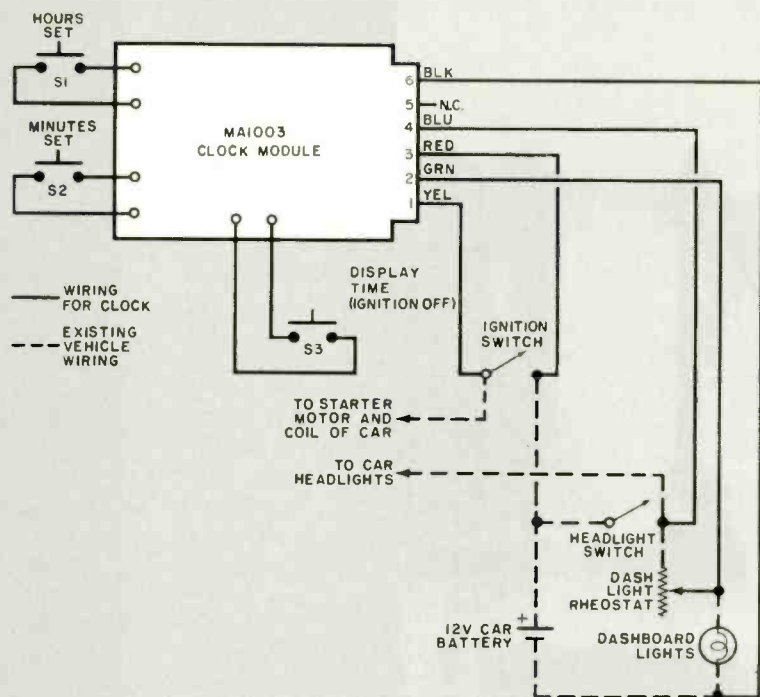
Still another approach that works for heating the plastic is to use a 500-watt photoflood lamp. Again, use wood strips to frame the bend line. Hold the plastic about 10" (25.4 cm) away from the lamp as shown in Fig. 5.

Once the plastic has been heated, it can be bent to shape using a bending jig as shown in Fig. 6. Note here that, to get the angles correct during bending, the actual-size cross-section of the body of the clock case is drawn on the base of the jig. A 4" (10.2-cm) long nail is then driven into the indicated corners of the drawing and the plastic is aligned with the drawing and gently bent around the nails. When the bending operation is complete, there will be a small open slot where the ends of the plastic sheet do not quite meet. This slot is used for running the wires between the vehicle's electrical system and the clock module, without drilling holes.

Next, cut the triangular end pieces for the case from the same plastic sheet from which the case body was cut, using Fig. 1 as a guide. After sanding the edges smooth and buffing them, cement one side piece to the case body as shown in Fig. 7. Slip the clock module into the case. Then fasten down the pushbutton switches in their appropriate holes and route the electrical-system hookup wires through the slot in the body of the case. Cement the other side piece to the case.

Decide where in your vehicle you want to mount the Kar Klok and cement Velcro strips to the bottom edges of the case end pieces with the solvent cement and to the dashboard with a silicone adhesive. Finally, route the wires coming from the clock module into your vehicle's electrical system (see box for hookup details). The use of Velcro strips to mount the clock allows you to remove the clock and put it out of sight to reduce the possibility of theft.

**A Simpler Case.** Perhaps you do not



## ABOUT THE CLOCK

As shown in the schematic diagram, the Kar Klok is a very simple project to put together. It is built around National Semiconductor's new MA1003 clock module that requires the addition of only three momentary-action pushbutton switches and five wires to be connected into the vehicle's electrical system.

With the Kar Klok wired as shown, the display will be on continuously as long as the vehicle in which it is installed is running. The clock remains powered even with the ignition turned off, but power is removed from the display to conserve battery power. However, even with the ignition off, the time can be displayed on demand simply by pressing switch S3.

Switches S1 and S2 provide the means for setting the hours and minutes for the correct time. These switches are activated only when the ignition is on. With the ignition turned off, the time-setting switches are disabled.

