Electronics World

FEBRUARY, 1967
60 CENTS

INTEGRATED CIRCUITS AND THE AUTOMOBILE
ELECTRONIC IGNITION SYSTEMS
RADAR SIGNATURE ANALYSIS
THE NEW TETRODE TRANSISTOR

ELECTRONIC MUSICAL INSTRUMENTS

A ZIFF-DAVIS PUBLICATION

Beginning Next Month, There Will Be One Stereo Receiver Obviously Superior To All Others.

It Will Have These Features . . .

ACTUAL SIZE

World's Most Advanced Stereo Receiver . . .
New Heathkit® Solid-State AR-15 . . . 150 Watts . . . AM-FM-STEREO . . . $299^95*

Please send Free details on AR-15 stereo receiver.
☐ Check here, if you don't have new 1967 Heathkit catalog.
☐ Please reserve my AR-15 for March delivery.

Name____________________

Address____________________

City__________ State__________ Zip______

HF-199

HEATH COMPANY Dept. 15-2
Benton Harbor, Michigan 49022

PLACE 5c STAMP HERE

The World's Most Unique Solid State Stereo Receiver, the new Heathkit AR-15 . . . crowning achievement of the world's most experienced solid state audio engineers! There's nothing else like it anywhere. Start with its power output. An incomparable 75 watts of music power per channel . . . an astounding 150 watts that deliver the cleanest, most natural sound you've ever heard.

And for the first time in any stereo/high fidelity component . . . two dramatic space-age innovations. First, the use of two integrated circuits in the IF amplifier to provide high gain for hard limiting, rock-steady temperature stability and maximum reliability. Second, two crystal filters replace the IF transformers . . . no IF coils to align! Add all-silicon transistor circuitry plus FET's in the FM front-end, plus short-circuit protection, and you have today's most advanced stereo receiver.

Additional Advanced Features . . . besides those already illustrated. STEREO THRESHOLD CONTROL for automatic switching to stereo *and* automatic switching to MONO when signal/noise ratio becomes too low for good stereo reception . . . AUTOMATIC FM SQUELCH CIRCUIT to eliminate annoying between-station noise when tuning . . . COMPLETE AM as well as FM-FM STEREO listening . . . ADJUSTABLE PHASE CONTROL so *you* can dial the best stereo obtainable . . . STEREO ONLY SWITCH for stereo station reception only (silences mono broadcasts) . . . WIDE RANGE MAGNETIC PHONO INPUTS with extra overload characteristics (2-155 mv dynamic range) . . . FM STEREO NOISE FILTER eliminates noise *without* diminishing high frequency response . . . TWO STEREO HEADPHONE JACKS on the front panel for private listening . . . BUILT-IN TEST CIRCUIT VOM — the signal strength indicator doubles as a VOM for check-out during kit construction . . . DIRECT COUPLED OUTPUT CIRCUIT for improved high frequency response—no output transformers . . . CAPACITOR COUPLING to speaker terminals for speaker protection.

You can install the AR-15 just about any way . . . horizontally or vertically in a wall, your own custom cabinet, or in the optional factory assembled Heathkit walnut cabinet. For full details on the AR-15, plus our liberal credit terms, mail the post card (opposite). The Heathkit AR-15 will be available beginning in March.

***Kit AR-15,** 28 lbs., less cabinet **$299.95**
Assembled AE-16, 7 lbs., optional walnut cabinet **$19.95**

SPECIFICATIONS

AMPLIFIER: Dynamic Power Output Per Channel (Music Power Rating): 8 ohm load; 75 watts. **Continuous Power Output, Per Channel*:** 8 ohm load; 50 watts. **Power Bandwidth For Constant 0.5% Total Harmonic Distortion*:** 5 Hz to 25 kHz. **Frequency Response (1 watt level):** ±1 db, 5 to 50,000 Hz. ± 3db, 2 to 80,000 Hz. **Harmonic Distortion:** Less than 0.5% from 20 to 20,000 Hz at 50 watts output. Less than 0.2% at 1,000 Hz with 50 watts output. Less than 0.2% at 1,000 Hz with 1 watt output. **Intermodulation Distortion (60 Hz: 6,000 Hz=4:1):** Less than 0.5% with 50 watts output. Less than 0.2% with 1 watt output. **Damping Factor:** 45. **Input Sensitivity:** PHONO; 2.2 millivolts (overload 155 mv). TAPE; 200 millivolts (overload 2.8v). AUX; 200 millivolts overload 2.8v). **Hum & Noise:** Volume control at minimum position; —80 db. PHONO; (10 millivolt reference); —60 db. TAPE & AUX. (200 millivolt reference); —62 db. **Channel Separation:** PHONO; 45 db. TAPE & AUX.; 60 db. **Output Impedance (each channel):** 4, 8 & 16 ohms. **Tape Output Impedance:** 100 ohms. **Input Impedance:** PHONO; 47 K ohm** (RIAA equalized). AUX., TAP & TAPE MON.; 100 K ohm. **Tape Output:** 0.7 volt. **FM SECTION (Monophonic): Tuning Range:** 88 to 108 MHz. **Intermediate Frequency:** 10.7 MHz. **Frequency Response:** ±1 db, 20 to 15,000 Hz. **Antenna:** Balanced input for external 300 ohm antenna, unbalanced, 75 ohm. **Volume Sensitivity:** 0.7 uv*. **Selectivity:** 70 db*. **Image Rejection:** 90 db*. **IF Rejection:** 90 db minimum*. **Capture Ratio:** 2.5 db*. **AM Suppression:** 50 db*. **Harmonic Distortion:** 0.5% or less*. **Intermodulation Distortion:** 0.5% or less*. **Hum & Noise:** 70 db*. **Sensitivity:** 1.8 uv*. **Spurious Rejection:** 100 db*. **FM SECTION (Stereophonic): Channel Separation:** 40 db or greater. **Frequency Response:** ±1 db. 20 to 15,000 Hz. **Harmonic Distortion:** Less than 1% at 1,000 Hz with 100% modulation. **19 & 38 kHz Suppression:** 45 db or greater. **SCA Suppression:** 35 db. **AM SECTION:** Tuning Range: 535 to 1620 kHz. **Intermediate Frequency:** 455 kHz. **Sensitivity:** 7 microvolts at 1,000 kHz. **AM Antenna:** Built-in rod type, connections for external antenna. **Image Rejection:** 55 db at 600 kHz. 45 db at 1400 kHz. **IF Rejection:** 55 db at 1,000 kHz. **Harmonic Distortion:** Less than 1.5% at 400 Hz, 90% modulation. **Hum & Noise:** 50 db. **GENERAL Transistor & Diode Complement:** 66 transistors, 28 diodes & 2 integrated circuits. **Front Panel Controls & Switches:** AM & FM Tuning; 535 to 1620 Hz and 88 to 108 MHz. SOURCE Switch; PHONO, AM, FM, TAPE & AUX. Dual Tandem VOLUME Control; Dual Tandem BASS Control; provides 16 db boost and 20 db cut at 20 Hz. Dual Tandem TREBLE Control; provides 17 db boost and 15 db cut at 20 kHz. The Bass and Treble controls can be disabled for FLAT frequency response. BALANCE Control. SPEAKERS Switch. POWER Switch. MODE Switch. TAPE MON. Switch. FM Switch. NOISE FILTER Switch. LOUDNESS Switch. PHASE Control. SQUELCH Control. STEREO THRESH (Threshold) Control. L & R AUX. Controls. AM-FM Level Controls. PHONO Level Controls. TAPE Level Controls. TAPE MONitor Level Controls. SEP ADJ (Separation Adjust) Control. 19 kHz Test-Adjust Switch. SIGNAL Meter V, R, Normal Switch. **AC Outlet Sockets:** Accessory outlets, rear chassis apron, one switched (225 watts maximum), and two unswitched (350 watts maximum). **Power Requirements:** 105-125 or 210-250 volt 50/60 Hz AC. **Dimensions:** Overall, 16⅞" wide x 4¾" high x 14½" deep. **Mounting Position:** Horizontal or vertical.

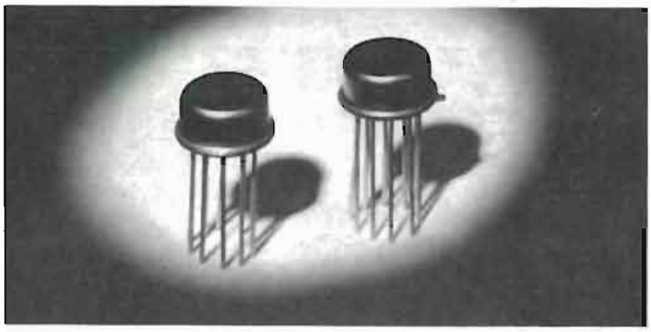
*Rated IHF (Institute of High Fidelity) Standards.
**RIAA (Record Industry Association of America).
Prices and specifications subject to change without notice.

"Black Magic" Panel Lighting

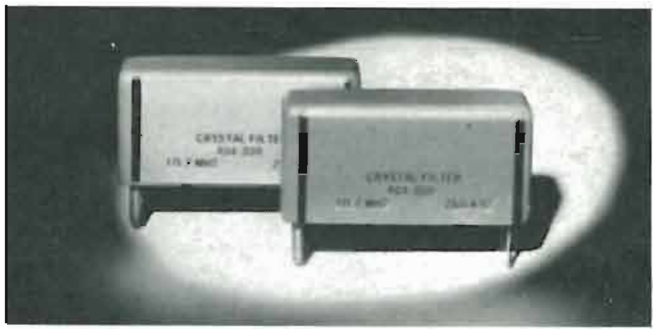
Even when not in use, the new Heathkit AR-15 remains quiet and well-mannered . . . its majestic midnight face unmarred by any dial or scale markings. And when you're ready for the finest in stereo listening, a simple touch of the power switch and presto! . . . the "black magic" panel lights up with an extended 8½" slide-rule dial for easy tuning (calibration accuracy 0.1%), and immediate identification of all controls. The "black magic" is in the unique tinted acrylic "dual-panel" design.

Beginning Next Month, There Will Be One Stereo Receiver Obviously Superior To All Others.

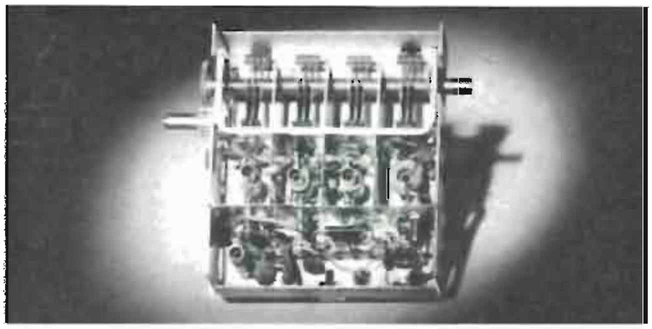
It Will Have These Features . . .



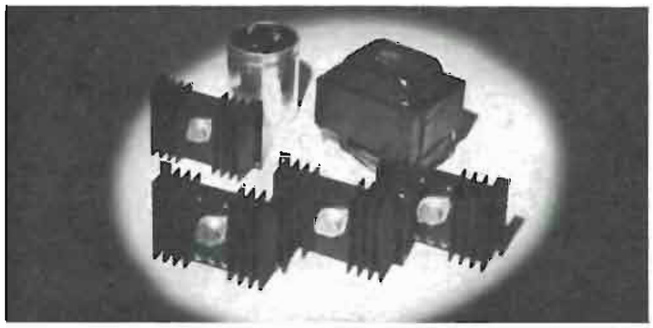
INTEGRATED CIRCUITS . . . tomorrow's electronic miracle today . . . first time ever in a stereo-hi-fi component. Two are used in the IF amplifier section for hard limiting, excellent temperature stability and increased reliability. Each integrated circuit is the size of a tiny transistor, yet each contains 28 actual parts . . . 10 transistors, 11 resistors and 7 diodes!



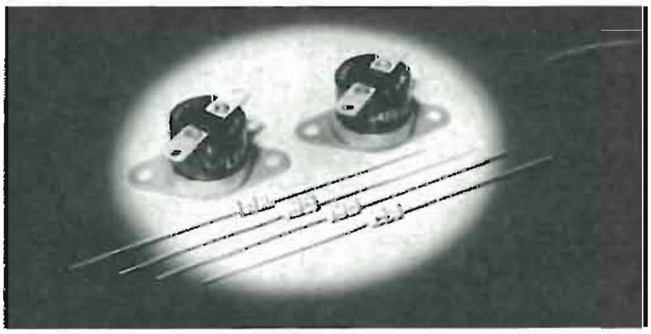
CRYSTAL FILTERS . . . another exclusive. Two are used in the IF amplifier section to replace the usual transformers. No coils, therefore no alignment or adjustment is ever required. Precise controlled bandwidth produces the finest fidelity with adjacent channel selectivity of 70 db.



FIELD EFFECT TRANSISTOR FM TUNER . . . cascode 2-stage FET RF amplifiers and an FET mixer provide high overload capability, excellent cross modulation index and image rejection. The completely shielded tuner has a 4-gang variable capacitor and 6 tuned circuits for extreme selectivity under the most adverse conditions.

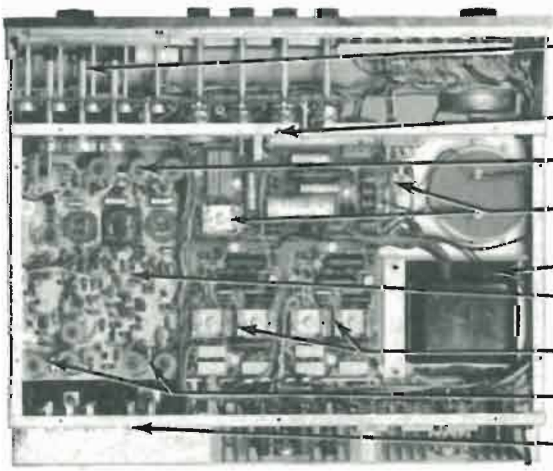


150 WATTS DYNAMIC MUSIC POWER . . . the highest power output of any stereo receiver! Made possible by 4 conservatively rated, individually heat-sinked and protected output transistors powered by an unusually large power transformer and filter capacitor. 75 watts music power per channel — 50 watts continuous power per channel.



POSITIVE CIRCUIT PROTECTION . . . four Zener diodes and two thermal circuit breakers protect the driver and output transistors from overloads and short circuits of any duration. A special front-panel Hi-Temp indicator shows when the thermal breakers have opened.

TWO CALIBRATED TUNING METERS . . . another exclusive! A signal strength indicator tells you when you receive the strongest signal . . . a special "Center-Tune" meter puts you on exact station frequency. Both meters use d'Arsonval movements.



All-Silicon Transistor Circuitry . . . for maximum reliability, superior stability.

- **Front Panel Input Level Controls** . . . up front for convenient adjusting — protected from accidental setting changes by an attractive hinged door.
- **Tone-Flat Switch** . . . bypasses tone control circuitry for completely flat response.
- **Super SCA Filter** . . . removes SCA and noise frequencies above 57 kHz for clean, quiet listening.
- **Electronic Filter Circuit** . . . provides power supply with exceptionally low ripple and excellent regulation.
- **Massive Power Supply** . . . for low heat and superior regulation — electrostatic and magnetic shielding for lowest hum and noise.
- **Noise-Operated Squelch** . . . a step ahead of the normal circuitry to hush between-station noise *before* you hear it.
- **Transformerless Design** . . . direct coupling between driver and output stages for lowest phase shift and distortion.
- **Filtered Left & Right Channels** . . . for direct "beat-free" stereo recording . . . a low cost way to build your own music library.
- **Recessed Inputs & Outputs** . . . no protruding array of leads to waste valuable space — fits flush against any wall or surface.

*RCA's new Hi-Lite Color Tube with Perma-Chrome

If you've been waiting half an hour for the picture tube to warm up every time you repair or install a set, here's good news. RCA's new rectangular Hi-Lite Color Tubes with Perma-Chrome lock colors in place instantly, eliminate distorted color as the set warms up. Colors are true and unchanging from turn-on to turn-off. Saves hours of set-up time. New Hi-Lite Color Tubes with Perma-Chrome now in RCA Victor consoles. **New service switch in all 1967 color chassis.** Three-position for Normal, Service and Raster. When Raster is selected, all video and noise is removed from the color picture tube, leaving a noise-free Raster. Purity is adjustable without removing an IF tube or using other means to remove noise and/or interference from the screen.

RCA The Most Trusted Name in Electronics

THIS MONTH'S COVER ties in with our theme this month, which is electronic musical instruments. The instrument at the left is Selmer's electronic saxophone. By using the associated Electro-Voice electronics, it is possible to alter the tone color, introduce echo and tremolo, and extend the range of the sax by one full octave below its fundamental tone. The cherry-colored guitar in the center is the new Heath-Harmony electronic guitar, one of a line of three available from the company in kit form. The white instrument at the right is the Vox (Div. of Thomas Organ Co.) electronic guitar. In addition to the usual special effects produced by such guitars, this instrument can be made to sound like an electronic organ. Detailed stories on electronics in music can be found in this month's issue. ....(Cover photograph: Louis Mervar)

Electronics World

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CONTENTS

MONTHLY FEATURES

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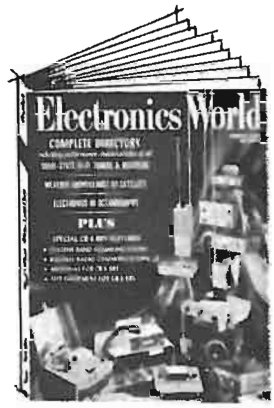
COMING NEXT MONTH



SPECIAL FEATURE ARTICLES ON:

CB & Business Radio Service

Selecting a CB Transceiver—What features do you really need in a transceiver for mobile? for base-station use? What effect will the growing number of licensees and the sunspot cycle have on your need for more sophisticated circuitry? Before you buy, read Len Buckwalter's thoughtful analysis of the "pro's" and "con's" of various features.

Business Radio Communications—The advantages and disadvantages of each of the four bands available in this relatively new area of communications are discussed with an eye to making the right decision for the job at hand. Equipment suitable for BRS is discussed and illustrated to help the prospective user make a wise choice.

Test Equipment for CB and Business Radio—There is a good selection of generalized and special-purpose test equipment for both the professional technician and the user. Various types of equipment for servicing and maintaining CB and BRS gear are covered.

Antennas for CB & Business Radio—A round-up of various antennas available for use in these two services, including comparative characteristics and electrical performance data. A number of commercial models are pictured and described.

ELECTRONICS IN OCEANOGRAPHY

Both mechanical and electronic instruments are now playing a part in measuring temperature, pressure, conductivity, velocity, time and wave motions of the sea. John Althouse describes some of these ingenious devices.

DIGITAL PLOTTING TECHNIQUES

Curves, charts, maps, drawings, and other displays can be generated as analog plots of digital data from computers. Louis E. Frenzel, Jr. discusses how such plotters are being used in weather forecasting, for geophysical and oil surveys, to display business financial data, in roadbuilding, and in automatic drafting applications.

WEATHER SURVEILLANCE BY SATELLITE

Tiros, Nimbus, and successor ESSA satellites are providing global weather information that may one day lead to global weather control.

All these and many more interesting and informative articles will be yours in the March issue of ELECTRONICS WORLD . . . on sale ***February 21st.***

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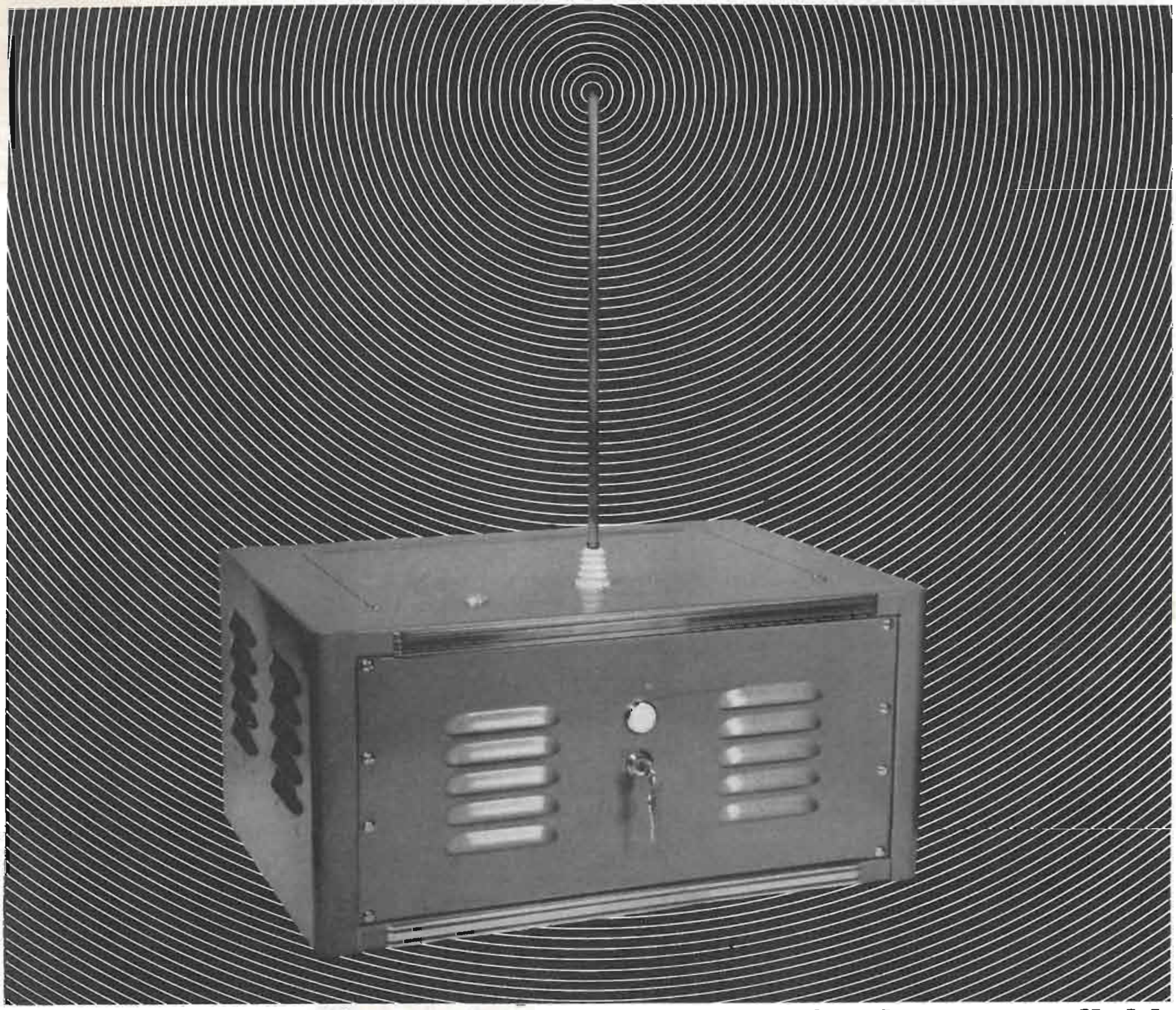


You are now in Radar Sentry Alarm's r.f. microwave field. Don't move a muscle!

This security system is so sensitive, it can be adjusted to detect the motion of your arm turning this page.

And if this Portable Model Unit were within 35 feet of you and you moved... people up to a half-mile away could hear the siren. Plus with optional equipment, it can detect fire... turn on lights... even notify police.

What does a burglar alarm have to do with you?