Basically, only three connections need be made from the vehicle's electrical system to the clock module. Constant dc power from the positive battery terminal, with the ignition on and off, is made to pad 3 on the module, while the negative side of the battery, or chassis ground, goes to pad 6. The ignition-controlled display on/off connection goes from the other side of the ignition switch to pad 1.

Optionally, you can add brightness control to the display by connecting a lead from the headlight switch to pad 4 on the module. Now, when the headlights are

turned on, the brightness of the display is reduced by two thirds, which reduces glare under nighttime driving conditions. Additionally, if your car is equipped with a dashboard-light level control (rheostat), a final wire from the wiper lug of the control to pad 2 on the module allows you to control the brightness of the display from full to about one-third brightness. No connections need be made from the vehicle's electrical system to pads 2 and 4 on the module for the clock to operate.

The green vacuum fluorescent display consists of four 0.3" (7.6-mm) digits with a colon between the minutes and hours. The green display allows the use of blue, green, or yellow filters.

The clock module itself is protected against automotive voltage transients and reversals. It is designed to keep time with supply potentials of nominally 12 volts down to approximately 9 volts dc. The clock draws 5 mA when operated with the vehicle's ignition off.

For wiring between the clock module and the vehicle's electrical system, it is best to use 20-gauge stranded hookup wire. You can use 22- or 24-gauge stranded hookup wire between the switches and module. (A kit of parts, including the MA-1003 clock module, three pushbutton switches, and triangular case described elsewhere in this article, is available for \$26.95 from Digi-Key, Box 677, Thief River Falls, MN 56701. Please ask for the Kar Klok kit. Minnesota residents, please add state sales tax.)

wish to go to the bother of bending a sheet of acrylic plastic to make a case for your Kar Klok. In this event, you can substitute an acrylic cylinder for the body of the clock and use square end pieces (see Fig. 8). Select tubing with a 1 3/4" (44.5-mm) inner diameter and 1/8" (3.2-mm) wall thickness and cut it to 3 1/8" (8 cm) in length. The end pieces should form squares that measure 2 1/4" (57.2 mm) on each side from 1/8" or 1/4" thick acrylic plastic sheet.

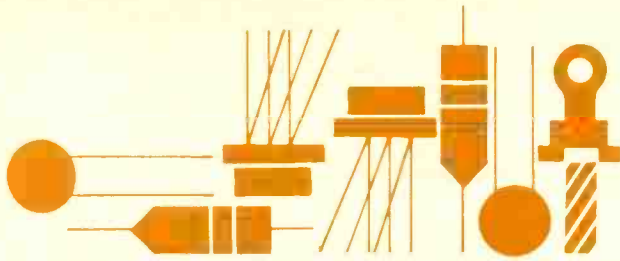
Acrylic tubing for craft work is usually crystal clear. However, if you prefer a transparent color tint, solvent-based dyes that simply brush onto the plastic are available. You can use the crystal clear tubing as is with crystal clear or color tinted end pieces to better show off the Kar Klok's "innards."

To locate the holes for the three pushbutton switches, slip the module into the acrylic tube and note and mark where the holes should be drilled. When you drill the holes for the switches, drill a fourth hole of the same diameter for the wires that connect to the vehicle's electrical system to exit the case. Then drill a line of 1/8" holes at the top and bottom of the case, spacing them about 3/8" (9.5 cm) apart to allow air to cool the clock module when it is installed in the case.

Cement one end piece to the cylindrical body. Slip the clock assembly into the case, fasten down the switches in their appropriate locations, and route the electrical-system hookup wires through the hole drilled for them. Then cement the other end piece to the case. Finally, use Velcro strips to mount the Kar Klok to your dashboard and connect the wires to your car's electrical system as shown in the box.

**In Closing.** The world of acrylic plastic provides the electronics hobbyist with a practical and inexpensive means for custom designing and fabricating cases for his projects. In this article, we have detailed the basic techniques for working with acrylic plastics. With a little practice and by exercising some imagination, you can be making custom cases for all your projects in short order. For example, you might substitute wood for the end panels of your cases or use a wood base with a brushed aluminum pedestal on which to mount an acrylic-cased project. The combinations of materials and styles are almost limitless.

The Kar Klok project presented here is a practical automotive accessory that is particularly suitable for exercising your imagination in designing custom plastic cases. ◇



# Solid State

By Lou Garner

## IC AUDIO PREAMPLIFIERS

**S**EMICONDUCTOR devices have been used in audio amplifiers ever since the transistor first became a practical commercial product. In fact, to a large degree it was the continuing search for improved and more efficient audio amplifiers and switches which led to the invention of the transistor by scientists of the Bell Telephone Laboratories in the late 1940's. The first consumer application of transistors was as audio amplifiers in hearing aids, followed shortly thereafter by their use in the audio sections of AM radio receivers and as preamplifiers for vacuum tube operated audio systems. As time passed, the mass production of junction transistors for the hearing aid industry resulted in a surplus of units which didn't meet the critical requirements of hearing aid designs but which, nonetheless, were excellent amplifiers. These devices were made available to the retail market through local distributors as moderately priced "experimenter's transistors," opening a whole new field for the experimenter and hobbyist.

Originating back in the heydays of vacuum-tube amplifiers, the preamplifier often was an afterthought—that is, an extra retrofitted circuit used to boost relatively weak signals prior to processing by a conventional amplifier. Sometimes the preamp, as it came to be known, was incorporated as part of an external signal source, such as a condenser microphone or magnetic phono pickup. In other cases, the preamp was an add-on circuit mounted directly on the main amplifier chassis and using the same power source. In still other cases, it was a separate piece of self-contained equipment with an integral supply as well as input and output jacks. In those early days, the preamp generally was a single- or dual-stage circuit designed to furnish some frequency compensation as well as modest gain. It seldom was equipped with gain or tone con-

trols, however, for these were found in the main amplifier assembly.

Today's preamp designs range from simple single-purpose configurations to complex circuits with nearly as many controls as an oscilloscope. Depending on equipment performance requirements, the preamp may be used only as a buffer or isolation amplifier. More often, it serves to provide additional gain and impedance matching as well as frequency compensation, equalization, and control. While early solid-state audio preamps usually employed from one to four discrete transistors, current designs commonly feature one or more integrated circuits. General-purpose operational amplifiers are perhaps the most widely used devices as preamps, with FET-input types increasingly popular among design engineers because of their high input impedance characteristics.

Typical IC audio preamp designs are illustrated in Figs. 1 through 4. Abstracted from manufacturers' data sheets, application notes and similar published literature, these circuits all feature standard devices and commercial components and, therefore, are suitable for a variety of experimenter and hobbyist projects. Generally, layout and lead dress are not overly critical as long as good wiring practice is observed. This permits the circuits to be assembled using standard construction techniques, including pc or perf boards, solderless wirewrap, or conventional point-to-point wiring. In general, too, dc circuit power may be obtained either from batteries or well filtered and regulated ac line operated power supplies, at the builder's option. Since the required assembly and wiring time is but a few man-hours for most of the circuits, the designs are excellent for weekend projects.

Selected from data sheets published by the Signetics Corporation (811 East Arques Ave., Sunnyvale, CA 94086), the four simple audio preamp circuits shown in Fig. 1 are based on the NE542 dual low-noise preamp IC. However, the general designs may be used with a variety of amplifier IC's having similar electrical characteristics, including the LM381, LM381A, and LM387, with few, if any, changes in component values. Of course, pin connections vary with different IC's and an adjustment in dc supply voltages may be required for some types to achieve optimum performance. Of the four IC's in-