Just this: Radar Sentry is no ordinary alarm. It is the most modern and effective security system available. And it's also electronic.

That's why we need you. We need Dealers with technical knowledge. For the most successful Dealers for Radar Sentry Alarm are men who know electronics. This is a product that sells itself when demonstrated properly.

It's been proven time after time. In fact, many of the more than one thousand readers of electronics magazines who became Dealers in the past year—sold a system on their *first* demonstration.

And that's why we need men with technical knowledge and experience.

Men like *you*.

How about it?

Do you want to start a business of your own... or expand your present business with a product that in 8 years has become the world-wide leader in its field?

Do you want to earn up to $5,000 a year in your spare time?

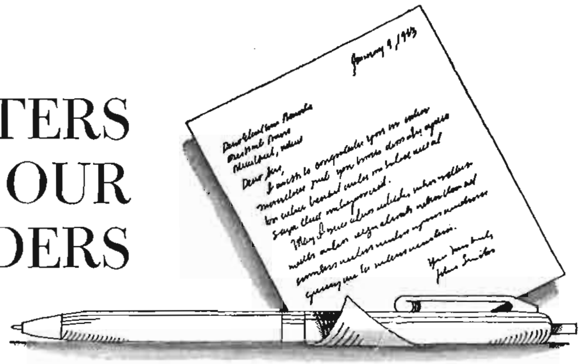
Do you want to earn $20,000 and more full time? We'll show you how.

O.K., now you can move.

Fill out the coupon and get complete Dealer/Distributor information... free.

CIRCLE NO. 96 ON READE

LETTERS FROM OUR READERS



TOOTHBRUSH BATTERIES

To the Editors:

I have run across an unusual (to me, at least) problem with a sealed battery. I assume it is nickel-cadmium; it is used in an electric toothbrush. I dug clear back to your October 1963 issue with its special article on batteries but found nothing mentioning this type of trouble. Have I got a freak toothbrush?

When not in use, the unit sits in its recharging wall-mounted cabinet and is of course fully charged at all times. However, I found that it was losing power: the motor would stall if I pressed too hard on my teeth. Then I went on vacation and took only the toothbrush, not the charger, with me. In my suitcase, the switch got flipped on and the toothbrush ran itself down. I had to spend my whole vacation brushing manually. What a bore!

After returning home, I returned the toothbrush to the charger and the next day it had renewed vigor—just like the day it was new. There was no loss of power and no stalling. Several months later I began to get the power loss again, so one day I left the toothbrush on to run down and then recharged it. Now I find that every two or three months, when I notice power loss, I can run it through a discharge-recharge cycle and it operates perfectly.

My theory is as follows. The time in use is minimal compared to the charging time. We can consider that the battery is on continuous charge. Under these conditions, might not some polarization take place resulting in gas formation and reduced power?

I've also learned to put a piece of Scotch tape over the switch to keep it "off" when I pack the toothbrush in a suitcase!

Bill White
Princeton, Fla.

ny other theories about ns?—Editors

* * *

CY MEASUREMENT

:

on "Frequency and Fre- rement" in the October esting but seemed to me te. The editorial subtitle er to expect a survey of the present art in the field rather than a discussion of highly accurate means of determining high frequencies.

Can we expect a fill-in on the lower frequencies?

My interest stems from my recently having obtained a patent (3,267,448) on a device for extending a burst of as few as two pulses into a sustained series. (At present, practical considerations would appear to limit the device to the lower audio frequencies.)

In situations in which parameters to be monitored can be translated into characteristic frequencies by such means as *RC* circuits, a large number of brief samplings can be transmitted to a remote point on a single channel, each sampling then being fed into a pulse series extender for subsequent readout by means of a frequency meter.

At the time of the invention's original conception, the measuring device of choice was the vibrating-reed frequency meter. It would be of great value to me to learn of other devices that may be used in this range and to have a comparison of such characteristics as temperature effects and positive rejection of harmonics found in the readout.

Thank you for the increasingly broadened scope of coverage in your publication and the technical caliber of the articles.

Roland Gunther
100 Joanne St.
Princeton Junction, N.J.

* * *

HOW PERMANENT ARE MAGNETS?

To the Editors:

With the widespread use of permanent magnets in loudspeakers, meters, and other devices, I wonder just how long these components retain their usefulness. For example, will my v.o.m. lose its sensitivity due to loss of magnetism after being around for, say, 10 or 15 years?

Thomas F. McDonnell
Chicago, Ill.

According to Portus M. Wheeler, President of Crucible Magnet Division *of* Crucible Steel Co., *a permanent magnet "loses about 1% of its magnetism as soon as it's energized. It*

(Continued on page 12)

This *Remington* PREMIER PORTABLE TYPEWRITER

FREE

WHEN YOU BUY THIS RCA WR-64B COLOR BAR/DOT/CROSSHATCH GENERATOR...THE ESSENTIAL COLOR TV TEST INSTRUMENT

Here's a deal you can't afford to miss! A FREE Remington portable typewriter—yours when you purchase the most essential color-TV test instrument—the RCA WR-64B!

Just imagine how handy your new typewriter will be—in the shop or at home. You'll use it almost as much as you use the RCA WR-64B—standard of the color TV servicing industry.

Here's how to get your FREE Remington Typewriter. Mail in the warranty card plus the gold label from the shipping carton of your new RCA color bar generator to RCA Test Equipment Headquarters, Bldg. 17-2, Harrison, N. J. We will ship your new Remington portable typewriter to you direct, freight prepaid. But remember—this offer covers only equipment purchased between February 1, 1967 and May 15th, 1967. To allow for postal delay, we will honor cards postmarked up to May 31st.

Plan NOW to take advantage of this BIG offer—a FREE Remington portable typewriter with your purchase of an RCA WR-64B color bar/dot/crosshatch generator.

The standard of the Color-TV Servicing Industry. Generates all necessary test patterns—color bars, crosshatch, dots plus sound-carrier. *Only* **$189.50***

*Optional Distributor resale price. All prices subject to change without notice. Price may be slightly higher in Alaska, Hawaii, and the West.

Ask to see it at Your Authorized RCA Test Equipment Distributor

RCA Electronic Components and Devices, Harrison, N.J.

RCA® **The Most Trusted Name in Electronics**

CIRCLE NO. 97 ON READER SERVICE CARD

1 Start Fast with NRI's New Remarkable Achievement Kit

The day you enroll with NRI this new starter kit is on its way to you. Everything you need to make a significant start in the Electronics field of your choice is delivered to your door. It's an outstanding way of introducing you to NRI training methods . . . an unparalleled "first dimension" that opens the way to new discoveries, new knowledge, new opportunity. The Achievement Kit is worth many times the small payment required to start your training. No other school has anything like it. Find out more about the NRI Achievement Kit. Mail the postage-free card today.

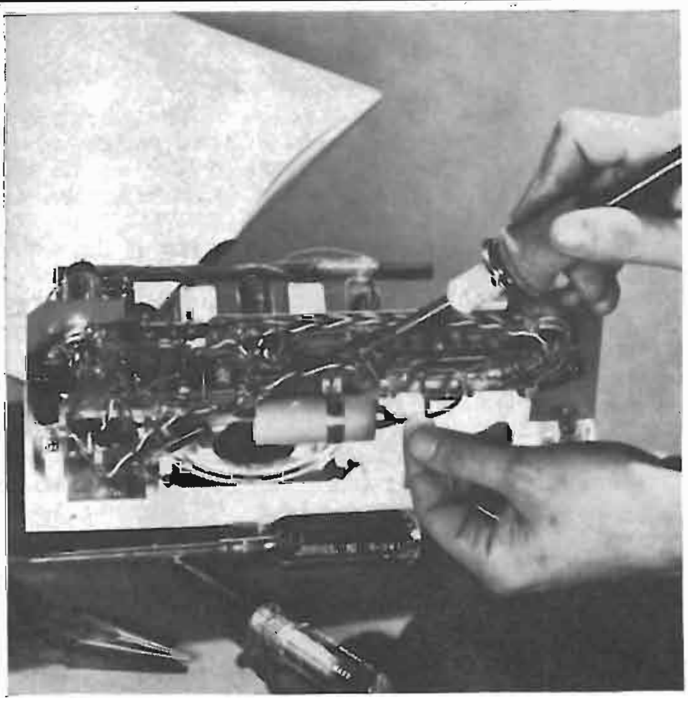
2 NRI "Bite-Size" Lesson Texts Program Your Training

Certainly, lesson texts are a necessary part of any training program . . . but only a part. NRI's "bite-size" texts are simple, direct, well illustrated, and carefully programmed to relate things you read about to training equipment you build. Here is the "second dimension" in NRI's training method. Here are the fundamental laws of electronics, the theory, the training of your choice, presented in a manner you'll appreciate. And in addition to lesson texts, NRI courses include valuable Reference Texts related to the subjects you study, the field of most interest to you.

3 Custom-Designed Training Kits Make Learning Come Alive

Electronics becomes a clear and understandable force under *your* control as you build, experiment, explore, discover. Here is the "third dimension" . . . the practical demonstration of things you read about in NRI texts. NRI pioneered and perfected the use of training kits to aid in learning at home. NRI invites comparison with equipment offered by any other school, at any price. Prove to yourself what 750,000 NRI students could tell you . . . that you get more for your money from NRI than from any other home-study Radio-TV, Electronics school. Mail postage free card for your NRI catalog. (No salesman will call.)

AVAILABLE UNDER NEW GI BILL — If you served since January 31, 1955, or are in service, check GI line in postage-free card.



(Continued from page 6)

loses another 0.2% during the next 12 months for a total loss of approximately 1.2% during the first year. It then loses only another 1% during the next 100,000 years. That's why they are called permanent magnets."—Editors

* * *

SPECIAL SECTION REPRINTS

To the Editors:

I wish to express my thanks for having had the opportunity of placing a manuscript in ELECTRONICS WORLD.

The editorial staff is to be congratulated on the presentation of all material in the special section dealing with chokes and coils (October, 1966 issue)—in particular, the handling of special photos and artwork.

I wonder if you have reprints available on this special section and on some of the other special sections you have run in the past.

W. R. COURTNEY
Chief Engineer
J. W. Miller Co.
Los Angeles, Calif.

Thanks to Author Courtney for his kind words. Yes, we do have reprints available of some of the special sections we have run in the past, including the ones on "Batteries," "Fixed Capacitors," "Variable Resistors," "Solid-State Diodes," and "Chokes and Coils." These are available at 25¢ each directly from our editorial offices at One Park Avenue, New York, N.Y. 10016.—Editors

* * *

DIODE METER PROTECTION

To the Editors:

The article on "Diode Meter Protectors" in your November, 1966 issue was very informative, but it contains a piece of misinformation or incomplete information regarding fusing.

In Fig. 3B, the fuse in position *A* will cause a gross measurement error with any of the shunt resistors shown because of its resistance. Also, the fuse resistance is probably not precisely controlled so that it would be impractical to compensate for its effect in the circuit.

In the circuit of Fig. 3C, the fuse has much less possibility of causing measurement error because of the higher circuit resistance as compared with the fuse resistance; however, the effect of the fuse resistance should be given consideration in design of this circuit.

JOSEPH RISSER
Reliability Engineering
Consolidated Electrodynamics Corp.
Pasadena, Calif.

Judging from the amount of reader mail we have been receiving commenting on this particular article, there seems to be a lot of interest in the simple protective circuits and devices that were covered in the story.—Editors ▲

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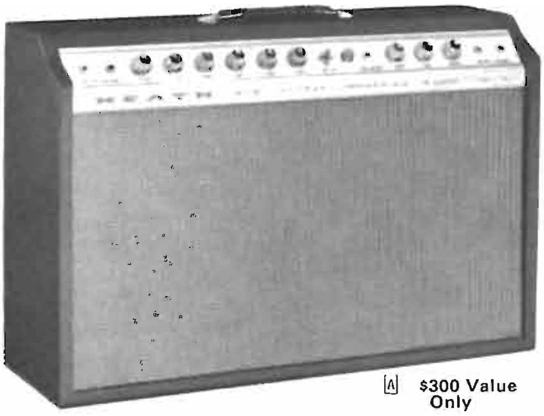

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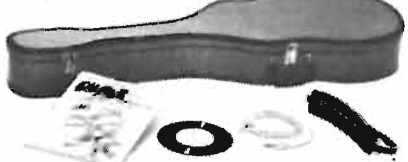

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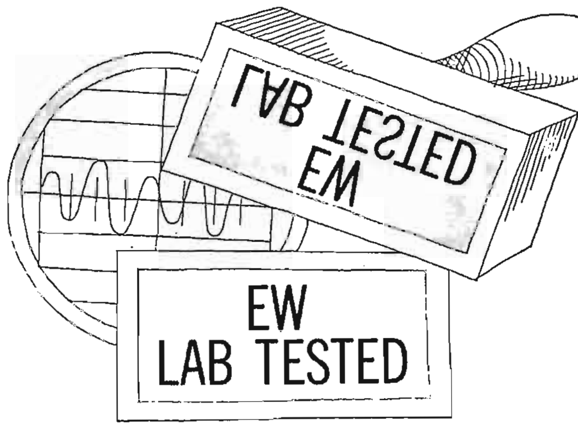


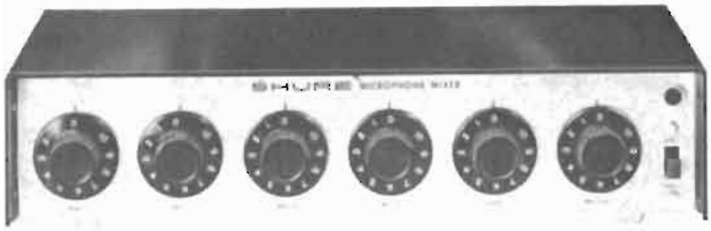
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Shure Model M-68 Microphone Mixer
Ampex Model 1115 Speaker System
Sonotone "Velocitone Mark V" Cartridge

Shure Model M-68 Microphone Mixer

For copy of manufacturer's brochure, circle No. 24 on Reader Service Card.



THE new *Shure* M-68 microphone mixer is a versatile, moderately priced unit which bridges the gap between the low-priced, relatively inflexible passive mixers and the costly, professional recording and broadcast models.

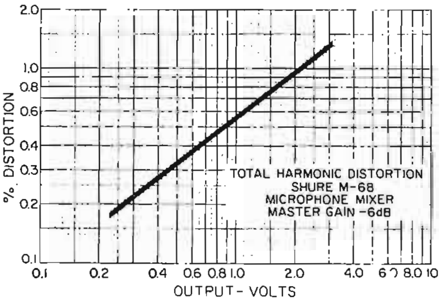
The mixer accommodates up to four microphones, plus a high-level auxiliary input. Each input has its own volume control, and a master volume control regulates the over-all output. There is no interaction between the input controls. The microphone inputs are through *Cannon* XLR-3-14 connectors in the rear of the mixer. A standard phono jack is used for the high-level "Aux" input. Three output levels are provided: a low-impedance (50 to 250 ohms) and a high-impedance (33,000 ohms) through an XLR-3-14 connector, and a high-level, high-impedance output through a standard phono jack. There is also an accessory 28-volt d.c. power jack, which may be used to power the M-68 from a battery supply or to provide power to the Model A68P phono-cartridge preamplifier. This accessory converts the auxiliary input into an equalized magnetic or ceramic phono cartridge input.

Each microphone input and the microphone output have an adjacent switch which converts them from low impedance (50 to 250 ohms) to high impedance (greater than 20,000 ohms). The voltage gain in the high-impedance setting is one-tenth of that in the low-impedance setting. The auxiliary input has a nominal 50,000-ohm impedance rating.

The maximum output level before clipping occurs is rated at 60 millivolts for low-impedance microphones, 0.85 volt for high-impedance microphones, and 4.0 volts for the high-impedance "Aux" input. The rated frequency response is ±2 dB from 30 Hz to 20,000 Hz.

Our measurements on this mic mixer confirmed the manufacturer's ratings in all respects. On the low-impedance inputs, the frequency response was down 3 dB at 30 Hz and down 1 dB at 20,000 Hz, or within ±1.5 dB from 30 to 20,000 Hz. On the high-impedance input, the response was ±0.5 dB from 20 to 20,000 Hz. The distortion at 2-volts output was 1%, with 20-millivolts input and the master gain set to —6 dB. At lower outputs, the distortion fell to a small fraction of a percent. At maximum gain settings, the hum and noise were from 50 to 56 dB below one-volt output on the several microphone inputs, and —68 dB on "Aux." At minimum gain the noise was —68 dB. At maximum gain, 10 millivolts to the high-impedance microphone inputs produced approximately one-volt output.

The flexibility of the mixer is enhanced by the available accessories. In addition to the A68P phono equalizer, there is a carrying case, battery power supply, a locking panel to prevent tampering with control settings, a cable adapter kit for matching the mixer to practically any p.a. system, a stacking kit to permit several mixers to be used together, and a rack-panel kit for permanent installation.



The list price of the *Shure* M-68 mixer alone is $125.00. ▲

Ampex Model 1115 Speaker System

For copy of manufacturer's brochure, circle No. 25 on Reader Service Card.

LIKE many other tape-recorder manufacturers, *Ampex* has several models with built-in playback power amplifiers and small monitor speakers. Recognizing that such speakers can never do justice to the quality of the tape recorder, the company now produces external speaker systems in several price ranges. Not only do these make a tape recorder a complete playback system, but they can also be used with other units such as receivers and amplifiers.

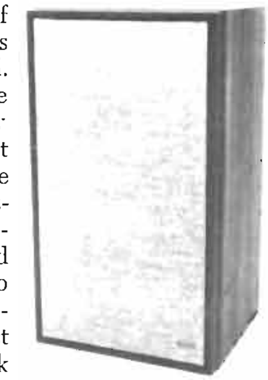
One intermediate-priced model of the manufacturer's speaker line is the Model 1115. This is a compact bookshelf unit, measuring 23¾" x 11⅜" x 13½" and attractively finished in oiled walnut. It is a three-way system, with a 10" high-compliance woofer, two 3" cone speakers for the middle frequencies from 2000 to 10,000 Hz, and a small super-tweeter taking over above 10,000 Hz. A continuously variable level control on the rear of the cabinet sets the level of the mid- and high-frequency speakers relative to that of the woofer. The nominal impedance of the Model 1115 is 8 to 16 ohms.

We measured the frequency response of the speaker at eight points in the test room, at a distance of three to twelve feet from the speaker, and at various angles to its axis. The averaged response curve, corrected for the known

low-frequency characteristics of the room, was quite smooth and free from holes or peaks over most of the audio range. The peaks at 40 and 60 Hz are due to room resonances and are not chargeable to the speaker. Above 1000 Hz, the response curve had a "shelved" characteristic, 3 to 5 dB below the mid-range level, with the tweeter level control set at maximum.

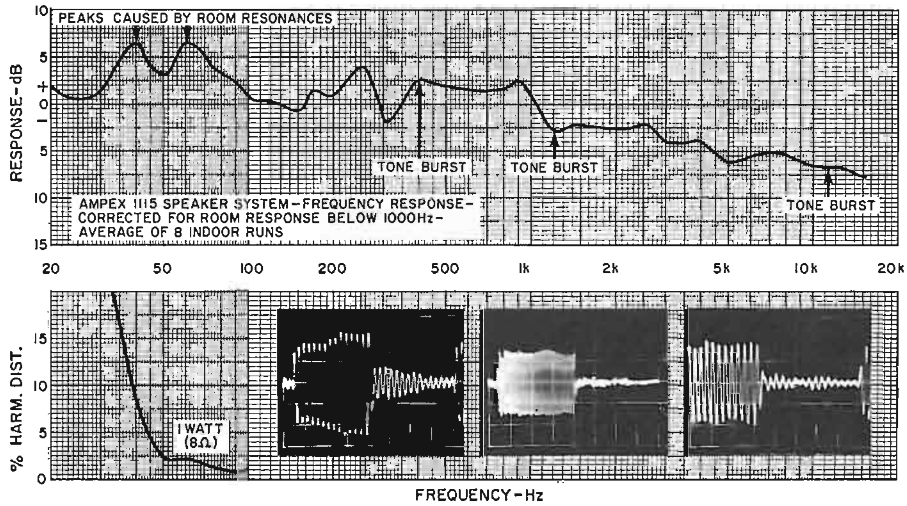
At most frequencies, the tone-burst response of the speaker system was good to excellent. The photos taken at 400 Hz, 1.2 kHz, and 11 kHz are typical. At about 7.3 kHz, there was evidence of transient distortion, although we did not observe any response-curve discontinuity at this point. This effect, occurring very sharply at one frequency, could not be heard.

Harmonic distortion at one-watt drive level was low down to about 50 Hz, rising sharply at lower frequencies. We would estimate that the effective lower limit of the speaker's response is about 40 to 45 Hz, a quite respectable figure for a 10″ woofer.



The sound of the speaker is rather subdued. Even with the high-frequency level control at maximum, there is never any "sizzle" or stridency. We found it desirable to use some high-frequency boost on the playback amplifier. In very live or bright listening rooms, the system should sound nicely balanced, where many other speakers would be overpoweringly bright. On the other hand, in a "dead" room, amplifier treble boost would probably be required. The unit has none of the mid-range peakiness which adds "presence" to some speakers and is always a clean and easy-to-live-with speaker.

The *Ampex* 1115 is priced at $199.90 for a pair. ▲



Sonotone "Velocitone Mark V" Cartridge

For copy of manufacturer's brochure, circle No. 26 on Reader Service Card.

A NUMBER of years ago, ceramic phono cartridges were considered inferior to magnetic types and certainly not of a quality suitable for use in good component high-fidelity systems. Largely through the efforts of *Sonotone,* a pioneer in ceramic cartridge development, these low-cost rugged cartridges have been proven capable of excellent quality, and they frequently outperform more costly magnetic types.

The *Sonotone* series 8T and 9T cartridges have evolved into the new 100T series, known as the "Velocitone Mark V." Both performance and cost have risen to the point where the 100T cartridges are priced with some of the best magnetics and can rival or even surpass many of them in quality.

The 100T stereo cartridge is available with a choice of three diamond styli, identical except for tip radius. The available tips are the 0.7 mil, 0.5 mil, and an 0.8 × 0.3 mil elliptical. All have a rated compliance of 15×10^{-6} cm/dyne, a 15° vertical tracking angle, and a rated tracking force of 1.5 to 2.5 grams. Since a ceramic cartridge is inherently amplitude-responding, a pair of plug-in equalizer networks is supplied with each cartridge to convert the

(*Continued on page* 66)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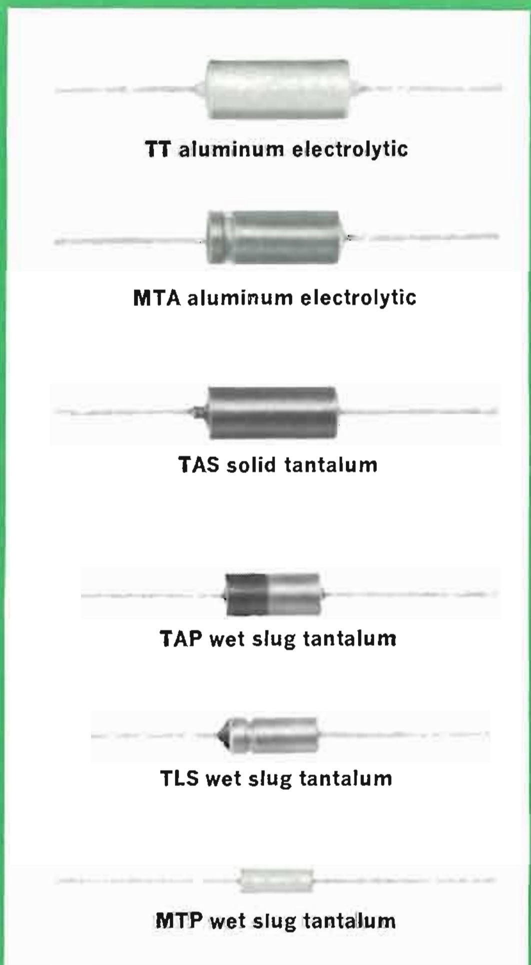
MALLORY **Tips for Technicians**

Which miniature electrolytics for transistorized AM-FM radios?