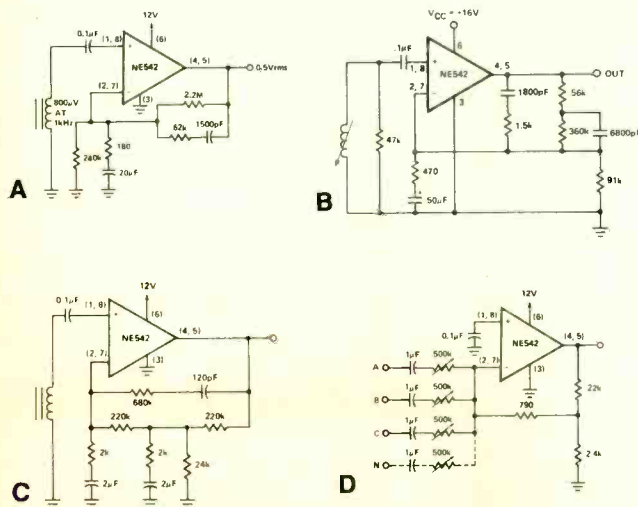


Fig. 1. Audio preamp circuits: (A) tape playback; (B) RIAA phono; (C) NAB tape preamp; (D) mixer.

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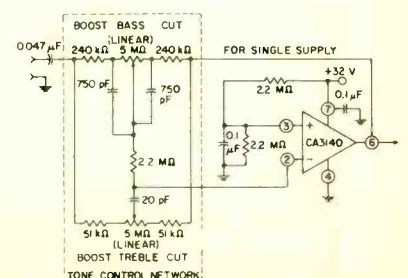
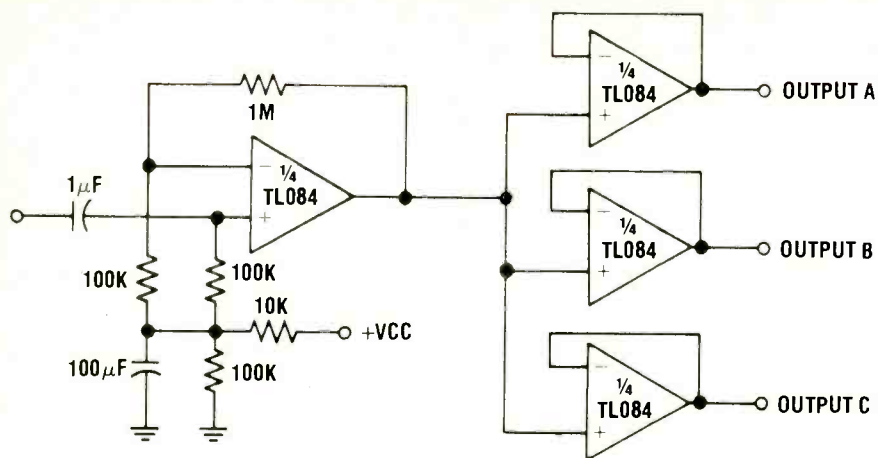


Fig. 2. This Baxandall tone control circuit uses a BIMO5 unit.



*Fig. 3. This audio distribution amplifier circuit features multiple isolated outputs and can be used effectively in electronic musical instruments to achieve special effects.*

icated, types NE542 and LM387 are supplied in 8-pin Mini-DIP's, while types LM381 and LM381A are furnished in standard 14-pin DIP's. All contain dual amplifiers, permitting a single device to be used for two-channel (stereo) systems.