COMPARATIVE SIZES OF CAPACITORS ALL RATED 10 MFD., @ 25 WVDC
(shown actual size)



The new portable AM-FM radios are so compact you wonder how they get all those components into that little box. You wonder even more when you have to replace some of the parts.

Electrolytic capacitors, for example. The original electrolytic usually turns out to be a tiny thing jammed in among a dozen other midget gidgets. Getting it out is a trick in itself. Getting a suitable replacement is even tougher! And unfortunately, you're apt to need replacements, because many of these tiny capacitors just aren't much good. They don't meet the quality specs of good domestic capacitor makers. But high quality domestic capacitors are often just a bit too big to fit in the space available.

What's the answer? Search the town for another "little-bitty" original capacitor? Tell your customer you can't finish the job?

Don't give up. We have a few suggestions.

First, try a Mallory TT aluminum electrolytic. This is a real quality capacitor, rated 85°C, and it's pretty doggone small. Or a Mallory MTA, a revolutionary molded case aluminum electrolytic with excellent quality at low-low price.

If neither of these will fit, try a Mallory tantalum capacitor. The TAS solid tantalum is about the same size as the TT, but it's rated 125°C. Need still smaller size? Take a look at the Mallory "wet slug" tantalum types TAP and TLS—and the super-miniature MTP, which gives you the most microfarads in the smallest size of anything on the market. The pictures at the left show you comparative sizes, all for a 10 mfd, 25 WVDC rating.

Sure, you'll pay a little more for the tantalum capacitor. But not as much as you might think. The TAP only costs 42c more than the TT, in the rating shown. And you get the utmost in reliability.

We certainly don't expect you to use a tantalum capacitor to replace every aluminum electrolytic. But they come in mighty handy sometimes. And you can get them when you need them from your Mallory Distributor. Ask him for our latest catalog, or write to Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Indianapolis, Indiana 46206.

DON'T FORGET TO ASK 'EM—*"What else needs fixing?"*

CIRCLE NO. 105 ON READER SERVICE CARD

Typical of the radars used for signature analysis is this advanced projects terminal measurements radar built by Raytheon for the White Sands Missile Range in New Mexico.

Radar Signature Analysis

By EDWARD A. LACY

Every satellite and missile produces a distinctive pattern of radar echoes. These can be employed to deduce satellite size, shape, as well as motion.

WHEN our satellite-tracking radars detect a new foreign space vehicle, it surely must cause some worrisome moments for our intelligence experts. For, after all, such a satellite could be anything from a harmless scientific experiment to a surveillance vehicle or, worse yet, a satellite equipped with a nuclear or biological warhead.

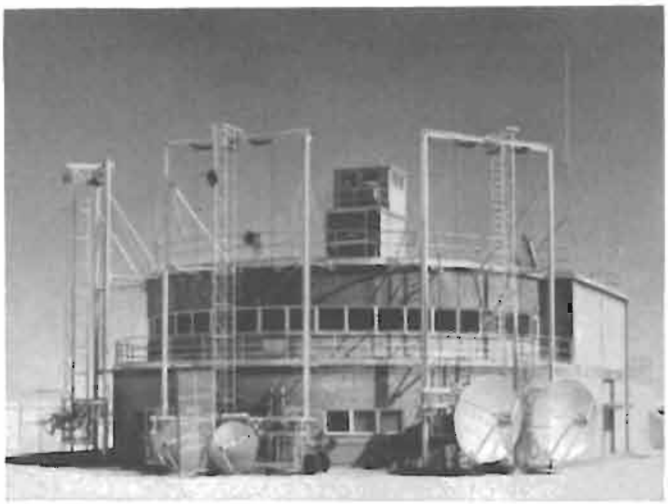
With hundreds of satellites, old rockets, and assorted space junk now in orbit and with many of them passing over the continental United States, it has become important to our military peace of mind to know the origin, capabilities, and intentions of each of these objects. To determine this, the Air Force is building a surveillance system to detect, track, identify, and catalogue all objects in space on their *first* orbit.

Lest this sound like a simple matter, it should be noted that until recent years it just was not possible for us to determine much, if anything, about such objects. Of course, our radars told us the altitude, range, and velocity of a given satellite, but even with the most precise radars it was not possible to "paint" a picture of the satellite, that is, resolve the target in angle. As shown in Fig. 1, a radar's beam is ordinarily too wide to give any indication of the *shape* of a satellite which is an important factor in determining its mission or intent. At a distance of 100 nautical miles from the antenna, for instance, a radar beam may be a mile or more wide. To use such a beam to paint a silhouette of an object only a few feet in diameter is like trying to fill in a "paint by number" drawing with a 6-inch brush.

While much of this information is still "classified" by the military, enough has been released to indicate how a new technique, called "signature analysis"—a remarkable bit of engineering detective work, is being used to determine satellite size, shape, and motion.

Radar "Fingerprints"

Although the new system hasn't been refined to that extent as yet, it is almost as if each satellite or reentry body has its own radar "fingerprint", which is a plot of the signal



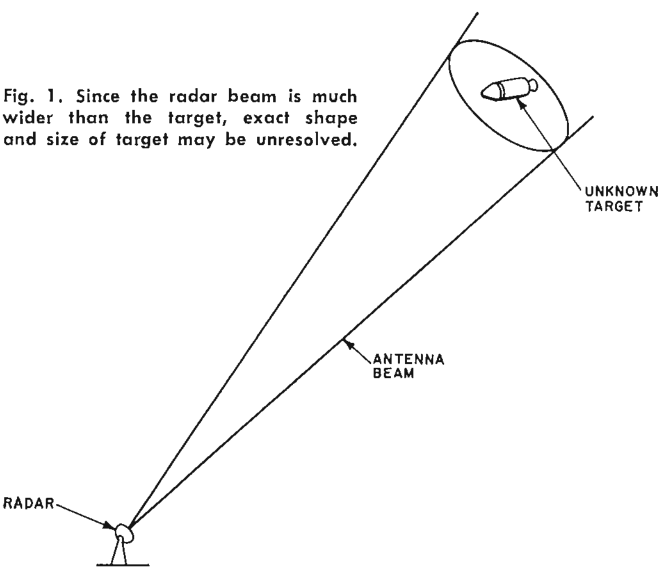
Over-all view of the control house at the Air Force radar target scatter site (Rat Scat). The two antennas at the right are 10-ft dishes, while two at the left are 6-ft dishes. These antennas are elevated on individual tracks when they are being used for radar target measurements.

strength of the radar echo (as recorded in the automatic gain control circuit) *versus* time. In this technique, plots or signatures of the target echo are broken down into patterns that represent the returns from objects of known shape. These shapes are then put back together to define the complete shape of the satellite—whether it is a cone, cylinder, sphere, or some combination of these shapes (Fig. 2). Using other techniques of signature analysis, it is then possible to determine the size of the satellite, its orientation if it is not tumbling, and its tumble rate if it is tumbling.

Knowing these characteristics of the satellite, the analyst may then be able to determine the satellite's intended mission. For example, if the satellite is always oriented toward the earth as it passes over us, then it could very possibly be a surveillance satellite. Particular shapes are optimum for certain types of sensors used on surveillance satellites. On the other hand, extreme altitudes would indicate that the satellite probably is not spying on us. By using this information and making deductions, we can obtain a pretty good description of the craft.

Although plots of aircraft radar echoes have been available for several years, it should be noted that signature analysis really began only in 1958. In that year D. Barton of *RCA* was able to deduce the contours of Sputnik 2 from the plots of echoes received on an AN/FPS-16 radar. By this process it was shown that complex patterns of radar returns could be resolved into combinations of returns representing simpler shapes and then put back together to indicate the original shape. In the *RCA* publication, "An Introduction to Target Recognition", from which much of the information in this article was derived, Charles Brindley reveals many of the techniques used in signature analysis.

Fig. 1. Since the radar beam is much wider than the target, exact shape and size of target may be unresolved.



Cross-section Measurements

Signature analysis is based on radar cross-section: predicting it, measuring it, recording it, and recognizing it. Radar cross-section is simply the size of an object as it appears to a radar, irrespective of its actual size. While there is no simple relationship between radar cross-section and actual size, generally the larger the object, the greater its radar cross-section or reflectivity.

Obviously, the greater an object's cross-section, the easier it will be for the radar to see it. Conversely, the smaller the cross-section, the harder it is for the radar to acquire. The enemy takes advantage of this by shaping reentry bodies so as to reduce their radar cross-section and by coating the vehicles with a radar-absorbing material. Radar cross-section depends on radar frequency, the angle at which the beam strikes the target, and the polarization of the signal.

To obtain laboratory cross-section data of actual satellites and other objects is a difficult matter: it is hard to maneuver the satellite into known aspects, satellites are expensive, and it is hard to repeat measurements. These difficulties have lead to the development of test ranges, both indoors and out, for plotting the cross-sections of various objects at rest.

In the indoor test range, called radar or microwave anechoic chambers, scale models of various shapes and sizes

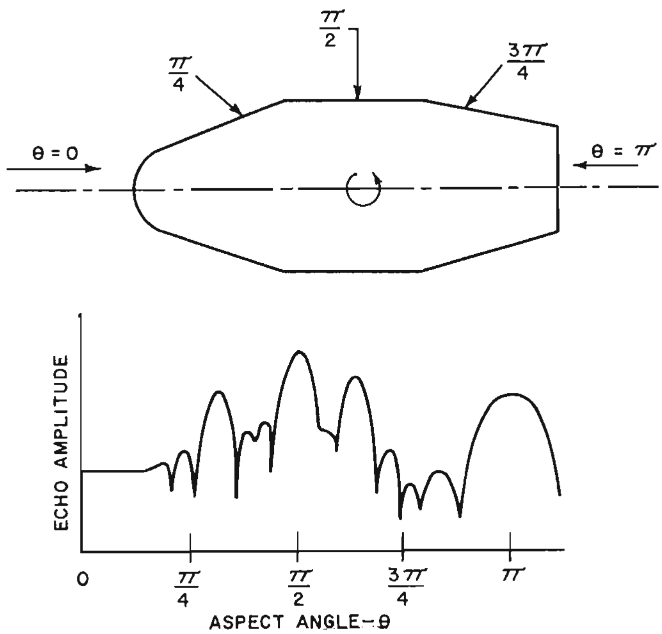


Fig. 2. A compound body along with its radar signature.

are observed with radars which are scaled down in size and up in frequency. Special radar absorbing materials are placed on the walls of the chamber to prevent unwanted reflections. The scale-model test object is placed on a turntable so that various aspect (viewing) angles may be obtained. The radar signal is bounced off the object and the signal strength of the echo is recorded on a strip-chart.

Anechoic chambers have the advantage of being immune to bad weather: you can use them when it is raining, something you can't do with outdoor ranges since the rain absorbs too much of the signal at the frequencies used on the model ranges. Such chambers, though, can be an expensive proposition when waveguides and models are built to small scale.

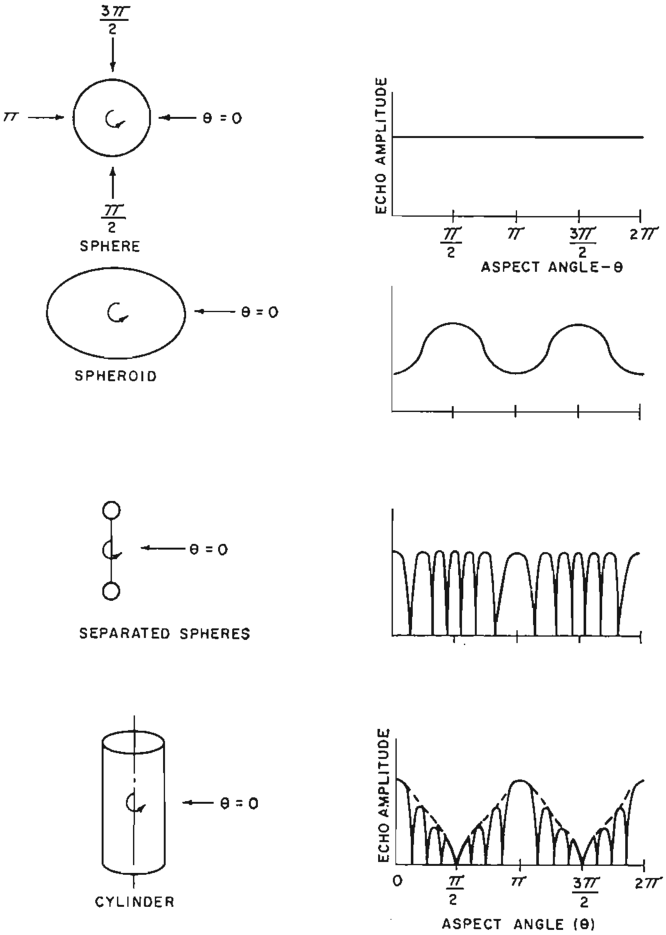


Fig. 3. Typical patterns produced by symmetrical bodies.

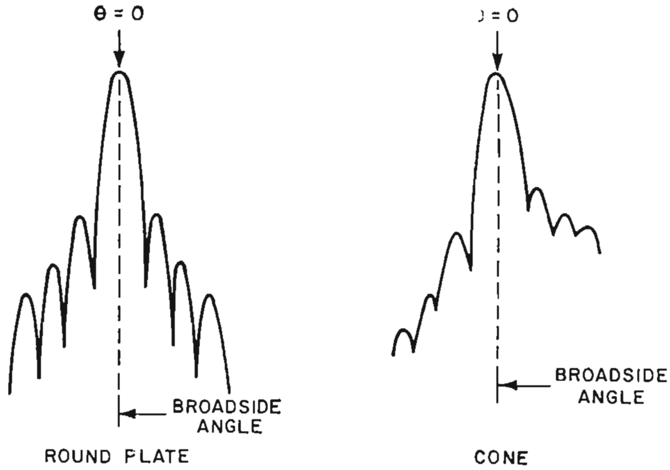


Fig. 4. Patterns produced by rotating plate and cone.

With outdoor test ranges the models do not have to be nearly as small. *Avco* has a test range where 2500-pound models can be suspended up to 300 feet in the air. At the radar target scatter site (called "Rat Scat") near Holloman Air Force Base, New Mexico, static cross-section measurements can be made on objects weighing up to 8000 pounds at frequencies from 100 to 12,000 MHz. On outdoor ranges such as these, special care must be taken to eliminate or discount the return from the tower or other supporting structures on which the target is placed since the tower may have a greater cross-section than the target.

Various Types of Signatures

Now let us consider the various types of signatures or returns which we obtain for bodies of various shapes, based on test range measurements. Figs. 3 and 4 show the returns for a sphere, cone, cylinder, and other shapes. The returns shown are for rotating bodies at a fixed position: the lobes may vary in width and number for moving bodies.

Since a sphere looks like a sphere no matter how you view it, its radar cross-section will be a constant level with no variation because of different aspect angles. The cone and cylinder have more complicated returns because the strength of the echo will depend on the angle or aspect at which the beam strikes the object. By the use of certain approximations, most symmetrical bodies can be considered to be made up of combinations of these basic shapes. If the satellite is not symmetrical (for example, if it has solar cells mounted on paddles), the analysis problem becomes more difficult.

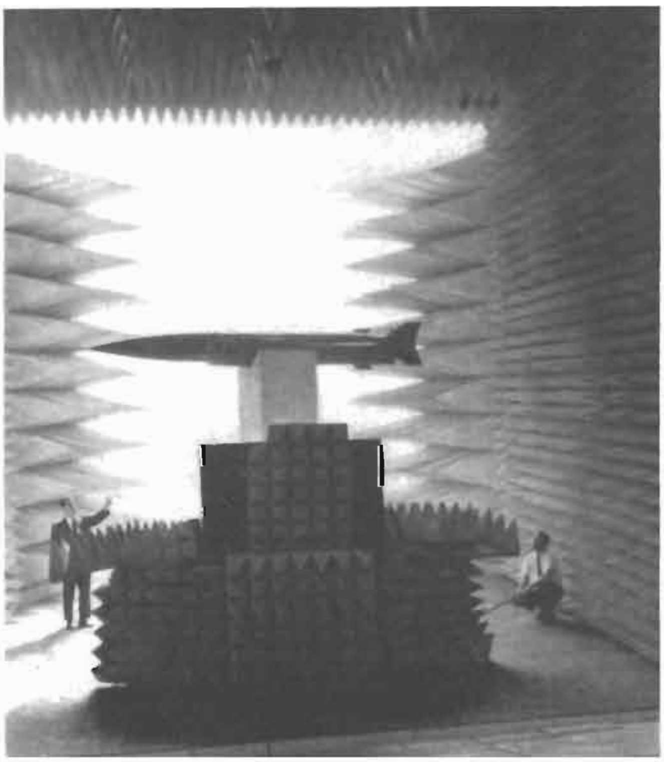
In either a test range radar or an operational radar, the target signature may be obtained from the automatic gain control circuit or the video circuits of the radar receiver. The recording of the a.g.c. voltage *versus* time is usually made with an analog strip-chart recorder. While this technique gives a good indication of the average strength of the return signal, it is being replaced at many stations by a video tape recorder which furnishes much more information since it records on a pulse-by-pulse basis.

Using the recording of an operational radar and knowing the characteristic returns of certain bodies obtained with a test range radar, the signature analyst can be expected to come up with a reasonable approximation of the unknown body, provided that both radars were looking at the target at the same angle.

Now that we've established the shape of the satellite, let's consider its motion. While the more sophisticated satellites will be stabilized, it is possible for the satellite to be tumbling which would indicate either a failure of the satellite to perform as programmed or a lack of engineering ability on the part of the designers and builders. In either case, it is important to know if the satellite is tumbling and, if it is, the tumble rate. This can be determined by observing periodic repetitions of the same cross-section pattern.

Thus far we have considered the cross-section just as a pattern and have ignored units of measurement. To use cross-section to determine actual size of a satellite, it is necessary to calibrate the radar. One method that has been used is to track a 6-inch sphere suspended below a balloon and then calibrate the relationship of the radar cross-section and the radar return accordingly. (*Continued on page* 78)

The target end of Bunker-Ramo Corp.'s microwave anechoic chamber. Foam plastic pyramids lining chamber absorb radiation.



Design of an ELECTRONIC GUITAR SYSTEM

By JACK ARNDT/Music Product Line Manager, Heath Co.

Technical details on the new Heath line of electronic guitars and their accompanying solid-state amplifier, with its light-dependent resistor tremolo circuitry.

KIT-MAKERS from *Heath Co.* working with guitar-makers from *Harmony Co.* have recently introduced three styles of American-made electronic guitars, all in kit form. Following detailed instructions, the kit builder assembles and installs the electronic parts, mounts the vibrato assembly, tuning keys, bridge, strings, and other hardware, and then adjusts and tunes the entire guitar. There is no wood working or wood finishing involved. The guitar body and neck wood parts are supplied prefinished in a gleaming cherry red along with the carrying case which will later hold the assembled, tuned instrument. *(See cover photo for the Model TG-46 guitar and amplifier. —Editors)*

The three guitar kits are different in construction and therefore different in assembly. Average building time is from three to six hours, depending upon the unit. The two-pickup solid-body guitar is the easiest to build. On this unit, the two volume and tone controls, the pickup selector switch, and the output jack are mounted on and wired to a plastic guard plate before they are fastened to the guitar. On the two-pickup single-cutaway and the three pickup double-cutaway electro-acoustic guitars, the wires and components are formed into a completed harness before installation. The harness is fed into the guitar body through the F-shaped holes, and detailed instructions tell how to "fish" the components through the proper holes in the body. (Fig. 1 shows the circuit used in the three-pickup guitar.)

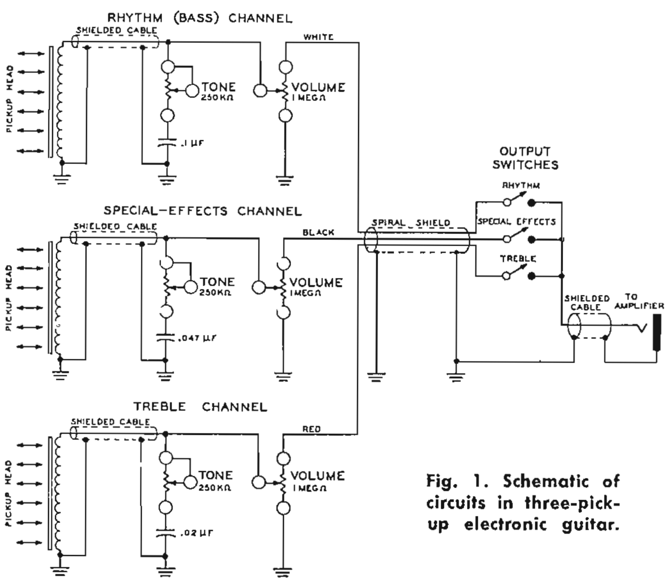


Fig. 1. Schematic of circuits in three-pickup electronic guitar.

After the electronic elements are mounted, the hardware parts are fastened to the guitar with screws through starter holes. Next, the bridge is precisely positioned and the strings loosely strung. Careful checks are then made of the adjustments for neck-bow and vibrato action.

Tuning

After the guitar is assembled, it is necessary to tune it. Several methods of tuning are described in the manuals and two means are furnished with each kit. An audible means is provided in the form of a small phonograph record which supplies actual guitar string tones. In this case, the tuning keys are adjusted until the guitar is in perfect tune with the record.

Another means, a visual one, is provided in the form of a new and ingenious little device called a "Vu-Tuner." This uses a resonant reed and indicator tuned to the lower E or sixth string tone of the guitar. The "Vu-Tuner" is clipped to a string adjacent to the bridge, and when the sixth string of the guitar is brought into proper tune, the reed of the device will vibrate in very noticeable resonance. Then the "Vu-Tuner" is removed and the fifth string is tuned in unison with the sixth string as the sixth string is held down behind the fifth fret. Next, the fourth and third strings are tuned in the same manner, each with the preceding string held down behind the fifth fret. Then the second string is tuned to the third string, while the latter is held down behind the fourth fret. And last, the first string is tuned to the second string, while the second string is held down, again behind the fifth fret. This provides quite excellent tuning, and because of the visual check of the initial step, it becomes quite an easy operation even for the inexperienced musician.

The Model TA-16 guitar amplifier has two channels of operation, each with bass, treble, and volume controls and two input jacks. One channel has tremolo and reverberation effects available (with foot-switch on-off action) while the other channel amplifies straight through.