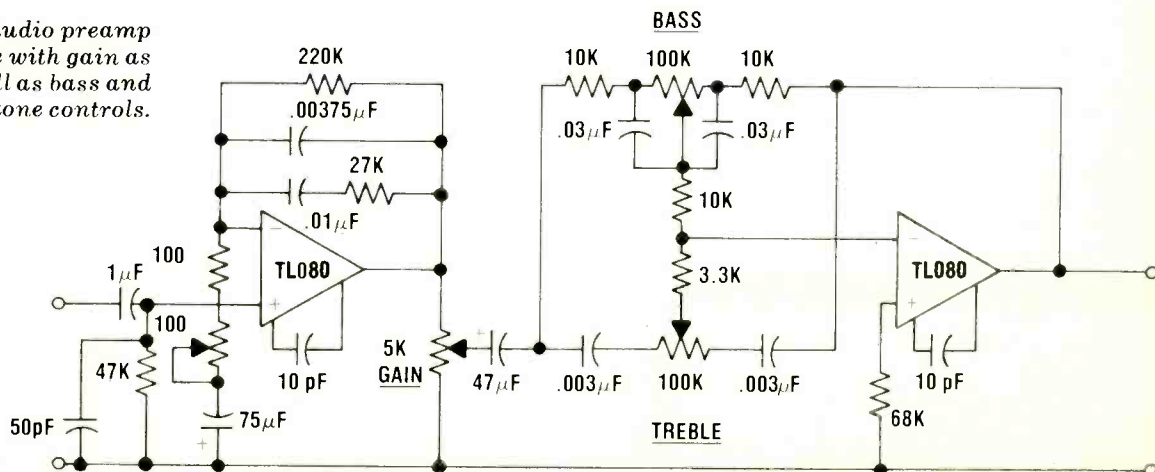
A typical magnetic tape playback preamp circuit is illustrated in Fig. 1A. Requiring relatively few components, the circuit will deliver 0.5 V rms output when driven with an 800- $\mu$ V input signal (nominally, at 1 kHz) by the pickup coil. A modified preamp design providing RIAA equalization for use with standard magnetic phono cartridges is given in Fig. 1B. Intended primarily for broadcast equipment applications, a two-pole fast turn-on NAB tape preamp circuit is shown in Fig. 1C. Finally, a multiple input audio mixer circuit with independent gain controls is illustrated in Fig. 1D. All four preamp circuits are designed for operation on conventional single-ended dc power supplies.

Featuring a BIMOS device, the Baxandall tone-control circuit shown in Fig. 2 is one of a number of suggested applications described in a 20-page data brochure (File No. 957) published by RCA (Solid State Division, Box 3200, Somerville, NJ 08876) for the CA3140 op amp family. As described in April's column, the CA3140 is a dual-technology unit which combines a high-impedance MOSFET input stage with a bipolar output amplifier in a single op amp. The CA3140 devices are furnished in standard 8-lead TO-5 type metal cases. Using linear potentiometers, the Baxandall circuit, according to RCA, can furnish up to  $\pm 15$  dB bass and treble boost or cut at 100 Hz and 10 kHz, respectively, while providing a full peak-to-peak output of up to 25 V to at least 20 kHz. The amplifier's output is only  $-3$  dB down at 70 kHz from its 1-kHz reference

level. With the controls set for a flat frequency response, the circuit offers unity (0 dB) gain. As shown, the circuit is intended for operation on a single-ended dc power supply. It can be modified easily for operation on a dual  $\pm 15$ -V dc source, however, simply by removing the offset bias network and returning pin 3 (+input) to circuit ground while connecting pin 4, bypassed to ground with a 0.1- $\mu$ F capacitor, to the negative supply terminal rather than to ground; all other circuit connections remain unchanged.

In contrast to the multiple input mixer described earlier (Fig. 1D), the audio distribution amplifier circuit illustrated in Fig. 3 features multiple isolated outputs. It can be used effectively in electronic musical instruments for special effects as well as in PA, music distribution, and intercom systems requiring multiple drives for several power amplifiers to achieve high output levels. It also can be used in light organ, audio control, and test instrument designs. Abstracted from 20-page Bulletin CB-248, published by Texas Instruments, Inc. (P. O. Box 5012, Dallas, TX 75222), the distribution amplifier employs a type TL084 quad operational amplifier. A member of TI's BIFET family, the TL084 comprises four identical JFET input op amps in a single 14-pin DIP. The device can be operated on dc supply voltages of up to  $\pm 18$  V, with each amplifier section offering an input impedance of  $10^6$  megohms, a unity gain bandwidth of 3 MHz, a slew rate of 12V/ $\mu$ s, internal compensation, and continuous integral output short-circuit protection. Individual amplifier pin connections are not identified in the schematic diagram because the amplifier sections are interchangeable and the final selection can be made best by the equipment designer to achieve optimum layout and lead

*Fig. 4. An audio preamp complete with gain as well as bass and treble tone controls.*





dress. In all cases, however, dc power supply connections are to pins 4 (+) and 11 (-).