The amplifier is rated at 60 watts of maximum peak power (peak ratings are commonly used in this industry), 25 watts of music power out- (*Continued on page 79*)

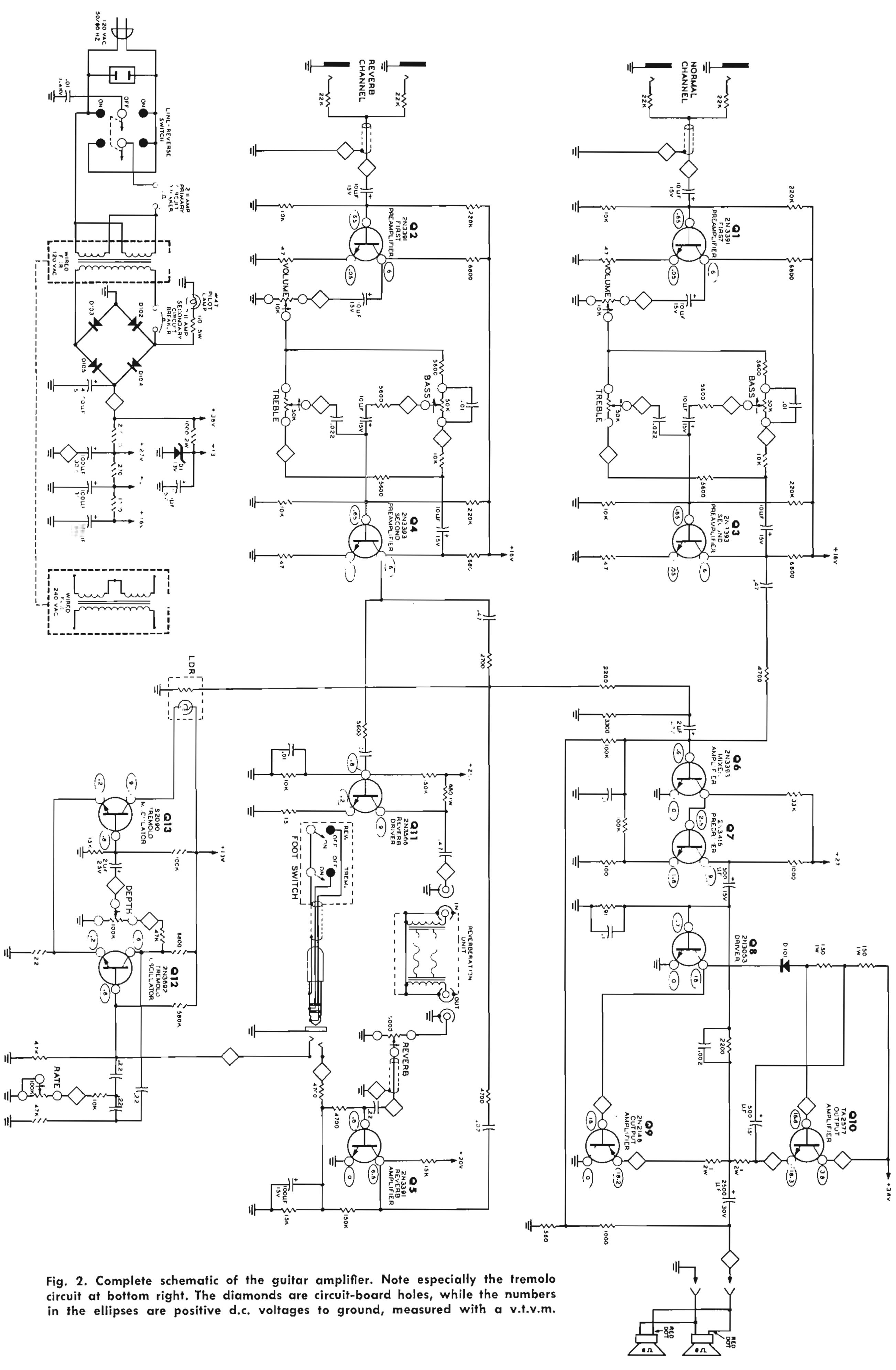


Fig. 2. Complete schematic of the guitar amplifier. Note especially the tremolo circuit at bottom right. The diamonds are circuit-board holes, while the numbers in the ellipses are positive d.c. voltages to ground, measured with a v.t.v.m.

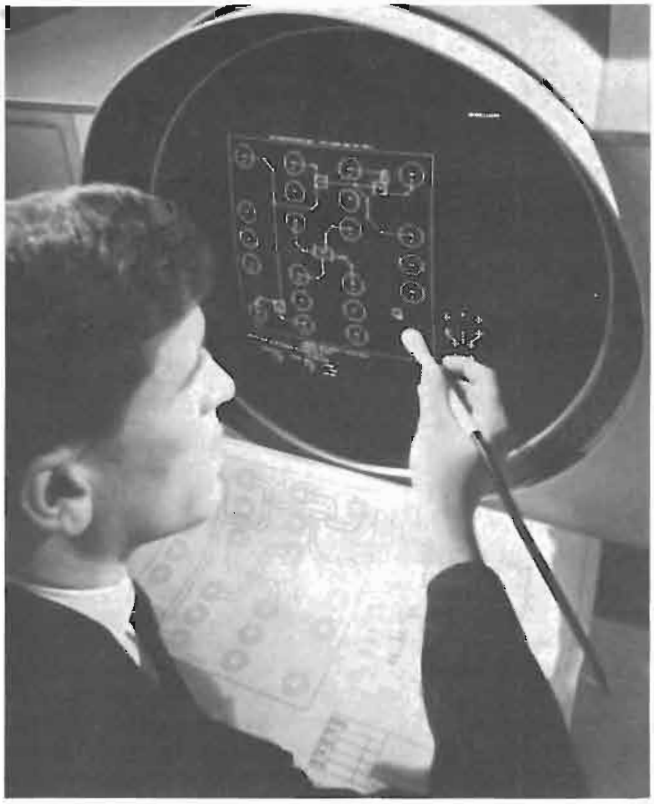
RECENT DEVELOPMENTS IN ELECTRONICS

Anti-Submarine Trainer. (Top left) Navy ship crewmen at the Fleet Anti-Submarine Warfare School, San Diego, Calif., are practicing a simulated, but realistic, attack on a submarine. The mock attack is being carried out in the Underwater Battery Plot Room of a new $3.5 million attack training system built by Honeywell. Sailors at the two attack consoles (in the foreground), using information from sonar equipment (in the background), are able to simulate the firing of an anti-submarine rocket missile at their target with deadly accuracy. The system also permits computer-controlled battles to be fought with moving symbols on a make-believe sea that is displayed on a large projection screen. Six operating areas encompass 3000 sq ft of floor space—conning station, combat information center, underwater battery plot, problem critique display room, launcher captain's station, and computer room.

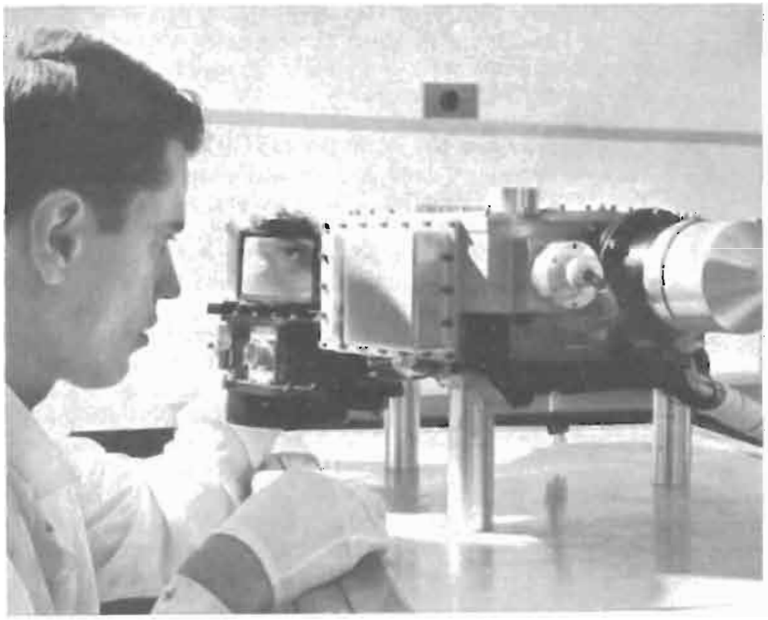
Long Laser Rod. (Center) Laser rods, the key working elements of most high-power pulsed lasers, are getting longer. Smaller than a cigarette a few years ago, such rods now may be three feet or more in length as shown by this lengthy specimen. Made of glass containing a trace of an impurity called neodymium, the rod is used in experiments aimed at increasing the size, power output, and efficiency of laser systems suitable for welding, drilling, and micromachining. The laser rod, made by Pittsburgh Plate Glass Co. for Westinghouse research laboratory experiments, is shown illuminated at both ends with ordinary light to bring out its uniformity of structure. The entire laser is in the background.

Superconductive Magnet. (Left) This superconductive magnet is used to test the high-field properties of specially coated wire ribbon during the manufacturing process. The magnet generates a field intensity of 110 kilogauss in almost a 3-inch clear bore. The special ribbon is wound into a solenoid which is then submerged in a bath of liquid nitrogen. At the extremely low temperature, resistance disappears, and very high currents can be made to flow and be sustained in the solenoid. This results in the production of a very intense magnetic field. The superconductive ribbon, which is now being offered commercially by RCA, is made from crystalline niobium-tin that has been vapor-deposited on a flexible stainless-steel alloy substrate and then electroplated with silver. Superconductive magnets are widely employed in laboratories in the fields of high-energy physics, medicine, and biology.

Computer Helps Design Computers. (Right) Using a computer-controlled display screen and a special "pen" that writes with light, an IBM engineer lays out the design for electronic-computer circuit. After he has experimented with various patterns and is satisfied with the final design, the computer produces a precise scale drawing of the circuit. The drawing shown beneath the screen in the photo is a computer-generated hard copy of the circuit that was sketched by the engineer. Intermediate drawings, which must be redrafted when the engineer modifies his design, can be eliminated.

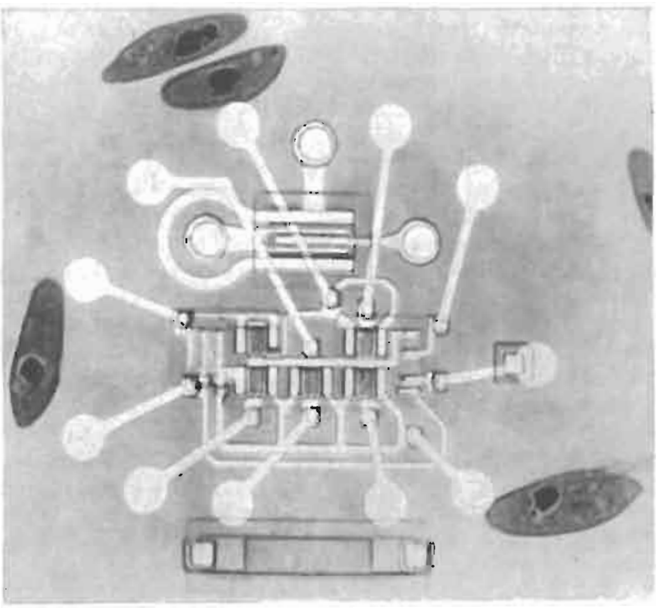


Dielectric Tape Camera System. (Center) The scanning mirror of a new dielectric tape camera system developed for weather and cartographic satellites is shown here. The new system combines the functions of camera and tape recorder in a single unit that is smaller, lighter, and requires less power than film and tube camera systems now in use. Heart of the system is a unique electronic "film" which can be erased and reused indefinitely, can store information for long periods of time, has a high immunity to radiation, and uses a completely electronic processing of photos requiring no chemicals or heat. The scanning mirror reflects light from the scene being photographed through optical lenses onto the special plastic tape, where the images are recorded electrostatically. The system is being developed for NASA by RCA.



Fastest Integrated Circuit. (Below left) Paramecia, microscopic single-celled animals, seem huge compared to this experimental, high-speed circuit. The monolithic circuit, in which all the components are built into a single chip of silicon, is believed to be the smallest and fastest ever reported. It operates in less than 400 picoseconds (trillionths of a second) and occupies an area of about 10 thousandths of an inch square. Each transistor (striped structures in center) is about 0.001-in square—smaller than a paramecium's nucleus. The larger transistor above the circuit (keyhole-shaped structure) is included in this experimental integrated circuit in order to facilitate testing by the developer, IBM.

Electronic Platform Scale. (Below right) A new portable electronic platform scale determines the load imposed by the wheels of the 70,000-lb frontloader to an accuracy of 99.95 percent. Battery-powered and designed for use in remote areas, the unit's platforms and ramps weigh only 800 lbs. The combined load on the platforms, each with a capacity of 100,000 lbs, is transmitted through electronic load cells to the readout instrument, where the signal is amplified to translate into the actual value of the load being applied. Weighing system is made by Revere Corp. of America.



The "VARITONE" ELECTRONIC SAXOPHONE

By DAN TOMCIK / Chief Engineer, Organ Div., Electro-Voice, Inc.

Details on electronically enhanced instrument that permits user to double with himself by adding a sub-octave output.

ELECTRONICS has been applied with a great deal of success and popularity to percussion and stringed musical instruments. The organ, the guitar, and even the bass fiddle, "electronically enhanced," have experienced wide acceptance, especially in "pop" music. But little or nothing has been accomplished that would allow wind instruments to hold their own in competition with their amplified cousins. This is really a pity because some of the more satisfying sounds in music are produced by the reed and horn families. The flute, for instance, and the saxophone are usually completely overcome in a combo by a thumping electronic guitar.

But the mere amplification of natural instrument sounds is only one reason to call on the help of electronic circuitry. Modern musicians, both in pop and progressive fields, are constantly experimenting and searching for "new sounds." Electronics has the ability to put at the fingertips of the musician an almost unlimited variety and combination of effects, allowing the performer's artistic ingenuity a new freedom of expression.

About two years ago, *H. & A. Selmer, Inc.*, one of the country's largest band-instrument manufacturers, started to develop an electronic saxophone. The company called on *Electro-Voice* to assist in the electronic portions of the product. Much more than just an amplified saxophone evolved. Through suggestions and developments from both companies, entirely new concepts in tone generation resulted. With the final product, the musician has electronic control over tone quality and volume, can add echo or tremolo, and can even couple a sub-octave to the note being played.

From the very first discussion of the new development, several important concepts were laid down. First and foremost, any attachments to the instrument were not to affect the basic playing technique or quality. The saxophone was to remain a musical instrument, not become an electronic one. Whatever added features were to be available, the musician must have the ability to "turn them off" and play in a perfectly normal manner. The instrument and any associated equipment had to be rugged to withstand travel and rigorous playing conditions. Electronic controls were to be uncomplicated, quickly operable, and if possible mounted directly on the instrument itself.

The Microphone and Its Location

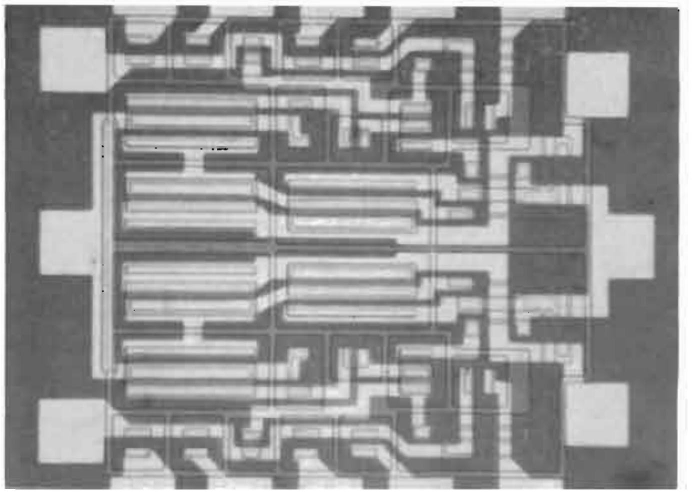
The initial concept of sound pickup and microphone placement had been developed in France by Jean Selmer, an engineer at *Henri Selmer et Cie.*, Paris. He found that a sampling of sound from inside the horn was necessary to reproduce tone patterns generated by the instrument without interference from external acoustics. The placement of the pickup microphone became the first technical problem.

A series of standing waves inside the body of the saxophone during playing creates many nodal points of increased or reduced sound pressure. These pressure points vary with playing technique and the note being blown. Contrary to what may seem obvious, the bell of the horn, although a most convenient location, may not be the best place for the pickup. The best possible method of sound pickup probably would be to place a different microphone at each tone hole on the instrument. This was mechanically impractical, of course, as well as being inordinately expensive.

Since all the standing waves emanate from the mouthpiece and neck of the saxophone, this becomes the optimum location for the microphone. However, a thorough knowledge of acoustic theory and mathematics along with years of experimentation had been necessary before the best precise spot was determined. This is definitely not a "do-it-yourself" undertaking—the pickup location cannot vary a fraction of an inch. The experimenter could drill a series of holes in the neck of the instrument in an attempt to find that spot, but most musicians would object to this treatment, not to mention the slight difficulty in playing. When the pickup is not at the correct point, some notes will sound louder than others, and there will be a definite loss of tonal quality.

The microphone itself was the second important development. Under license from *Selmer-Paris*, *Electro-Voice* refined the original pickup using a ceramic pressure-sensitive element. The stiffness of this device is high enough to compare with that of the instrument itself. Velocity microphones, having resonant frequencies within the range of the saxophone, caused wide variations in loudness. Also to be considered were the extremely high sound pressure levels generated in the instrument and the acid moisture condition created by the performer's breath. The resulting microphone is about ¾" in diameter and ½" thick. It is constructed and placed so that the normal playing technique of the musician is not affected in any way.

Once the basic pickup design and (*Continued on page* 82)



New Amelco high noise immunity dual buffer operates from 12-15 V, has large output transistors to drive lamps.

Integrated Circuits and the Automobile

By ROBERT A. HIRSCHFELD
Microcircuit Engineering, Amelco Semiconductor

Integrated circuits now make possible the creation of a very small digital computer for use in the automobile that will monitor almost all functions of both car and engine, and alert the driver to any possible malfunction.

A COMBINATION of factors is inevitably pushing the American automobile manufacturer toward greater sophistication. The economic concept of mass-production, which has guided the giant industry from its infancy, must now be applied to solving the problems of today's high-speed-capability roads, of increasing congestion, and of the higher degree of driver awareness and control that these latter-day conditions require.

Why Use Integrated Circuits?

The integrated circuit is in many ways ideally suited to automotive applications. Inherently a mass-produced device, it will allow many of the basic control and warning functions presently performed mechanically to be replaced by electronic modules which can perform the job better, more reliably, and due to the large number of cars built each year, at lower unit cost. In many cases, it will perform more complex and useful functions than can its present counterpart. In the case of a warning system, this could mean an earlier warning of impending danger; in a control system, higher operating efficiency and longer life for mechanical components. An additional attraction to manufacturers, dealers, and purchasers alike would be that in the unlikely case of malfunction, the circuit can monitor its own failure, and can be replaced as easily as changing a fuse.

The Automobile Environment

Components in any automotive system must be able to withstand a fairly rigorous environment. Local underhood temperatures can vary from winter sub-freezing to some hot-spots above the boiling point of water. While passenger compartment temperatures may be less troublesome, auto manufacturers have in the past shied away from inexpensive germanium components because of their temperature susceptibility. The only semiconductor generally in use in the engine compartment today is the silicon power diode used in alternators.

Electronic control of mechanical components requires the circuit to supply power to drive servo motors, solenoids, etc., but this power can be moderate if it is amplified as it is in today's cars by mechanical, pneumatic, or hydraulic means.

Additional restrictions are a single, fluctuating 12-volt power supply, noise generated by the ignition system, and various forms of mechanical vibration.

Limitations and Capabilities

The inherent limitations of the monolithic process are now well known: difficulty in attaining high breakdown voltages, lack of control over absolute resistor values, heat dissipation limitations of small silicon chips, saturation characteristics of monolithic transistors which, unlike discrete devices, must have collector contacts from the upper surface of the chip, and parasitic capacitances arising from the junction isolation system.

Yet, none of these limitations seriously hinders automotive use. The 12- or 15-volt breakdown voltages required are easy to obtain. In most switching-type circuits, resistor values are not critical and in analog circuits, differential construction can eliminate resistor value dependency. Where large currents and high-power outputs are required "monobrids" consisting of monolithic devices can still be economical. Since most functions will be d.c. or low frequencies, high-frequency limitations are of little importance. The additional gain and complexity which the monolithic circuitry allows will encourage the use of closed-loop feedback systems, hence individual component requirements will become less critical.

The special capabilities of integrated circuits are just as important as their potential cost-saving advantages. Circuits are reproduced with nearly identical operating characteristics. Logic circuitry can have a large number of separate inputs and outputs without the cost penalties found in discrete circuitry. Circuit complexity is no longer an economic factor, as long as chip size is kept small. Much of the costly interconnecting wiring is already done on the chip.

Integrated circuits will withstand a wider temperature range than is likely to be found in the auto environment. Moreover, temperature compensation, using predictable diode characteristics, can be designed into a given circuit. In general, resistance to all of the physical environments (vibration, corrosion, etc.) is excellent.

Since more sophisticated designs are economically feasible than with discrete components, it is a simple matter to make the circuits insensitive to noise and power-supply variations.

Perhaps of greatest importance is the inherent reliability of silicon integrated circuits, especially in life-saving safety warning functions. The statistical failure rate for a complex circuit is about the same as for a single transistor of equal area. An integrated circuit installed at the factory could reasonably be expected to outlast every moving part in the automobile.

Applications

Some of the applications to be discussed are accompanied

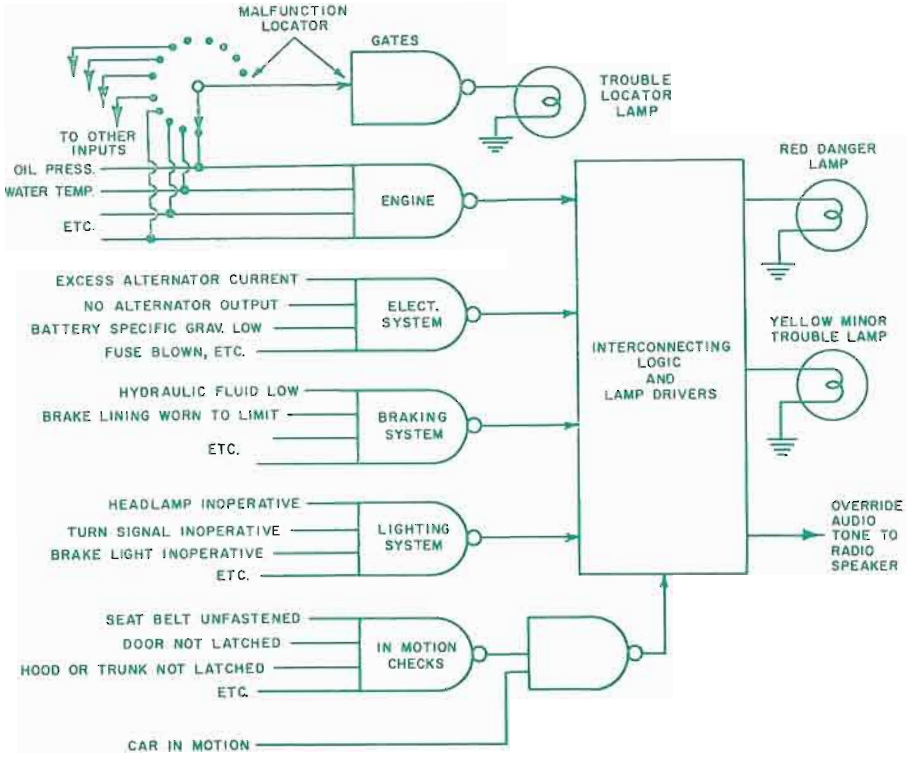


Fig. 1. This multiple-input malfunction indicator uses interconnecting logic to determine severity of a problem and indicate on a yellow or red warning light.

by illustrative circuits; any commercial circuit must, of necessity, be a compromise giving the best performance for a given cost. Therefore, the following applications are suggested as guidelines, rather than predictions of exact techniques.

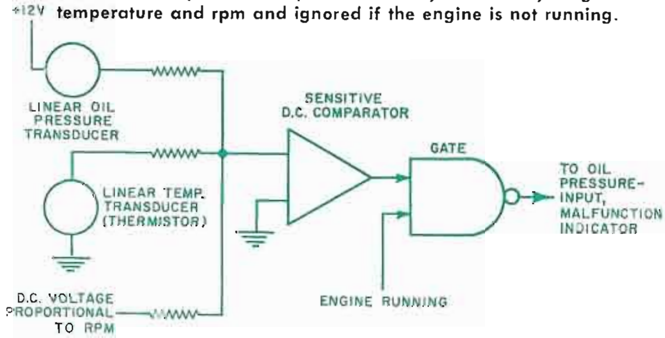
There are four basic areas in which integrated circuits will be useful; malfunction alarms, engine and drive train controls, driving aids, and passenger services.

Malfunction Alarm

Sports car fans have long derided the ubiquitous "idiot light" which has replaced nearly every instrument panel meter on the modern car. Yet there is much to be said in favor of a positive, attention-getting, malfunction lamp which allows the driver to focus his attention on the road until the lamp requires his response. One limitation on present dashboard indicator lights is that not enough panel space is available to provide a sufficient number of separate lamps to monitor every essential point. To know that alternator and oil-pressure systems are operating is certainly necessary, but it is also important to know that the brake system is about to fail or that a passenger has left his seat belt unfastened or that pressure in one tire is dangerously low.

The simplest alarms really do not require integrated circuits; they are switches, temperature- or pressure-operated, directly driving panel lamps, and wired in parallel-series combinations to perform a certain degree of wired logic. Consider, however, the advantages of a rudimentary digital computer such as that shown in Fig. 1. Now, malfunction signals could be processed to determine the severity of the problem. A yellow lamp could indicate a minor problem which could wait to be taken care of at the next service station. A red lamp could indicate clear and immediate danger, requiring that the driver stop at once and, if ignored for a specified length of time, could give audible warning through the radio loudspeaker or even throttle back the engine.

Fig. 2. Since pass-fail criteria may depend on other engine parameters, a d.c. comparator may be driven by summing resistors driven from several linear transducers. For example, minimum oil pressure requirements may be set by engine temperature and rpm and ignored if the engine is not running.



Functionally, such an indicator would consist of multiple-input gates driven by sensing switches and, where required for more sensitive measurements, by high-gain comparators driven by linear transducers (see Fig. 2). Monolithic circuits which are capable of driving lamps directly already exist, thus all appropriate logic could be designed into a single chip. A side benefit would be that sensing wires from various points would no longer be required to carry lamp current and could be made very small.

Just how much processing of malfunction signals should be done before presentation to the driver is, at present, a matter of philosophy, but the ever increasing demands made by modern traffic conditions upon the attention of drivers may soon make such processing necessary.

Engine and Drive-Train Control

The basic operation of the four-cycle, reciprocating-piston, gasoline engine has not changed since the turn of the century. That such a crude device is today churning out such phenomenal and reliable power is partly attributable to an ever increasing sophistication in the methods of its control. Each of the major controls (ignition, carburetion, cooling system, etc.) may be regarded as a self-contained analog computer or, in some cases, a closed-loop feedback system.

As an example, consider the control of just one parameter—spark timing. Inputs on many cars are both mechanical and pneumatic. A centrifugal weight system senses rpm, a diaphragm connected to the induction system senses vacuum and produces a force bearing some complex proportionality to engine load, atmospheric pressure, and amount of opening of carburetor throats. The vacuum and centrifugal "inputs" are used to advance the spark timing, the contribution of each determined by calibrated springs. To replace this simple, effective control alone with an electronic system would probably be unprofitable. Both rpm and vacuum sensors would be required, as well as a proportional solenoid or motor-driven attachment to the distributor. But suppose that the rpm and vacuum sensors were required for some other control or monitoring system, then to make the spark advance dependent upon them would be a simple matter, as shown in Fig. 3. In fact, these two quantities are redundantly measured elsewhere, the vacuum-controlling operation of parts of the carburetor and rpm-controlling shift points in the automatic transmission.

There appear to be numerous duplications of function in the presently used mechanical-pneumatic system. With all due respect for the work that has gone into the present, localized control system, let's start from scratch.

Suppose that a linear transducer existed which would give an electrical voltage for each important operating parameter: vacuum, block temperature, driveshaft torque, rpm, atmospheric pressure, gas-pedal pressure, etc. Add to the inputs now measured some more exotic sensors: fuel octane rating, loaded weight of the car, rate of fuel consumption, etc. Each input could be fed to a central analog computer. Separate outputs from this computer could control spark timing, carburetor mixture and opening, automatic transmission gear ratio, battery charge rate, coolant circulation rate, oil pump rate, etc., in such a way as to optimize each of these controls for given instantaneous operating conditions. Given a set of switches, the driver could close this complex "feedback loop" in several ways. Making fuel consumption rate the main factor would force the system to operate at those control settings giving maximum mileage. Switching to another mode would force the system to generate maximum torque (at the expense of gas mileage).

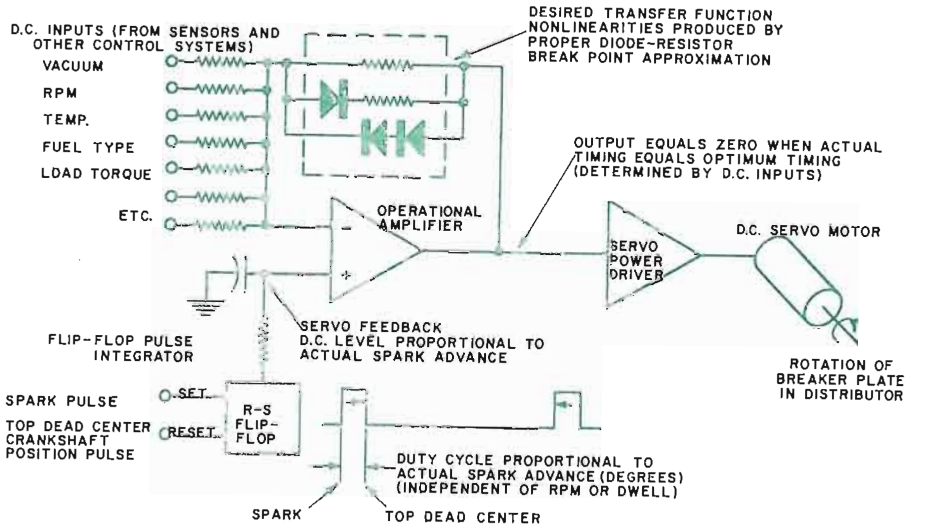


Fig. 3. In the ignition optimizer, inputs from many linear sensors are summed at the inverting input of an operational amplifier, producing a d.c. voltage proportional to optimum spark timing for those conditions. The flip-flop shapes pulses whose on-to-off time ratio is proportional to actual spark advance. An integrator applies this as a d.c. voltage to the non-inverting operational amplifier input, whose output drives a servo until it corrects the advance to optimum setting.

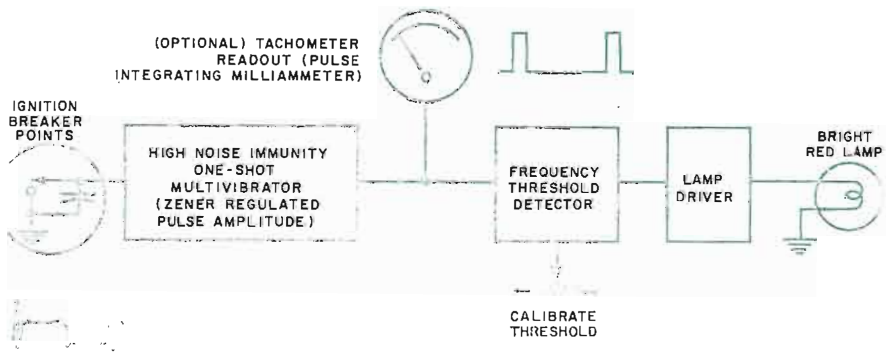


Fig. 4. In this electronic red-line tachometer, ignition pulses are standardized in height and width by a one-shot multivibrator, and also used to drive a milliammeter that indicates rpm. The pulses also drive a threshold detector that then lights a bright-red dashboard lamp above a preset number of engine rpm.

While early integrated circuit control systems might be adapted by solenoids or servo motors to existing control actuators, a natural outgrowth would be improved actuators, better suited to the integrated circuit's capabilities. For example, the present mechanical spark commutation system could be replaced by an all-electronic equivalent. Commutation might be done by a ring counter, pulsed by a photoelectric crankshaft position detector. Low-level pulses would go to each cylinder, where a spark plug would contain its own built-in step-up transformer plus a power switch (such as a silicon controlled rectifier). Such a system, made possible by continued research into ignition methods, could be highly efficient, reliable, free from r.f. interference, and would require no maintenance other than periodic cleaning of plug electrodes. Spark timing could be continuously controlled by the central control module, simply by introducing more or less delay into the ring counter.

An electric fuel pump which moves a metered amount of fuel per pulse could be driven by a pulse train from the central module to supply only as much fuel as is demanded. In this and in the previous example of an ignition system, the control signals would already be in a form ideally suited as inputs for metering circuits.

Arguments against a central control module are the same as those against over-centralized government: If part of the control fails, the entire system stops working. But perhaps such a failure mechanism, requiring immediate repair, is superior to today's decentralized automobile controls in which a partially defective vehicle is still capable of limping down the road, endangering its occupants and all vehicles in the immediate vicinity.

Driving Aids

To control his vehicle efficiently in everyday driving circumstances, the driver requires certain minimum information. Some of this information is presented to him on meters supplied as standard equipment; much more is available on accessory gages available as worthwhile options. Because of the electrical nature of most automotive indicators and because many car owners appear willing to pay the extra amount required for such equipment, it is likely that an early widespread appearance of integrated circuits in automobiles will be in this area.

Integrated circuits make numeric readouts more feasible thus allowing numbers to be precisely displayed much like today's digital voltmeters. Such a display could normally be the speedometer, with push-buttons able to momentarily convert it into a tachometer, temperature gage, miles-per-gallon indicator, odometer, etc. The same display could, in the event of a malfunction alarm, be used to diagnose the trouble on the spot.

It is often more important for the driver to know his speed relative to some arbitrary limit, rather than to know exactly what the speed is. Integrated circuits make possible digital readout speedometers in which lamps indicate precise thresholds at 5 mph intervals. The basic arrangement of such a system is shown in Fig. 4. Another interesting accessory would be analogous to flight recorders used in commercial aircraft: an inexpensive, continuous-loop recorder could, along with time and other information, record speed pulses, retaining them for the 5-minute period preceding its turn-off. This recorder could be used in analyzing the true causes of accidents and as evidence in marginal speed limit citation cases. (*Continued on page 68*)

The New Tetrode Transistor

By JOSEPH TARTAS

By adding another base connection to a conventional triode transistor, two control elements are provided. This unique advantage offers a great deal of circuit simplicity in formerly complex semiconductor circuits.

THE tetrode transistor has been around for almost fifteen years but unfortunately has not attracted circuit designers as much as the more familiar triode transistor. Because of the current interest in the FET (field-effect transistor), investigation is being conducted into the unique advantages of this extra-element transistor and the circuit simplicity it affords.

Mechanically, the tetrode transistor is built as shown in Fig. 1A. It greatly resembles the conventional triode transistor, with the exception of a second base connection.

In this case, the exact equivalent circuit is difficult to illustrate. However, one manufacturer presents it as an ideal transistor with the base-to-base resistance as an external component as shown in Fig. 1B, which could be better represented as illustrated in Fig. 1C. It is important to the working concept of the tetrode that the equivalent circuit representation show three facts. (1) The base-to-base resistance is a fixed ohmic resistance (except for larger than normal base currents). (2) The resistor divider action in the equivalent circuit is for a.c. only. (3) Most significant is the fact that the emitter and collector currents remain substantially constant for the entire range of minimum to maximum signal gain. While the latter is not true for the FET, the matter of the amount of signal modulation still holds true in essence.

To further clarify this, we must examine the base layer of the bipolar tetrode in relation to the signal path and emitter-collector current. Fig. 2 demonstrates the way in which tetrode action is obtained and the means by which the base 2 voltage controls the signal gain of the transistor while the collector current remains substantially constant.

In Fig. 2A, the arrows indicate the flow of electrons (in the case of the *n-p-n* tetrode) near the base 1 area of the base layer due to repulsion by the negatively charged base 2 end. This configuration represents the circuit under maximum gain conditions, with base 1 grounded for d.c. (common base) and the emitter grounded for a.c. (common emitter). Because of the resistance between the base connections, the base layer will have a maximum negative charge at the base 2 end, with the charge decreasing toward the base 1 end, so that in the narrowly confined area of base 1, the charge is all positive relative to both emitter and base 2. With such a charge, the emitted electrons are repelled by the negative base 2 charge and attracted by the positive base 1 charge. Under these conditions, all of the collector current (which is essentially all of the emitter current) flows through the base 1 region and is modulated by the incoming signal.

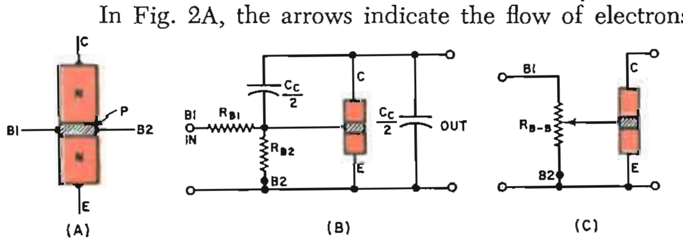
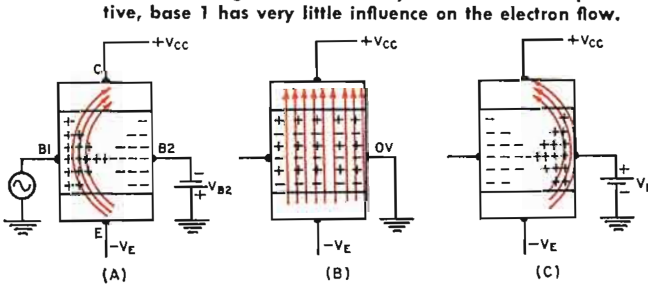


Fig. 1. (A) A tetrode transistor has two base connections. (B) and (C) Versions of the transistor equivalent circuit.

Fig. 2. How base 2 applies a.g.c. to device. (A) With base 2 negative, base 1 controls electron flow. (B) With base 2 at zero volts, gain is about unity. (C) With base 2 positive, base 1 has very little influence on the electron flow.



As the negative base 2 voltage is decreased (toward zero voltage), less of the electrons are repelled by base 2, and at zero volts the electrons flow randomly across the entire emitter-base-collector junctions shown in Fig. 2B. When this occurs, only a small amount of current flows near base 1 and hence only a small amount of signal modulation appears at the collector. Such a condition might represent a gain of unity or less.

If the base 2 voltage is allowed to reverse polarity and become positive by a small amount (relative to base 1) as shown in Fig. 2C, then the emitted electrons are repelled by the base 1 charge and essentially all of the current flows in the base 2 region. This state is minimum gain and actually represents attenuation of the incoming signal by 20 dB or more.

It is interesting to note that the linearity of the base-to-base resistance is dependent to a large degree on the amount of emitter current as well as the level of the base-to-base current. Because the tetrode transistor is intended for small-signal applications only (and hence a small emitter current), the base-to-base resistance is normally used within its linear characteristics, and it is just these characteristics that lend themselves nicely to r.f. and i.f. circuitry. For the transistor, there is practically no change in collector current and hardly any change in base current; therefore, there is essentially no change in input capacitance or loading. Because of this, the response of the amplifier does not shift or skew as the stage gain is radically reduced. The Miller effect, commonly encountered in vacuum tubes, is thus eliminated.

Since the total base 1 current is the sum of the base 1-emitter current and the base-to-base current, there is very little change in bias with an alteration in base 2 control voltage.

Because of the isolation provided by the second base, the need for neutralization is greatly reduced in the tetrode. Since the nature of feedback is analagous in both tubes and transistors, similar methods of compensation are possible in either case. However, for tetrode transistor circuitry, it is only in rare cases that the maximum potentialities of a tetrode circuit can be improved solely through neutralization.

Tetrode Circuits

The tetrode is useful only in small-signal applications, and in most cases the application is at r.f. frequencies where the convenience of the second base may be used to best advantage. Examples include a.g.c.-controlled i.f. stages; r.f. converters where the second base becomes a separate injection element; r.f. signal generators with the output level controlled through the second base; and either an r.f. or a video attenuator, when used as a variable impedance directly across a line.

While potential applications are unlimited, the familiar transmitter and receiver circuitry are easily adaptable to use of the tetrode, whether the transistor is bipolar or FET.

At the present time, the only bipolar tetrodes available are the 3N34 and 3N35, both manufactured by *Texas Instruments*. However, the more recently introduced FET tetrodes are beginning to appear in greater numbers each month. Nearly all the leading transistor (and also tube) manufacturers have tetrode FET's in their current transistor listings. There is also evidence that some companies are planning to produce pentode transistors by similar techniques.

Without going into a discussion of the field effect *vs* holes or electrons, it is interesting to find that the dual-gate FET (or tetrode), although different in physical construction, still obtains a variable gain control by a method similar to that of the bipolar tetrode. The FET, however, unlike the bipolar transistor, has a variable drain current (equivalent to the collector current) with a change in a.g.c., just as in a vacuum tube. The big difference is that there is little or no change in input capacitance with a.g.c., nor is there any significant change in input loading, in spite of the current change.

Powering Tetrodes

The FET is operated in a manner that is similar to that of both the vacuum tube and the bipolar grown-junction tetrode, except for the aforementioned differences. The bias may be derived from a divider where feasible, or a grounded-base (or gate) circuit may be used where preferable, as shown in Fig. 3. While the single supply of Fig. 3A is similar to that of the vacuum-tube circuit using a.g.c., it must be remembered that the separate base element of the transistor is used for that purpose. For high-frequency applications, it may be more desirable to return input circuits directly to ground, as shown in Fig. 3B, supplying a negative bias to the emitter. This configuration is described as common base for d.c. and common emitter for r.f. (through the emitter bypass capacitance). The resistor-capacitor network in base 2 lead is used only as a filter.

A.G.C. Supply

The a.g.c. voltage is usually derived from the detector circuit of a receiver, although in other types of equipment, it may be more elegant. Whatever the source, its prime

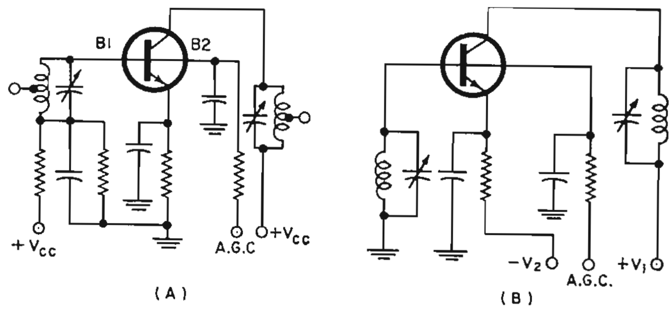


Fig. 3. (A) Circuit using a single positive supply source. (B) Similar circuit uses dual voltage supply to provide grounded base 1 circuit. This simplifies r.f. grounding.

purpose is to keep the output level of the stage or stages at a constant level over an extremely wide range of input levels.

The bipolar transistor literature originally recommended a constant-current source for the second base, but it was found that the voltage source for the required base current could be controlled with a less complicated circuit, with more standard results from unit to unit.

FET tetrodes require only a voltage source, with maximum gain occurring at zero volts on the second gate, at least for those elements used for a.g.c. action. All in all, the basic ideas used in either transistor or vacuum-tube a.g.c. are quite similar. The only precaution involved in the a.g.c. voltage is that it should be kept within the recommended limit, as breakdowns occur beyond this limit that can permanently damage the transistor.

Applications

Fig. 4 shows a number of typical applications of the tetrode transistor. Fig. 4A, a 45-MHz amplifier using an FET, shows a gain of 20 dB and an approximate a.g.c. range of 40 dB for a change of zero to 6 volts on gate 2. This gate may be returned to a fixed voltage source of 6 volts through a potentiometer for manual gain, or it may be returned to ground or to base 1 for a fixed gain with no control.

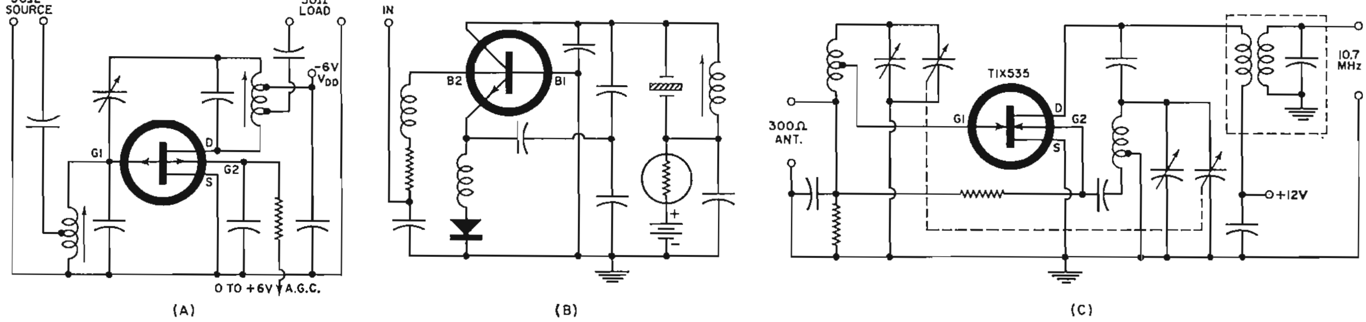
The crystal-controlled oscillator of Fig. 4B is frequency-modulated by applying a reverse a.c. current to base 2, thus causing a characteristic change in the output capacitance that shunts the crystal and tuned circuit.

In a similar application with a v.f.o. (non-crystal controlled), a 250-kHz swing was achieved for a center frequency of 750 kHz for a base 2 current of 150 to 200 μA.

An old favorite, the autodyne converter, has been modernized in Fig. 4C by using the two gates of an FET as separate injection elements for input and local oscillator signals.

Because of the control action exerted by the introduction of the second base element, there is almost no limit to the variety of possible applications for tetrode transistors. Automatic level controlled generators, variable load impedances, a.f.c. circuits, and switchable r.f. amplifiers are only a few of those that have been successfully developed. ▲

Fig. 4. Circuit configurations for tetrode transistors. (A) FET 45-MHz i.f. amplifier shows how a.g.c. is applied. (B) A crystal-controlled FM oscillator. (C) Simplified autodyne converter uses both gates of FET transistor.