Another TI BIFET circuit is given in Fig. 4—an audio preamp complete with gain as well as bass and treble tone controls. Intended for general purpose applications, the preamp can provide more than adequate drive for standard power amplifier designs. The circuit features the TL080, a single JFET input op amp which is offered in both 8-pin MiniDIP and TO-99-L style packages. Except for requiring external compensation (10-pF capacitors), the TL080's electrical characteristics are essentially similar to those of the individual amplifiers in the TL084, discussed earlier. The device's pin assignments are the same as those of such standard op amps as the LM301A, LM308, and  $\mu$ A748.

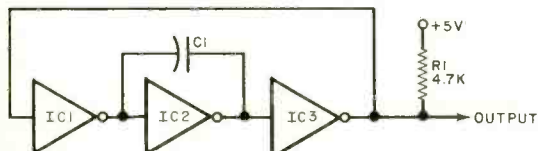


Fig. 5. Square-wave oscillator circuit can deliver signals from 1 Hz to 1 MHz as value of feedback capacitor is varied.

**Right On!** In last January's annual "predictions" column, you may recall, I predicted a further breakthrough in the pricing of digital electronic watches . . . that commercially available watches would be offered in the "ten-dollar range." Ah so! *Texas Instruments, Inc.*, which originally broke the twenty-five dollar price barrier for digital watches, per an even earlier prediction, *has done it again!* In a recent press release, TI announced a reduction in the suggested retail list price of its model 503 sports/youth watches from \$19.95 to a low \$9.95!

**Reader's Circuits.** If the bulging mail bag is any indication, many of our readers have been quite busy devising and testing new circuits.

While on the subject of mail—a personal word to those of you who may have written and not received answers to your letters and postcards. The volume of mail generated by a magazine with a readership of 400,000 is simply too much for one guy to acknowledge personally. However, be assured that all letters are read and given full consideration. If you don't receive an answer to your inquiries promptly (or even at all), it isn't due to a lack of interest. It's simply because we don't have time. But please, please keep us posted about your interests and keep sending those interesting circuits.

We have a twenty-year old French-Canadian reader, Guy Isabel (1725, Henri-Bourassa East Blvd., Apt. 25, Montreal, Quebec, H2C 1J8, Canada), to thank for the simple and inexpensive square-wave oscillator circuit illustrated in Fig. 5. It is capable of delivering signals at frequencies ranging from 1 Hz to 1 MHz as the feedback capacitor's value,  $C_1$ , is varied from 300  $\mu$ F to 300 pF. The circuit may be used as a "clock" in digital applications, as a simple square-wave generator for test instruments, or as a basic tone source for alarms and electronic musical instruments.

The duty cycle is approximately 50% and is independent of the feedback capacitor's value. The three active devices making up the oscillator,  $IC_1$ ,  $IC_2$ , and  $IC_3$ , are three sections of a standard type 7405 TTL open-collector hex inverter. Pull-up resistor  $R_1$  is a half-watt unit, while capacitor  $C_1$  may be a ceramic, plastic-film, paper or electrolytic type, depending on

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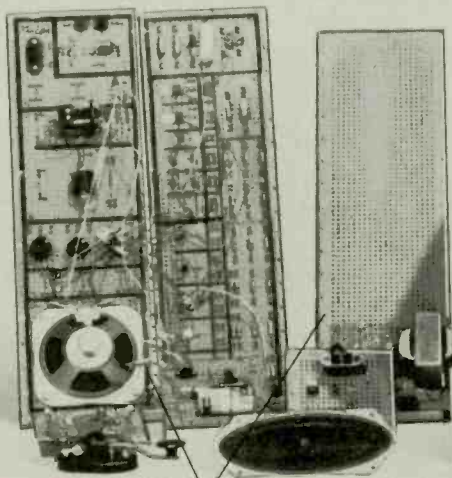
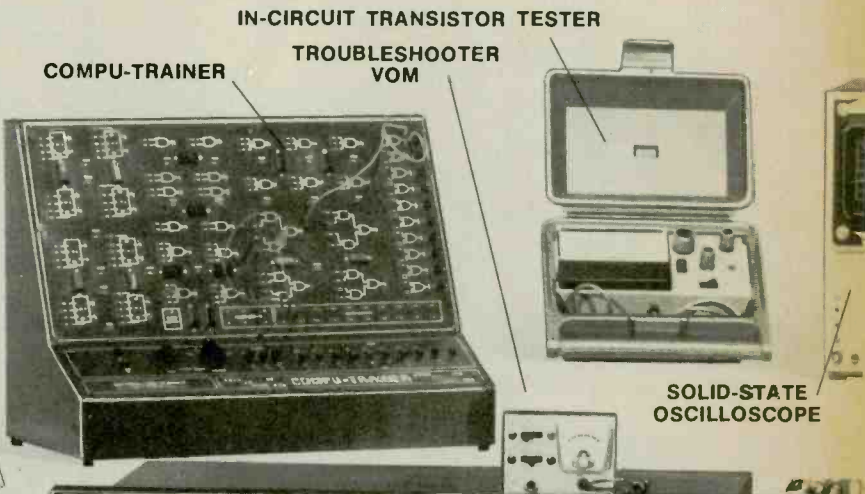
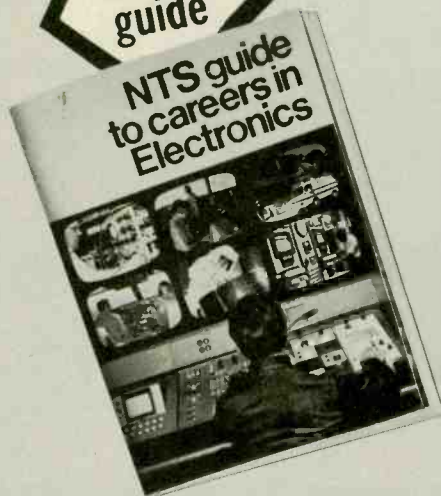
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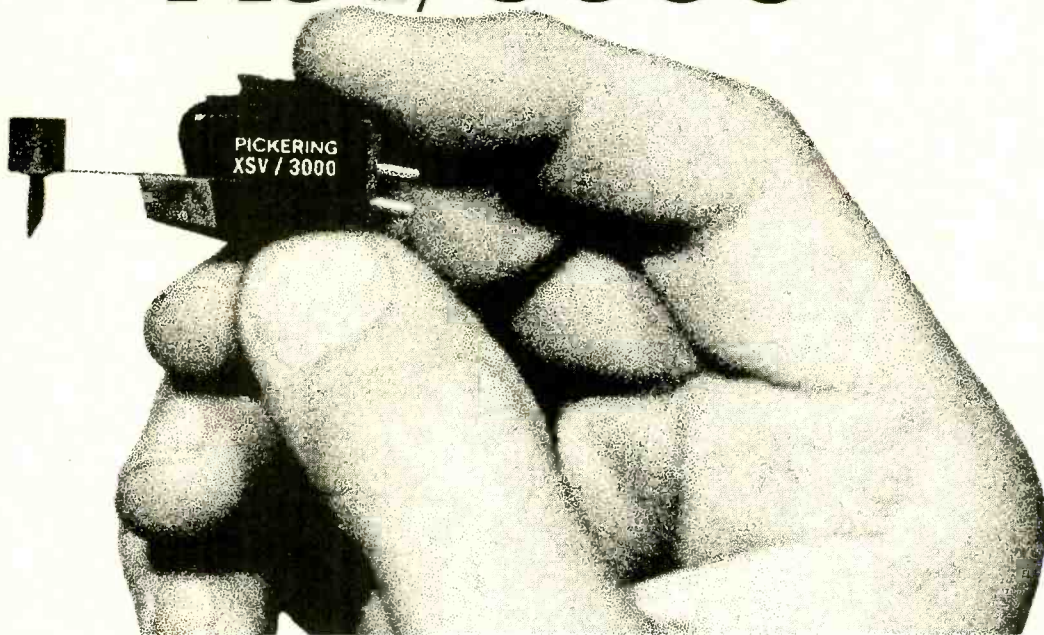
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