Electronic Percussion Instruments

By CHARLES MULLER, K2UHF

Construction details on battery-powered circuit that produces sound of drum, tom-tom, bongo, and blocks at press of a button.

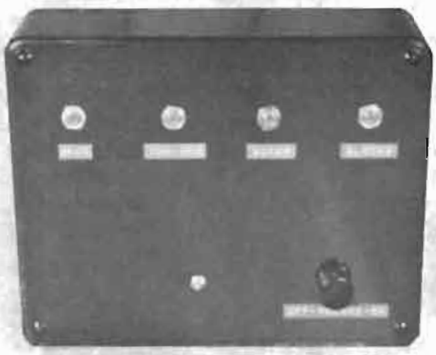


Fig. 1. A meter case, which measures about 6½ by 5¼ by 2¼ inches, houses 5-transistor, 4-push-button electronic percussion circuits.

THE simple electronic device described here allows anyone to accompany a recording or live music with four different instruments, individually or even simultaneously. The little battery-powered box shown in Fig. 1 can produce the sound of a drum, a tom-tom, a bongo drum, and blocks simply by pressing the right button. It is only necessary to connect the audio output of this unit to a good sound system and the beat of these four percussion instruments can be heard. Each time a button is depressed, the beat of the corresponding instrument is produced, regardless of how long the button is held down. If several or all buttons are depressed simultaneously, all four instruments will be heard. One does not have to have the skill of the drummer, or the tom-tom, bongo, or block player to be able to accompany any kind of music. One merely has to have the right rhythm and the ability to press a button.

The circuits are quite simple and easy to build, there is no critical layout, and all of the components can either be found in a well-stocked junk box or are readily obtainable from any electronics distributor. The unit is particularly suitable for accompanying electronic organs, pianos, or guitar amplifiers, for it supplies the rhythmic beat that enhances the music. When used for more serious purposes, the device is excellent for dubbing drums, tom-toms, or bongos to one's own tape recording of other instruments. This is particularly effective with a stereo tape recorder to add space effects to a mono recording. In addition, the unit can be used to judge the frequency response of audio amplifiers, speakers, and similar devices.

Circuitry

The unit uses four oscillators which are identical, except for the individual component values that make up the frequency-determining and shaping *RC* circuits (Fig. 2). A single transistor with base-to-collector feedback acts as a one-shot twin-T oscillator. This transistor can be a 2N404, 2N107, 2N109, or some similar type. Its collector and base are connected to a − 18-volt source supplied by two 9-volt transistor batteries wired in series. These batteries will last quite a long time since the oscillator draws practically no current, except during the period when it generates its tone output.

The fixed and variable resistors in the emitter serve to control the circuit gain and are adjusted to prevent continuous oscillation. Once *R*4 is set, it need not be adjusted again unless the transistor is replaced. *C*1 is a coupling capacitor and *R*5, *R*6, and *C*2 are the audio output *RC* filter. The actual frequency-determining circuit is composed of the twin-T networks consisting of *R*7, *R*8, *C*3, *C*4, *C*5, *R*9, and *R*10.

The "B−" voltage charges *C*7 through *R*12 until the push-button is depressed. This discharges *C*7 through *R*13 and sets up a brief oscillation in the twin-T networks. The duration depends upon many factors but is primarily determined by the time constants of resistors *R*13, *R*11, and *R*10 and capacitors *C*6 and *C*7. To make the different sounds of the drum or the blocks, for example, not only the duration but also the frequency content of the oscillation must be altered. The latter is accomplished by changing the values of the twin-T components, while duration is controlled as described above. This basic circuit is used four times with different component values, as shown in the parts list of Fig. 2, to produce the four different sounds.

To make the unit versatile enough for almost any audio system, the author decided to add a single stage of preamplification. As shown in Fig. 3, this is a 2N107, simply because this was the handiest type around, although any audio transistor will work equally well. All four oscillator outputs are connected to the summing resistor *R*14. If it is decided not to use an audio amplifier, the same summing resistor should be used as output load for the combined four oscillators. The volume control shown in Fig. 3 is not essential but very convenient, since it permits the player to use his thumb to control the loudness of his drum, tom-tom, *etc.* while playing along.

The switches and volume control were positioned so that this unit could be played with either hand and the volume control adjusted with the thumb without missing a beat. An inexpensive push-button switch was used which requires about 1/8 inch travel to make contact. If this is too long for fast playing, the spring arm can be adjusted so that the lightest touch makes contact. The plastic box which houses the unit was found at a local electronics distributor but any convenient metal box will do just as well.

The author did not have the facility for making his own printed wiring board, so all parts were mounted on perforated board and wiring was done on the reverse side. (See Fig. 4). To facilitate wiring and debugging, we have laid out each individual oscillator in exactly the same way, side by side with its companions.

Before mounting the components, the board should be fitted to the box. After the board is cut to the right size (approximately 4½ by 6½ inches in the illustrated unit), it is aligned with four spacers which will hold it against the back cover. It is suggested that the circuit for the drum be built first so that the others can be simply copied. The oscillator which generates the sound of the blocks does not use *R*6, *R*11, and *C*2, and this space was used for the preamplifier. We suggest that the drum oscillator and preamplifier wiring be completed first; then connect the wires to the button switch and volume control respectively.

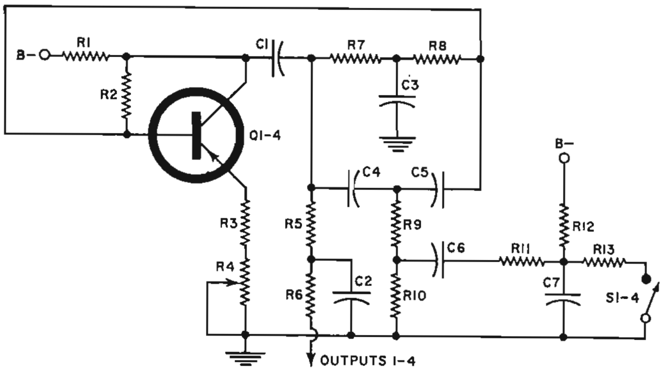
While any two 9-volt batteries can be used, the author prefers the inexpensive type 146 which is also the standard for most transistor radios. Battery clips are connected to the batteries and they are held against the case with a simple clamp made of an aluminum strip, screw, and nut.

Testing

Each of the four circuits can be tested individually. It is necessary to connect this unit to a good audio system since the quality of the audio amplifier and speaker has a great influence on how natural and true the electronic percussion instruments will sound. This is especially true of the drum which will sound really good when the hi-fi system has good low-frequency response.

To begin with, the volume control (*R*18) should be set approximately one-third above ground, and the volume and tone controls of the hi-fi system should be fixed at their mid-range positions. The emitter control (*R*4) of every oscillator should be adjusted for maximum resistance. Repeatedly depressing the button switch of the oscillator under test will permit setting the volume control of the preamplifier and of the hi-fi system to a suitable level—loud enough to simulate the respective instrument but not loud enough to overload the hi-fi system. Next, emitter conrtol *R*4 is adjusted gradually until the sound is clearly recognizable. Advancing this control further will cause continuous oscillation regardless of the switch action. Once a good position for emitter *R*4 has been found, this pot should not require any further adjustment. A little adjustment of bass and treble controls or the balance controls in stereo systems may help make the sound more realistic.

After the four oscillators have been adjusted and tested, the first practice session can start. The reader who has enjoyed building and using this device may want to experiment with some variations of it. It is possible, for example, to generate a series of drum beats by using a number of counter stages or a separate multivibrator to simulate the roll of a drum. In effect, this employs an electronic circuit to actuate the switch rapidly in succession. By varying component values, the sounds of other percussion instruments can be produced. Different types of drums, cymbals, and even bells can be electronically simulated under push-button control and played through the hi-fi system. ▲

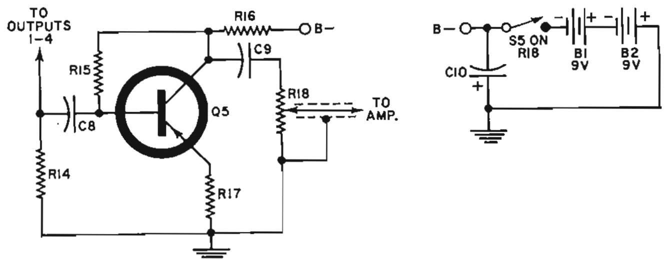


R1—68,000 ohm resistor
R2—1.2 meg resistor
R3—100 ohm resistor
R4—5000 ohm min. pot
R7, R8—56,000 ohm resistor

	DRUM	TOM-TOM	BONGO	BLOCKS
R5—	22,000	82,000	82,000	330,000 ohm res.
R6—	10,000	82,000	82,000	(Not used) ohm res.
R9—	2700	6800	6800	6800 ohm res.
R10—	2200	2200	2200	2200 ohm res.
R11—	82,000	22,000	27,000	(Not used) ohm res.
R12—	1 meg	0.56 meg	1 meg	1 meg ohm res.
R13—	2700	2700	2700	6800 ohm res.
(Note: All resistors are ½ watt, 10%.)				
C1—	.1	.047	.047	.047 μF cap.
C2—	.1	.01	.01	(Not used) μF cap.
C3—	.1	.047	.033	.01 μF cap.
C4—	.1	.027	.015	.0033 μF cap.
C5—	.1	.027	.015	.0033 μF cap.
C7—	.1	.1	.01	.1 μF cap.

C6—0.015 μF capacitor
(Note: All capacitors are dipped Mylar, 100 V.)
S1-4—Push-button switch (Switchcraft 961 or equiv.)
Q1-4—2N404, 2N107, or 2N109 transistor

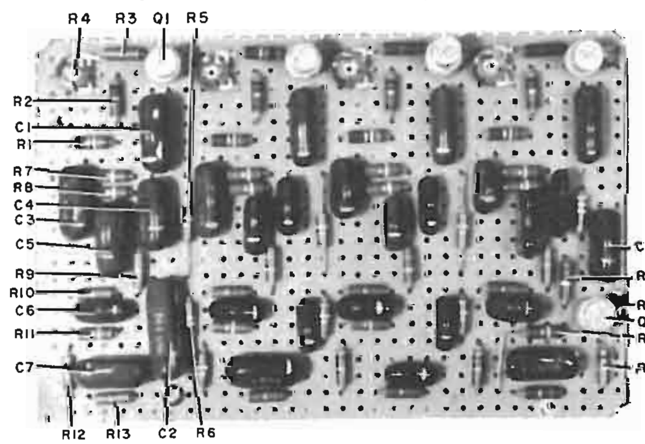
Fig. 2. Four of these one-shot twin-T oscillators are used.



R14—4700 ohm, ½ W resistor
R15—1.2 meg, ½ W resistor
R16—22,000 ohm, ½ W resistor
R17—100 ohm, ½ W resistor
R18—500,000 ohm min. pot
C8, C9—0.1 μF, 100 V cap.
C10—100 μF, 25 V elec. cap.
B1, B2—9 V transistor battery
Q5—2N107 transistor

Fig. 3. Output of this single-stage preamplifier can be applied to one of the inputs of a musical-instrument amplifier.

Fig. 4. All parts are mounted on perforated board. Components in one of the four identical oscillators and in the preamplifier stage have been called out in this particular illustration.



ELECTRONIC GUITARS and AMPLIFIERS

By DANIEL QUEEN / Chief Engineer, Audio Products
Perma-Power Co.

Starting from the vibrating strings and progressing through the pickup, amplifier, and loudspeaker, this article covers the various design parameters of this most popular of all electronic instruments.

THE electronic guitar has become a new instrument, not merely the old amplified. True, there are guitars with acoustic output that have amplifiers attached, and historically such combinations were the prototype of the modern instrument. Initially, the electronic guitar consisted of a contact microphone attached to the sound chamber of an ordinary mechanical guitar. The microphone was connected to a public-address amplifier which drove a jukebox speaker. In time, because the contact microphone picked up room sounds and was subject to acoustic feedback, the magnetic pickup was developed.

At first the pickups were attached to an ordinary guitar. Then, in some cases, the sound chamber was reduced in size and eventually eliminated, with the body serving only to support the instrument during use.

The Mechanical Guitar

The mechanical instrument has mass. It consists of lumps of matter which when at rest tend to stay at rest and which when in motion tend to stay in motion; that is, they have inertia. This mass is analogous to inductance in an electrical circuit, which also impedes a change in motion—electron motion. All solid matter also has elasticity. When a force deflects the material, the force is stored and will be returned later as a result of the property of elasticity. This is analogous to capacitance in an electrical circuit. These properties are combined into resonant networks to provide mechanical musical instruments with their characteristic tone or timbre.

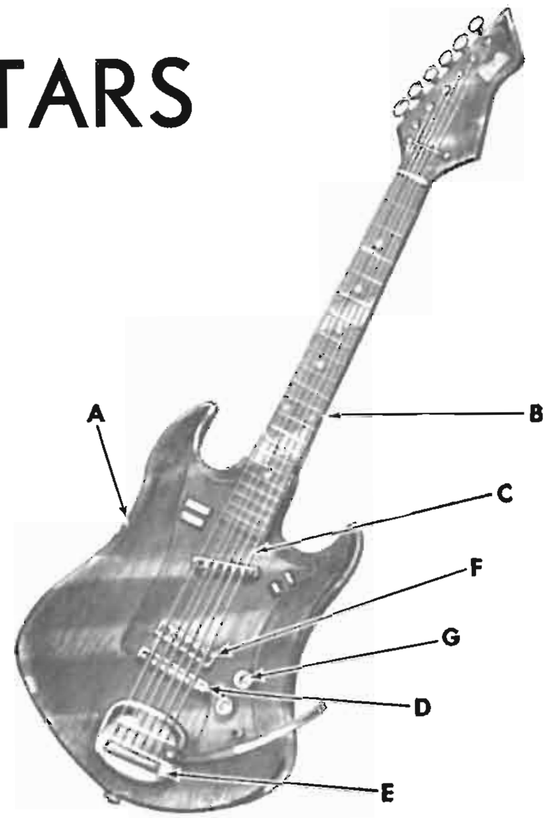
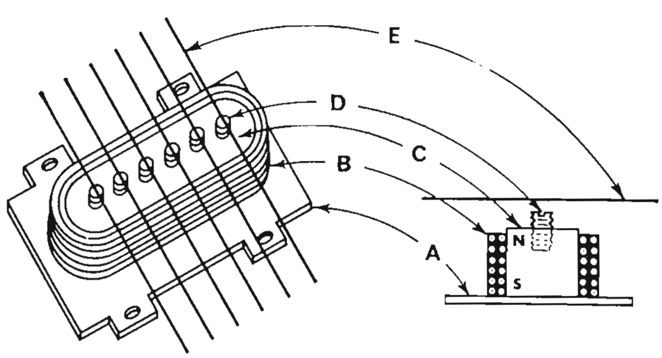


Fig. 1. Typical solid-body electronic guitar showing (A) body, (B) neck and frets, (C) strings, (D) bridge, (E) tailpiece and vibrato lever to change string tension, (F) pickup, (G) control.

Fig. 2. A guitar pickup with its non-magnetic metal housing removed showing (A) lower pole piece, (B) output voltage coil, (C) permanent magnet, (D) individually adjustable upper pole pieces, which are located under each of the separate strings (E).



Transient characteristics, that is, the sharpness of the attack and decay of tones, are determined similarly to the manner in which transient characteristics of electrical circuits are determined. A high-"Q" mechanical structure, having large mass and elasticity but with low frictional or viscous losses (analogous to resistance in an electrical circuit), can be expected to have poor transient response, just as a high-"Q" electrical circuit does.

In a musical instrument, such "poor transient response" may be the very characteristic which is desired. After all, what rings more than a bell, with its large mass and low viscosity?

All musical instruments produce sound from vibrating members, such as strings, reeds, columns of air, or the lips of the performer. To couple this vibration to the outer air, a mechano-acoustic system such as a horn, sounding board, or sound chamber is used. In a grand piano, the sounding board is very large compared with most of the wavelengths it must couple; hence, it is very efficient.

In a small instrument such as the guitar, the sounding board cannot efficiently couple the low-frequency tones. It must have additional help provided by structural and acoustic resonances built into the instrument. Small stringed instruments are in effect a series of closely coupled resonant circuits, spread across the tonal range of the instrument.

Pickups & String Motion

The advent of the electronic guitar made possible the removal of this restriction on the small plucked-string instrument. Fig. 1 shows the structure and important parts of a solid-body electronic guitar, one with no sound chamber.

The pickup (Fig. 2) consists of a magnet, with one pole toward and one pole away from the strings. Around this magnet a coil is wound. Some guitars utilize a single magnet and coil for all strings while others use separate magnets or pole pieces at each string or group of strings.

The vertical component of the string vibration varies the length of the air path for the flux and therefore varies the flux intensity. This varying magnetic flux, passing through a coil of wire, produces an output voltage representative of the string motion. Note that steel strings must be used for electronic guitars since the strings must influence the magnetic flux.

The string motion varies along its length. At the ends there is no motion, since the string is clamped. The greatest motion is possible at the center. The motion may be split into multiples on fractional sections of the string; such motions are harmonics of the string fundamental. The degree of their occurrence will depend upon the point of initial plucking and the width of the plectrum. In a mechanical stringed instrument, these harmonics will cause the bridge of the instrument to twist, coupling the vibrations to the sound chamber. In this path, the masses act as series inductances, attenuating the upper harmonics and integrating the attack and decay transients.

In an electronic guitar, only that part of the string which is vibrating above the pickup will have its motion reproduced as sound. All harmonics and transients present at the pickup can be converted to electrical output, if desired. Referring to Fig. 3, we see the vibration of a string at its fundamental and at its second and third harmonics. From this it may be seen that the tone of the guitar can be varied by positioning the pickup.

If the pickup is near the center of the string, it will produce more of the fundamental and lower harmonics, and this will result in a mellow sound. If it is placed near the end of the string, it will pick up more of the upper harmonics, and this will result in a sharper sound. Most guitars now in use have at least two pickups which are used either alone or in combination. Some guitars are available with five or more pickups. Others have separate selectable pickups for the low and high strings. Proper pickup location is important in producing the proper tone color (Fig. 4).

The Power Amplifier and Loudspeaker

The pickups are designed to work into a high-impedance input of an amplifier. This amplifier must be capable of producing the dynamic and frequency range of the instrument and must have very good transient overload recovery.

Generally, an inexpensive amplifier that uses negative feedback will be on the verge of oscillation at a certain low and high frequency. A transient containing one of these frequency components will cause a damped oscillation, the amplitude of which may overload the amplifier, blocking it and causing severe unpleasant (non-harmonic) distortion. A guitar amplifier must be designed with these conditionally stable frequencies well outside the range of the guitar. Since the guitar tones come in bursts at much lower frequencies than the tones themselves, the amplifier must not oscillate at the burst frequencies.

Because the guitar amplifier is frequently being overloaded, it must have good transient recovery. The frequent occurrence of high-level, low-frequency tones together with high-level, high-frequency tones requires the amplifier to have low intermodulation distortion.

Only in frequency response is the guitar amplifier not required to match the usual high-fidelity amplifier. It is, in fact, desirable to design the amplifier with a narrower frequency response to improve transient stability. The lowest string fundamental on the electronic guitar is about 80 Hz. On the electronic bass guitar, the lowest string is 40 Hz. The highest string when fretted all the way down can produce a fundamental frequency of about 1300 Hz; it is doubtful that anything over the sixth harmonic of this string is worth reproducing, especially since the seventh harmonic is discordant. Thus, if one took the sixth harmonic of the upper string as the high limit, the required frequency response would be 40 Hz to 8 kHz.

There are two approaches to the loudspeaker system. It can either faithfully reproduce the vibration of the string above the pickup or it can be used to modify or color the tone.

First, a loudspeaker system can modify the tone by introducing its own resonances, much in the way the sound chamber introduces resonances in the mechanical instrument. Second, it can introduce non-linearities; that is, it can produce harmonic frequencies.

However, the loudspeaker is generally a single device, whereas a mechanical sound chamber is a multiplicity of structures, each responding differently. If a low tone and a high tone are struck on the mechanical instrument, they will excite different parts of the structure which will not interact harshly. In a loudspeaker, both tones move the same cone structure so that there will be interaction and possibly intermodulation distortion. For this reason, a guitar amplifier using a single loudspeaker designed with many resonances and non-linearities must be played carefully. Low-rhythm passages must not occur simultaneously with the high melody line. The use of well-spaced chords or bass figures while playing melody thus becomes nearly impossible. This

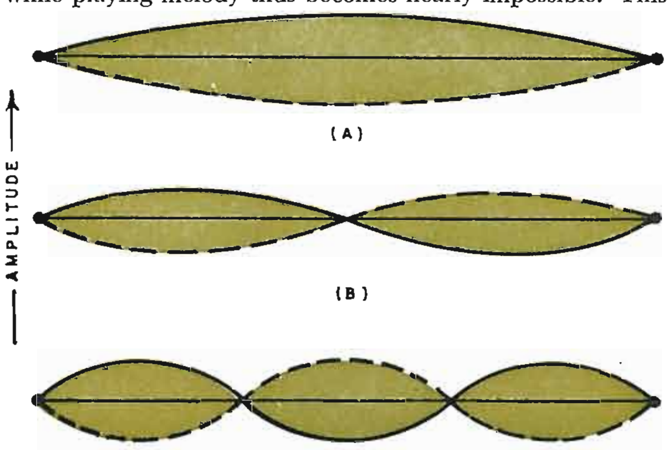
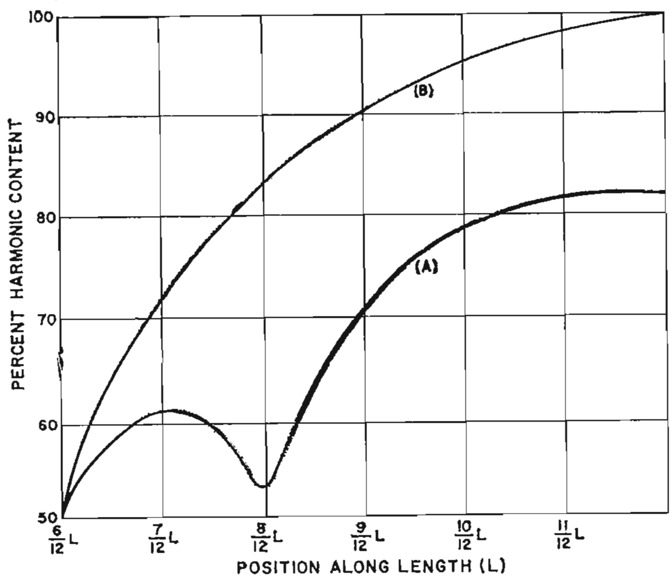


Fig. 3. The first three vibration modes of a stretched string are (A) the fundamental half-wave, (B) second, and (C) third harmonics.

Fig. 4. As the pickup is moved closer to the bridge, the harmonic content is increased. Curve (A) shows the harmonic content when the fundamental and second and third harmonics are excited equally. Curve (B) is for fundamental and infinite harmonics.



tends to further proscribe the playing style of the performer.

Furthermore, any system containing high-"Q" resonances must also have poor transient response. The sharp attack which is possible from the string and pickup system is no longer attainable, even if it is desired. It would be desirable, therefore, to use a loudspeaker having low distortion and few resonances. To obtain this, a thick, light cone is called for, and the speaker system must be able to handle the extremely high values of peak power that are produced.

How, then, can timbre and tonal effects be generated? Let us look at the non-linearity in the speaker (Fig. 5) which is graphed in Fig. 6. Low-amplitude signals are produced with little distortion, while high-amplitude signals are distorted. The low frequencies, which produce greater amplitudes of cone motion, will be distorted, while higher frequencies will not. The low tones, therefore, will be pleasantly rich in harmonics. The problem comes when the performer tries to play the high and low tones simultaneously. The high frequency is modulated by the low, producing non-harmonic raucous tones as shown.

To eliminate this, a separate loudspeaker for each range of tones could be used, but one would end up with at least one loudspeaker and crossover for each string. A better solution would utilize that which *can* be separate for each string—the pickup and its position.

From Figs. 4 and 6, one can see that the harmonics produced due to non-linearity and those produced due to off-center pickup position are very similar and will generate the same sound.

As the string is fretted to a higher frequency, the harmonic content will reduce, as it does in the non-linear loudspeaker. This is because the pickup is proportionally at a greater distance from the guitar bridge with respect to the length of the vibrating string.

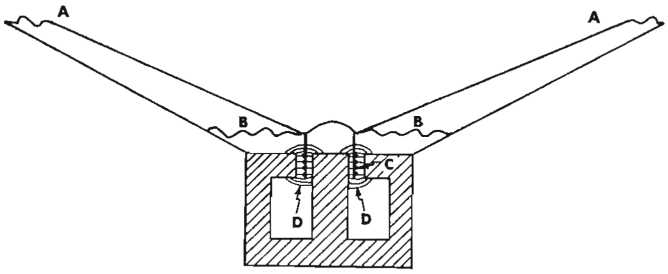


Fig. 5. A direct-radiator loudspeaker showing possible sources of non-linearity. The annular surround (A) or the spider (B) may be stretched beyond the point where they act as simple springs. Also part of the voice coil can move out of the magnetic gap at (C) and into the less dense leakage flux at (D).

Fig. 6. Loudspeaker non-linearity effects. A high-frequency signal (A), which is handled on the linear portion of curve, produces an undistorted output (D). A low-frequency large amplitude signal (B) may shift the operating point and produce the non-linear waveform at (E) which now contains harmonics. When both signals occur at the same time (C), the resultant at (F) contains harsh intermodulation distortion, shown alone (G).

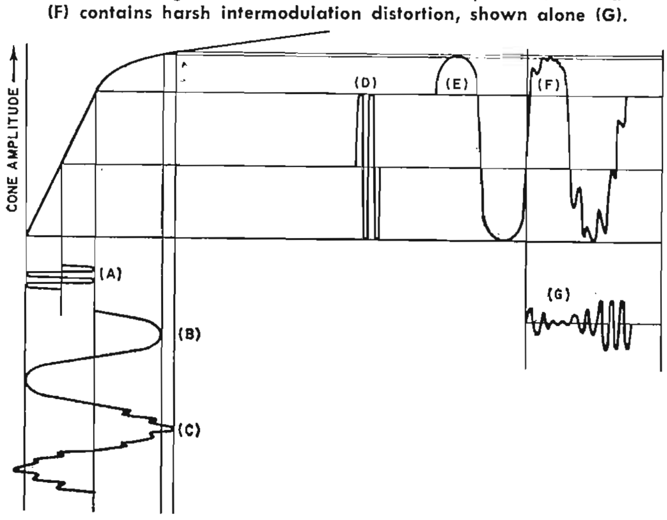


Fig. 7. The "Ampli-vox Baronet" guitar amplifier shown here has an output power of 5 watts and stands only 10-in high.

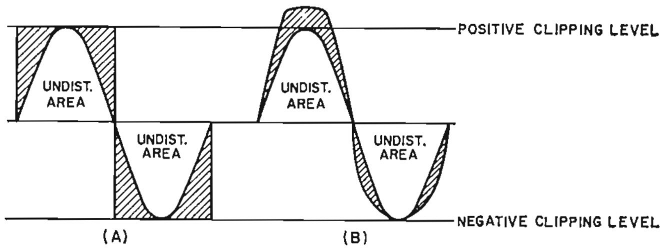


Fig. 8. (A) Amplifier that overloads in this manner with sharp clipping results in output containing many dissonant harmonics. (B) If clipping can be "softened" resulting in smoother waveform, as shown here, then the amount of dissonance is reduced.

Hence, judicious placement of the pickups, together with switching of the correct pickups by the musician, will produce the same timbre as harmonics intentionally added in the speaker system. Yet, because the sound originates at each individual string, the intermodulation distortion will be even less than that which can be obtained by having individual speakers for each tonal range.

Power Output and Overload

A large 100-watt system with 300 square inches of speaker cone area, while needed in a night club or concert hall, could hardly be used in a small practice room. On the other hand, a five-watt system (Fig. 7) will fill the practice room with as high a sound pressure level as the larger unit will produce in the concert hall.

Moreover, the two amplifiers, in their respective settings, can be designed to overload at almost the same sound level. The nature of this overload is of prime importance to the musician. Because the instruments are usually played in continuous overload for popular music, the overload characteristic must be carefully designed. It must result in the sound of harmony rather than distortion.

In Fig. 8, we see a sine wave that just reaches the clipping level of an amplifier. The sound intensity is the unshaded portion of the waveform. When the amplifier is fully overloaded, the shaded portion is added to the waveform, resulting in additional sound intensity. An amplifier with large amounts of negative feedback will produce a square wave at maximum overload (Fig. 8A), with 33% third harmonic, 20% fifth harmonic, 14% seventh harmonic, 11% ninth harmonic, 9% eleventh harmonic, etc.

In musical terms, the fundamental, third, and fifth harmonics are a non-dissonant spaced-triad chord consisting of the root, a doubled fifth, and a twice-doubled third, but the seventh, ninth, and eleventh harmonics are dissonant.

Table 1 shows the musical relationships of the harmonics. Tabulating the dissonance ratings of the odd harmonics in a square wave as shown yields a total rating of 12. On the other hand, the even harmonics of a rectified sine wave over this same approximate range of harmonics total only 4. Therefore, the best manner of overloading would *not* be one producing the familiar sharp clipping; instead, an overload waveform as in Fig. 8B containing a low dissonance rating is to be preferred.

The problem of overload characteristics is most acute for low notes, since their upper, dissonant harmonics are in a more sensitive region of the hearing curve. On higher notes, the upper harmonics are barely heard due to the lack of high-frequency response in the system.

The one component that will overload differently at low frequencies is the loudspeaker, as we have seen. For this reason, some amplifiers use speaker non-linearity to produce a favorable overload waveform. Often this is done by providing more undistorted amplifier power than the speaker can handle, consequently shortening the life of the speaker.

Another, more flexible method of softening the clipping at low frequencies involves the audio transformers. Fig. 9 shows the magnetization curves of a transformer core at middle and low frequencies. Note that the curve (A) is similar to the curve in Fig. 4B. When overload occurs at low frequencies, then, the waveform is rounded off instead of being sharply clipped. In class-B transistor amplifiers, non-linear *beta* will also serve this same purpose. However, this method may also result in high distortion at lower levels. Whatever method of overload characteristic modification is used, it is clear that the amplifier design certainly cannot stop at the clipping point.

Rating the Power Output

Because of the above considerations, the meaningful power rating of a guitar amplifier is not the steady-state sine-wave output, but rather the maximum output—distorted. Since the amplifier does not overload symmetrically, this is not simply a peak square-wave power output—or twice the sine-wave power—but is, instead, a function which will produce greatly differing readings depending upon the method of measurement. Hence manufacturers, with some justification, often base power ratings on the highest voltage obtainable with a peak-reading voltmeter.

The power from the output stage thus obtained is not yet a true measure of the performance of the system. Differences in speaker efficiencies can easily produce loudness differences equivalent to a factor of three in output stage power. A true comparative measurement would have to use the sound pressure level (SPL) produced by the loudspeaker.

For this reason, new "Ampli-vox" equipment is rated in maximum sound pressure level obtainable with pink noise (40 Hz to 8 kHz) input to the amplifier. The amplifier is placed in a reverberant room with a sound-level meter set on the "C" weighting curve. The inputs and controls are adjusted to give the highest reading with the noise input. To convert the reading of the meter to SPL in dB's at the loudspeaker, the reverberation time of the room must be measured using the amplifier for a sound source. From it, the absorption (a) can be calculated. The sound pressure level in dB above 0.0006 dyne/square centimeter is then expressed as follows: $\text{SPL} = \text{meter reading} + 10 \log_{10} a$.

The sound chamber of the mechanical instrument provides a musical effect in addition to coupling to the air. It allows the tone to sustain itself after the string is plucked. Having no sound chamber, the solid-body electronic guitar requires a method for obtaining *legato* effects. If we are avoiding multiple speaker resonances, a wide-range reverberation system provides a ready method.

Harmonic	Frequency (Hz)	Note	Degree	Dissonance Rating
1st	261.5	C	Root	0
2nd	523.3	C^1	Octave or doubled root	0
3rd	784.0	G^1	Doubled fifth	1
4th	1047	C^2	Octave or twice-doubled root	0
5th	1319	E^2	Twice-doubled third	2
6th	1568	G^2	Twice-doubled fifth	1
7th	1830	$A^{\#2}$	Twice-doubled augmented sixth	3
8th	2093	C^3	Octave or thrice-doubled root	0
9th	2350	D^3	Thrice-doubled second	3
10th	2630	E^3	Thrice-doubled third	2
11th	2878	$G^{\flat 3}$	Thrice-doubled diminished fifth	3
12th	3136	G^3	Thrice-doubled fifth	1
13th	3400	$A^{\flat 3}$	Thrice-doubled diminished sixth	3
14th	3663	$A^{\#3}$	Thrice-doubled augmented sixth	3

Table 1. Musical relationships of harmonics in key of C-major. Dissonance rating is based on classic theory of harmony. 0 indicates perfect consonant octave; 1 indicates perfect consonant fifth; 2 indicates imperfect consonance; 3 shows dissonance.

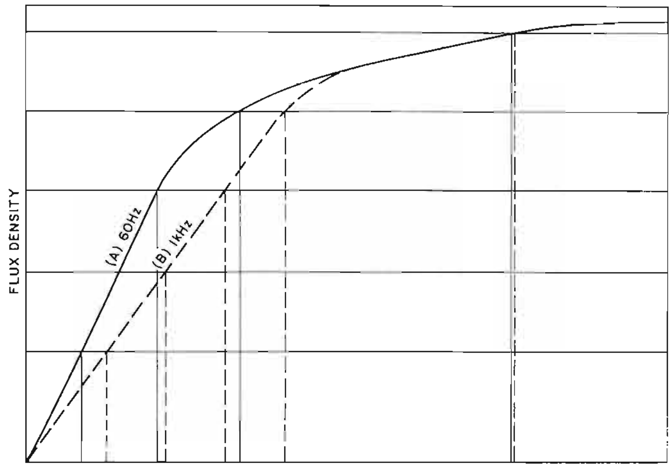


Fig. 9. Transformer core magnetization curves for two frequencies.

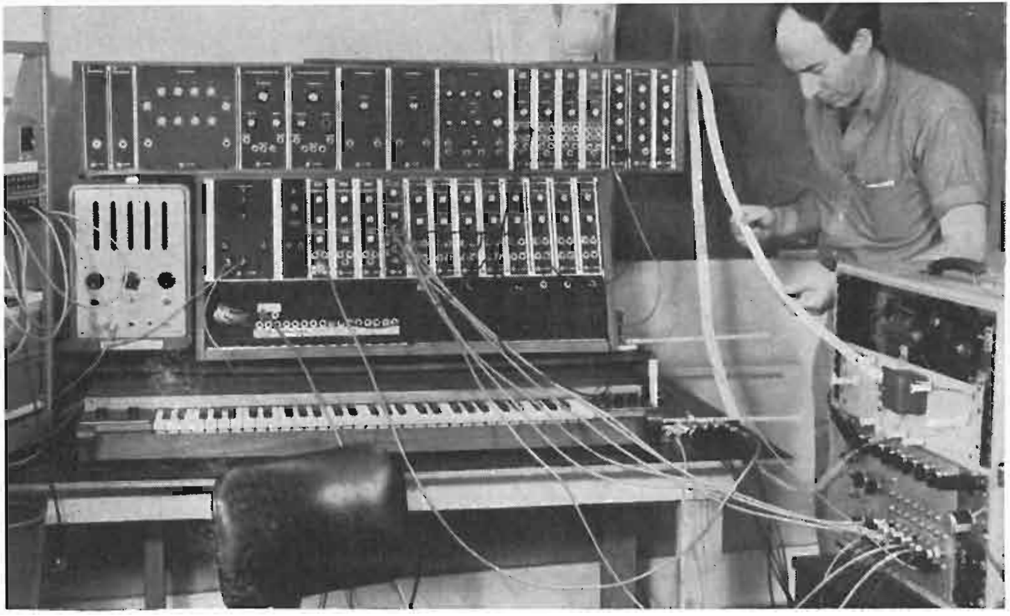
Most reverberation systems used in guitar amplifiers merely provide a large concert-hall effect because of the frequency response of the reverberation units. Fortunately, a depth control is included so that a slight amount of this reverberation can be made to sound fairly constant with frequency.

Ideally, the reverberation would vary as the mass of the string being played varies, so that one would have an effect similar to that obtained by the use of the damper pedal on a piano.

Interested in further increasing the versatility of their instruments, guitarists have demanded another form of tone modification—*tremolo* or *vibrato*. Both tremolo and vibrato are modulation of the carrier by a sub-audible frequency, usually in the range of 4 to 12 Hz. The method of modulation varies and will change the character of the tone.

In many cases, vibrato (frequency modulation) is accomplished by means of a lever attached to the tailpiece of the guitar. When this lever is moved back and forth by the player, it changes the pitch of the instrument to produce the desired effect. Tremolo (amplitude modulation) is often produced by means of a low-frequency oscillator in the guitar amplifier that modulates the output signal. Usually, both the frequency and depth of the modulation can be varied by the user. Some more expensive amplifiers use phase modulation in the high frequencies and amplitude modulation in the low frequencies.

Other methods of tone modification are also employed. Tone controls ranging all the way from a single treble boost and cut control to multiple bandpass filters are used. ▲



Composer Emmanuel Ghent in the studio of the Independent Electronic Music Center. The paper-tape reader at the right is being used to program the voltage-controlled instruments at the center. The frequency counter, which is located at the left, is employed to check on the accuracy of the program that is used.

By
ROBERT A. MOOG

ELECTRONIC MUSIC—
Its Composition & Performance

Introduced less than 20 years ago, this new type of music is rapidly assuming increasing importance to contemporary composers. This article describes the circuitry of some recently introduced electronic music-composing instruments and shows how these are employed to articulate this new musical language.

THE technology of electronics is ideally suited for application to the production (composition and performance) of music, as well as to its reproduction (broadcasting and recording). Music is, after all, a medium of communication between composer and listeners; it should permit the composer to produce any sound, or series or combination of sounds, to convey his musical message. The parameters of the sounds composers wish to control are basic to electronics: frequency, waveform, formant, amplitude, and duration. Oscillators, filters, amplifiers, and other electronic circuits capable of controlling musical parameters have been used extensively in all applications involving the generation and processing of analog (continuously varying) signals: radio and TV, analog computers, medical electronics, and many more. With some straightforward engineering and a little imagination, one can adapt familiar electronic circuits and systems concepts to the design of musical instruments, thereby greatly expanding the range of available sounds and increasing the composer's ability to control the sound parameters.

However, the language of music—the way in which sounds and sound patterns are used to convey messages—develops and changes slowly. The musical tastes of most of us are geared to the composers who lived and worked before this century. "Modern" music may tend to sound dissonant or unpleasant because the "meanings" of the sounds are generally different than those of earlier music.

A direct result of this reluctance to depart from established musical values is that musicians and the listening public have generally been slow in accepting new electronic musical instruments. Early instruments such as the Theremin, played by the free movement of the performer's hands in the space surrounding it, and the keyboard-controlled Ondes Martenot have been successfully used as solo instruments in the performance of orchestral music, but these instruments have not been accepted as the important additions to musical-instrument technology that they in fact are.

Actually, with very few exceptions, the only electronic musical instruments which have achieved commercial importance are those which are direct imitations of traditional instruments. These include monophonic (single-voice) instruments, such as the "Solovox" and the "Ondioline," and polyphonic instruments such as electronic guitars and the vast number of electronic organs now so aggressively competing with the piano for the place of honor in the home living room. Although we are generally familiar with these instruments, we would not say that they have revolutionized the language of music.

While the listening public is slowly adjusting its musical tastes in response to new developments, creative musicians are experimenting and pioneering in still newer musical languages. One of these new languages, the development of which began less than twenty years ago, is called "electronic music" and is assuming rapidly increasing importance to contemporary composers. This article will define electronic music and reveal how it is composed. It will also describe the circuitry of some recently introduced electronic musical instruments and show how they are employed in the articulation of this new musical language.

Classical Electronic-Music Composition

The introduction of the magnetic tape recorder immediately after the Second World War gave the composer the ability to store previously produced sounds and to physically shape and arrange them (by tape editing) into a musical composition. Recording media other than tape (disc and wire recording) existed before the tape recorder. However, no recording medium provides the high fidelity and editing ease of tape.

The tape recorder, used as a composing instrument, opened the door to electronic-music composition as it is usually practiced today. For the first time, the composer could create an entire finished composition and would not have to depend on performers to interpret his "message." He could use any sound that could be recorded or electronically generated. He could electronically process natural sounds in many different ways. He could compose series of sounds more closely and accurately spaced in time than any live performer could possibly produce. And finally, he could listen to his completed composition and change portions of it until he was satisfied with the finished product. Each of these possibilities could not have been conveniently realized before the advent of the tape recorder. Together, they constitute an entirely new and expanded means of musical expression—the central feature of electronic music.

At the present state of development, electronic music is defined as *the electronic generation and processing of audio signals, or the electronic processing of natural sound, and the manipulation and arrangement of these signals via tape recorders into a finished musical composition.* Although new techniques (to which the above definition may not apply) are being developed, the present definition specifically excludes the performance of traditional music on electronic instruments.

An electronic-music composer works in a studio which usually contains electronic signal generators (audio oscillators, white-noise generators), signal modifiers (filters, modulators, amplifiers, reverberation units, etc.), mixers, and at least two tape recorders. In general, all inputs and outputs are brought to a patch panel or other signal-routing facility so that the composer can set up connections between his instruments according to his requirements. A good set of power amplifiers and speakers, which enables the composer to hear exactly what he is producing, completes the basic studio equipment.

The first studios established in the United States were designed around instruments then commercially available. Laboratory test oscillators, white-noise generators, and filters, as well as commercial audio mixers, patch panels, and recorders, were installed. Variable gain amplifiers and assorted modulating devices were built from designs based on circuitry originally developed for communications equipment.

In order to work with such equipment, a composer carefully and patiently sets the operating parameters of each instrument (*e.g.*, frequencies of the oscillators, bandwidths of the filters, etc.) to achieve the desired sound and then records the sound. The segments of tape containing the sounds are then spliced together, one at a time, to produce the finished composition. This method of composition is now called "classical studio technique." A simplified block diagram of a typical classical studio is shown in Fig. 1. The University of Illinois electronic music studio, which is basically a classical studio, is shown in Fig. 2.

Voltage-Controlled Instrument Techniques

Classical studio technique has the advantage that composers can easily understand and master the processes involved. These include electronic tone and white-noise generation, filtering, modulation, amplitude control, reverberation, and tape manipulation—the "alphabet" of the new language of electronic music. However, classical composition tends to be tedious and time-consuming because each sound event must be generated and recorded individually. Moreover, it is difficult to produce complex, dynamically varying sounds with conventional laboratory and commercial audio equipment. New developments in equipment for electronic-music composition have therefore been directed at reducing the limitations of classical studio technique.

Engineers and composers now acknowledge that the consistent and systematic use of *voltage-controlled* instruments simplifies both the generation of complex, dynamically varying sounds and the arrangement of these sounds into a composition. *A voltage-controlled instrument has one or more operating parameters determined by the magnitude of an applied control voltage rather than by the settings of the panel controls.* It is generally easier to change a voltage rapidly and precisely than it is to reset panel controls with equal speed; also, the problems of changing the operating parameters of the instruments are reduced to the simpler problem of changing the control voltages determining the values of the parameters. Of course, in order to take full advantage of the benefits of voltage control, controlled instruments must have a fast speed of response and an accurate relationship between the magnitude of the control voltage and the controlled parameter.

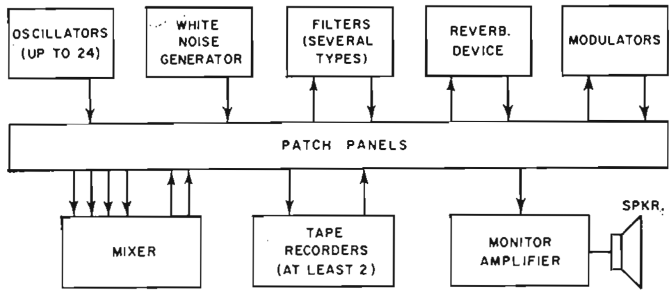


Fig. 1. Block diagram of a classical electronic music studio. Most such studios have used standard lab or audio instruments.

Three important classes of voltage-controlled instruments are now widely used by electronic-music composers: *oscillators, filters,* and *amplifiers.* A voltage-controlled oscillator (v.c.o.) may produce *audio signals* whose pitch is determined primarily by the frequency of oscillation and whose tone color is determined by the waveform and type of frequency modulation. V.c.o.'s are also used as *control-voltage* generators to periodically modulate other voltage-controlled devices. Finally, timing of musical events may be achieved by using the output of a slowly oscillating v.c.o. to *trigger* (initiate) the events.

Fig. 3 shows a simplified schematic diagram of a wide-range, high-quality v.c.o. Several control inputs are provided so that more than one type of frequency variation may be accomplished simultaneously. For instance, a slowly varying periodic voltage may be applied to one control input while the voltage at another input is stepped in fixed increments. The resulting output would then sound like a musical scale with vibrato (frequency modulation). The control voltages are added and a current I_o proportional to the exponential of the control-voltage sum is derived by two operational amplifiers. These circuits, which are shown in block form in Fig. 3, borrow their design concepts from analog computer technology. The exponential dependence

Fig. 2. University of Illinois Experimental Music Studio. Generating and processing equipment is on left, mixing and routing controls are in center, and the recorders are at the right.

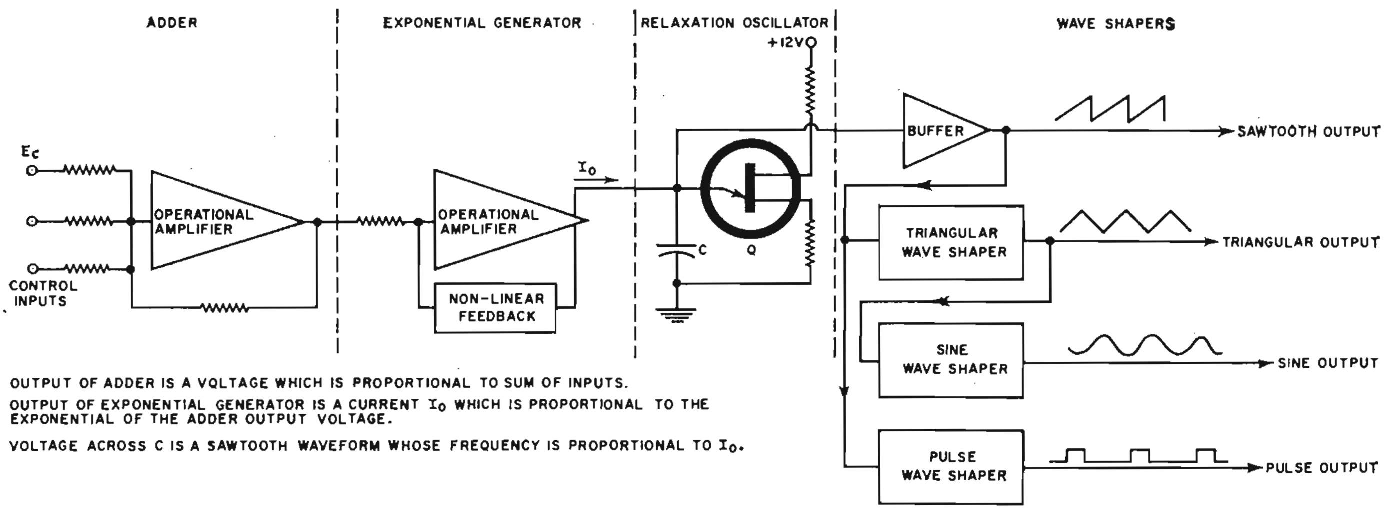


Fig. 3. Diagram of a wide-range, fast-response voltage-controlled oscillator along with the output waveforms.

of the output current I_o upon the control-voltage sum means that I_o will change by a certain *ratio* for a given *increment* in control-voltage input change.

In virtually all musical uses of periodic signals, frequency ratios rather than absolute frequency differences are important. In fact, a given musical pitch interval is nothing more than a fixed frequency ratio. An interval of an octave is a frequency ratio of 2:1; an interval of a semitone (the smallest interval in the common tempered scale) is a frequency ratio of 1.059:1 (1.059 is the twelfth root of 2). Musicians can easily understand this constant of proportionality between control-voltage change and frequency ratio: a one-volt increase in the control voltages will double the frequency (increase it an interval of an octave); a 1/12-volt increase in the control voltages will therefore increase the frequency one semitone. Thus, all tones in the tempered scale will be generated by integral numbers of 1/12-volt increases in the control voltage. Other scales can be generated with different patterns of control-voltage change.

The output current I_o is used to charge timing capacitor C. This capacitor is discharged by unijunction transistor Q whenever it reaches the unijunction's breakdown voltage. The resulting voltage across C is a linearly rising saw-tooth whose frequency is proportional to I_o and therefore proportional to the exponential of the sum of the control-voltage inputs. With careful design and component selection, it is possible to build v.c.o.'s whose exponential-frequency/control-voltage relationship is musically accurate over a 6-octave (64:1) frequency range and still useful over a 10-octave (1000:1) frequency range.

The saw-tooth waveform appearing across C is itself extremely useful in synthesizing musical sounds, since it contains all of the integral harmonics of the fundamental frequency of oscillation. Subsequent filtering, which attenuates some harmonics and boosts others, is generally used to impart one of a wide variety of tone colors to the signal. However, additional waveshaping may be employed to change the saw-tooth waveform into entirely different waveforms.

Three waveforms which are also musically useful are the sine, triangular, and pulse waves. The sine ideally contains no harmonics other than the fundamental frequency. Its sound lacks brightness and, in terms of harmonic structure, is the simplest of any signal. The harmonic content of the triangular wave is only 12% of the total and consists entirely of the odd harmonics. Its sound is muted and hollow like that of a flute. Finally, the spectrum of the pulse waveform depends upon the relative widths of the positive and negative portions of the wave, but it is characterized by the absence of certain harmonics within the spectrum. For instance, when the positive and negative portions of the wave are of equal width (*i.e.*, when the waveform is a square wave), then all the even harmonics drop out, and the spectrum consists only of odd harmonics. The pulse may be used in synthesizing a wide variety of orchestral colors, from the violin to the clarinet, depending upon the relative widths of the two parts of the waveform.

The triangular, sine, and pulse waveform circuitry are indicated in block form in Fig. 3. All the waveform outputs are available simultaneously and additional timbral effects may be achieved by mixing two or more waveforms.

Voltage-Controlled Amplifiers

After frequency and duration, amplitude is the most important musical parameter. A voltage-controlled amplifier (v.c.a.) capable of varying an audio or control voltage is shown in Fig. 4. Like the v.c.o., the v.c.a. shown here incorporates an adder and exponential generator to process the control inputs. The amplitude-controlling elements are $Q1$ and $Q2$, a matched pair of junction transistors. These transistors are driven by an input buffer with very low output impedance.

Junction transistors have the characteristic that a given base-to-emitter voltage change will result in fixed *percentage* collector current change, regardless of the magnitude of the average collector current. Thus, as the standing current in the transistor is increased, the absolute collector current change for a given base-to-emitter voltage change will increase proportionally.

In the circuit in Fig. 4, the constant base-to-emitter voltage is assured by the low output impedance of the input buffer. The combined standing current through $Q1$ and $Q2$ is I_o. The collector current variations appear across $R1$ and $R2$ as voltage variations and are amplified further in the output buffer stage. Thus, the gain from signal input to signal output is proportional to I_o, which in turn is proportional to the exponential of the sum of the control input voltages. This means that the gain will increase by a given ratio for a certain incremental increase in the control input voltage. The relation between gain and control voltage is set so that a one-volt increase in the control sum will increase the amplifier gain by 12 dB. With careful selection of components, the v.c.a. control characteristic will be accurate over an 80-dB range.

The signal portion of the v.c.a. is entirely balanced so that rapid gain changes can be affected without common-mode level shifts appearing at the output. This is especially important in synthesizing percussive sounds or other sounds which change rapidly in level. In addition, the v.c.a. is entirely direct-coupled so that slow-moving control signals as well as audio signals may be processed.

Voltage-Controlled Filters

With slight additional circuitry, the v.c.a. shown in Fig. 4 can be converted into a voltage-controlled filter (v.c.f.). One very useful type of v.c.f. is shown in Fig. 5. The adder, exponential generator, input buffer, and control transistors Q1 and Q2 are the same as those in Fig. 4. The collector currents of Q1 and Q2 may be thought of as passing through four more transistor pairs (Q3 to Q10).

The inputs to each of these pairs are shunted with fixed capacitors C. At low frequencies, the reactance of the capacitor is much higher than the emitter-emitter resistance of the transistor pair, and the signal passes up the "ladder" of transistors with little attenuation. At high frequencies, however, the signal is shunted around the emitter-emitter input and is sharply attenuated by the time it "emerges" from the collectors of Q9 and Q10. Thus, the filter in Fig. 5 is a low-pass filter.

The cut-off frequency is that at which the reactance of the capacitor is equal to the emitter-emitter resistance of the transistor pairs. The capacitors are fixed and the input resistances of the transistor pairs are varied by changing the control current I_o. The filter is capable of accurate variations of cut-off frequency over a *three-decade* (1000:1) frequency range. The relationship between the cut-off frequency and the control voltage is exponential and is set so that it will be exactly the same as the relationship between the v.c.o. oscillation frequency and control voltage: a one-volt increase in the sum of the control voltages will double the cut-off frequency.

The signal currents are "read out" across the emitter-emitter resistance of Q9-Q10. The variation of this resistance with I_o is just right to ensure that signals of frequencies below the cut-off frequency remain constant in amplitude as I_o changes. The gain of the output buffer is set so that the "insertion loss" of the v.c.f. as a whole is zero dB.

The addition of feedback resistor R_F introduces a narrow resonant peak in the response of the filter at the cut-off frequency and thus converts the v.c.f. from a low-pass to a resonant filter. When a "noisy" sound with many frequency components is passed through a resonant filter, the output sounds pitched, the apparent pitch being close to the resonant frequency of the filter. A voltage-controlled resonant filter thus allows the composer to work with virtually any sound in producing pitch patterns.

Control-Voltage Generators

With voltage-controlled oscillators, amplifiers, and filters, it is possible to synthesize virtually any musical sound merely by generating a few simple control-voltage waveforms. A modern electronic-music composition system contains, in addition to the voltage-controlled devices, a variety of control-voltage generators.

The most important of these are the *transient generators*, which produce voltages which rise to a specified level with one time constant and later decay back to zero with another time constant. These transient control voltages are of great value in producing rapid changes in frequency, formant, or amplitude. In synthesizing a trombone sound, for instance, it is essential that the sound start off with low harmonic content. This is produced by applying a rising transient control voltage to the v.c.f. so that the filter first allows through only the fundamental of a waveform of high harmonic content and then allows through the harmonics. Conversely, the sound of a plucked string (for instance, a guitar sound) is synthesized by beginning with a tone of high harmonic content and then rapidly reducing the amplitudes of the harmonics. A falling transient control voltage is applied to the voltage-controlled filter in order to produce this effect.

In addition to transient control voltages, periodic control voltages (from oscillators) are useful in imparting frequency modulation (vibrato, trill, and other less conventional effects) to a v.c.o., and amplitude and formant modulation to a v.c.a. and v.c.f., respectively. Random control voltages, derived from white noise, are used to introduce uncertainty to any of the voltage-controlled parameters, thus adding aural interest to an otherwise steady tone. Finally, specialized function generators, such as staircase generators, are used as control voltages to create distinctive patterns of parameter variations.

Control-voltage changes from transient generators, oscillators, random voltage generators, and special-function generators create an enormously wide variety of dynamic parameter variations.

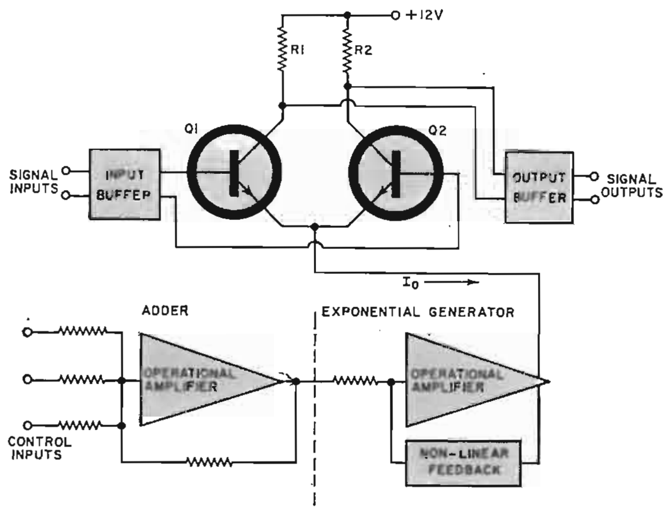
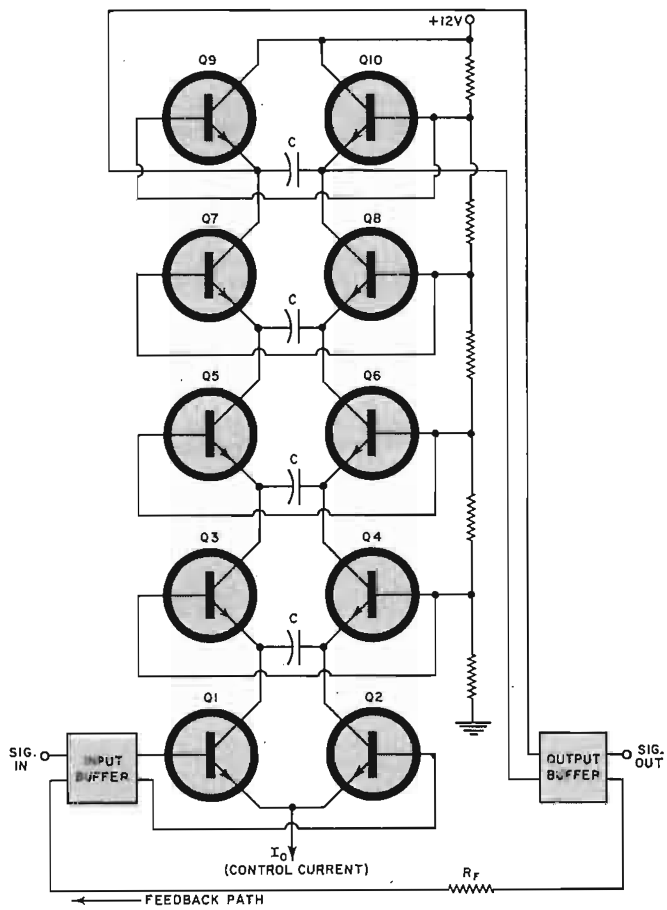


Fig. 4. Direct-coupled, balanced voltage-controlled amplifier.

Fig. 5. Voltage-controlled low-pass filter. The introduction of R_F changes filtering mode from that of low-pass to resonant.



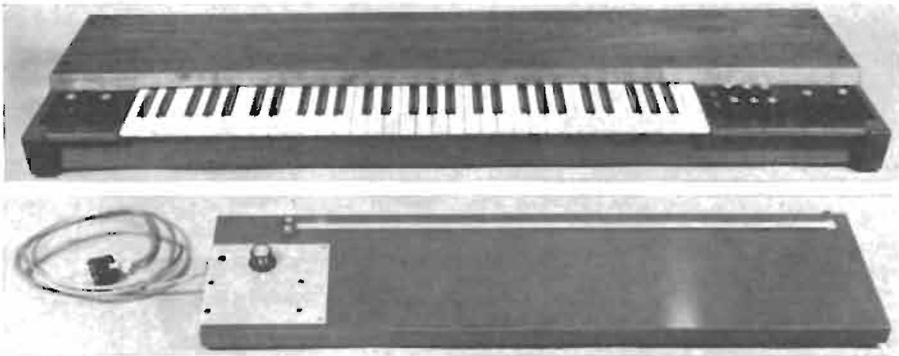


Fig. 6. (Top) Keyboard controller. Although the keyboard itself is a standard organ keyboard, the control-voltage output may be employed to control musical parameters other than the pitch. (Bottom) Linear controller. The musician slides his finger along the taut band to determine the control-voltage output.

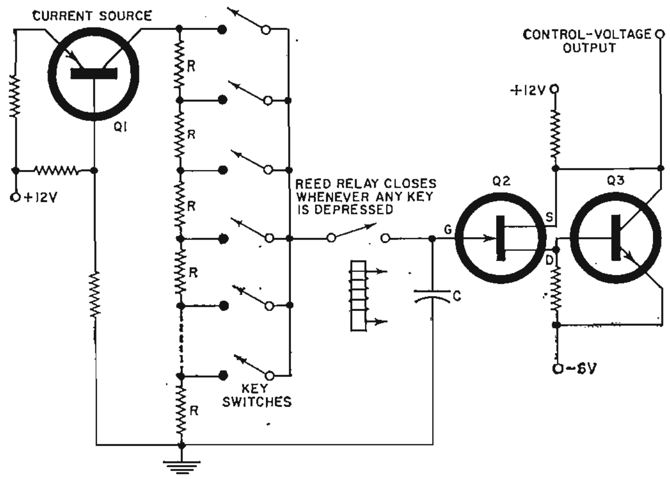


Fig. 7. Electronic circuitry of keyboard controller in Fig. 6.

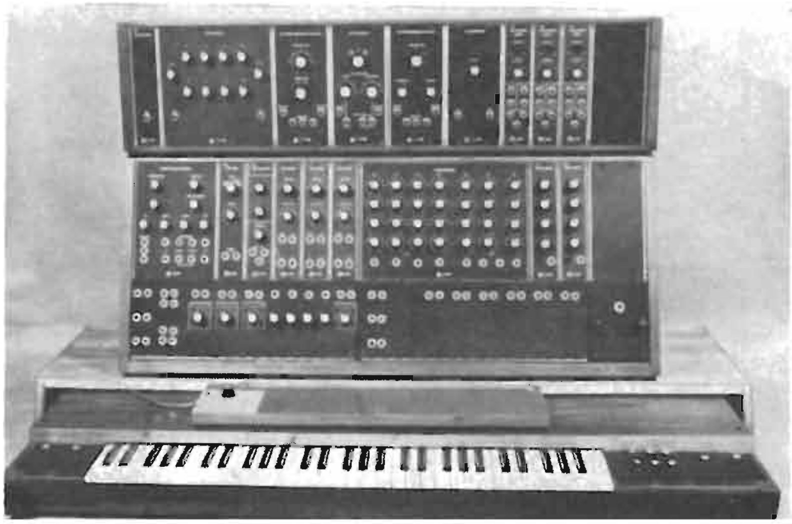
The use of rapid, regular control-voltage patterns results in sounds which are perceived as having characteristic complex qualities rather than clearly varying parameters. Only slowly varying control voltages result in distinct changes in musical parameters.

Devices for producing these all-important control voltages may be either manually operated or pre-programmed for automatic composition. Two types of manually operated control devices are shown in Figs. 6 and 7. Fig. 7 is a schematic diagram of a manual controller which produces one of 61 discrete, equally spaced control voltages. A constant-current source consisting of $Q1$ and its associated components supplies current to a series of resistors R. Each key switches in one tap on the divider string. The voltage at the tap is used to charge capacitor C through the reed relay which closes whenever any key is depressed. When the key is released, the reed relay opens and the capacitor holds its charge until the next key depression recharges it to a different value. A very high input impedance unity-gain amplifier, consisting of field-effect transistor $Q2$ and junction transistor $Q3$, delivers a control voltage equal to the voltage across C to any of the voltage-controlled devices. A photograph of a keyboard controller incorporating this circuitry is shown in Fig. 6 (top).

Fig. 6 (bottom) is a photograph of a manual controller which produces a continuously variable control voltage rather than a series of discrete voltages. The circuit is the same as that shown in Fig. 7, except that the series string of fixed resistors is replaced by a long strip of resistive material, and the bank of key switches is replaced by a single taut contact band which is positioned over the resistance ribbon. The composer moves his finger along the taut band to produce continuous changes in the control-voltage output.

Fig. 8 shows a modern signal-generating, processing, and controlling system for electronic-music composition. Except for the controlling devices, all the instruments are modular and are mounted in a single console cabinet. In addition to a full complement of v.c.o.'s, v.c.a.'s, and v.c.f.'s, this system contains a white-noise generator, a bank of half-octave bandpass filters, a reverberation unit, a multi-channel mixer, and a bank of transient control-voltage generators. The system uses silicon solid-state devices exclusively and is powered by a single regulated power supply. Interconnections between the instruments are set up by patch cords. Levels and impedances of the inputs and outputs are set so that the composer can establish all the basic interconnections simply by patching between the appropriate jacks. Thus, the composer is able to think in terms of "operations" (*e.g.*, frequency modulation, filtering, mixing, etc.) and does not have to concern himself with the details of the instrument circuitry that is used.

Fig. 8. The Moog Synthesizer II shown below is an audio-signal generating, processing, and controlling facility for electronic-music composition. The keyboard controller and the linear controller just above it permit control of the circuits by composer.



New Trends

The early development of classical studio composition technique has focused largely on the tape recorder as the means of assembling and manipulating sounds. While this path of development has given composers immediate access to the advantages of electronic signal generation and processing with simple audio equipment, it has also pointed up the relative inefficiency of tape editing in the composition of music. A piece of music composed in a classical studio may take months or even years to realize, and much of this time is spent in tape manipulation.

The most important applications of tape editing are the arrangement in time of a series of sounds and the changing of the time scale of individual sound events. Both of these functions can be performed by applying the appropriate control-voltage variations to a system of voltage-controlled instruments. The control-voltage variations can be programmed in advance of the actual signal generation or can be determined by the musician while the signal generation is in process. The first is called *programmed composition*, while the second is called *real-time performance*.

The first important device to (*Continued on page* 84)

ELECTRONIC IGNITION SYSTEMS

By RONALD L. CARROLL

Design considerations and operating characteristics of both the capacity discharge and the standard transistor ignition circuits. Comparison is made with present conventional system.

OUR advancing semiconductor technology has given us devices capable of handling the high voltages and currents required in automotive ignition circuits. Up until now, we had a choice of two different ignition circuits: the 1928 Kettering system, which is still standard on all cars, and the magneto. The magneto is still considered to be the best of all available systems, however, the price ($250 up) puts it out of the range of all but the most serious racing enthusiasts. Because of its limited application, the magneto system will not be discussed here. This leaves three basic practical circuits which will be considered: the conventional system; the transistor ignition; and the newest and perhaps most promising, the capacitive-discharge system.

First, however, we should clearly understand just what each of these circuits must do and how it does it.

Voltage Requirements

Essentially, we are concerned with producing "spark" to the spark plugs, using only the 6 or 12 volts available from the car's battery. We wish to amplify battery voltage to the potential necessary to ionize the gas between the spark-plug electrodes, thus producing the spark necessary to ignite the charge in the cylinders. This problem is further complicated by the fact that we must use direct current.

Fig. 1 shows the ionization potential of air *versus* the product of pressure × distance apart of the electrodes (pressure in millimeters of mercury × distance in cm). However, we are interested in a mixture of vaporized gasoline and air—not air alone. We can approximate this effect by increasing the voltage required in Fig. 1 by 20 percent. This factor is considered an average value since the gasoline-to-air mixture ratio varies from 1:10 to 1:18 with 1:16 being considered the ideal value. However, 20 percent is a reasonable factor. From Fig. 1, we see:

$V \approx C\ Pd$ (in dry air) ....(1)

where C is some constant, for $Pd > 10$ mm Hg × cm. Whereas for our purposes:

$V = a\ C\ Pd$ ....(2)

where $a = 1.2$ to take into account the 20% figure mentioned above for the gasoline and air mixture.

Temperature has the effect of reducing the required voltage but we can neglect any beneficial effect since we intend to approach the problem as a worse-possible case.

Frequency, in this case engine rpm, has no effect on the output potential required.

Typical spark electrode gap settings will vary from 0.025 to 0.035 inch. We shall consider an air gap of 0.040 inch for a worst-possible case.

Pressure is the next point of concern. Since the spark must be excited when the piston is at or very near the top of its compression stroke, typical compression ratios must be considered. They can vary from 7:1 to 13.5:1 with 16:1 being considered the maximum since charge detonation at these high pressures exhibits a sort of "diesel" effect. This sounds good but actually is not because it means that the engine would fire at 0 degrees advance (the very top of its compression stroke) and would not allow sufficient time for the charge to burn completely. For this very reason an automatic advancing mechanism is built into every engine and this senses the amount of advanced firing necessary to produce maximum horsepower at any engine speed.

Since about 90% of all cars have compression ratios between 8:1 and 9:1 we will arbitrarily choose 10:1 as our value.

With these two assumptions, from Fig. 1 we find that it

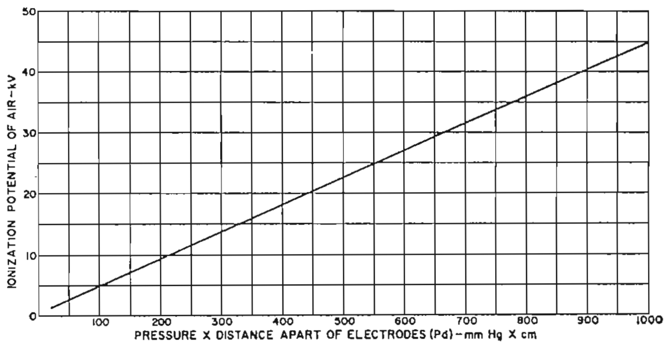
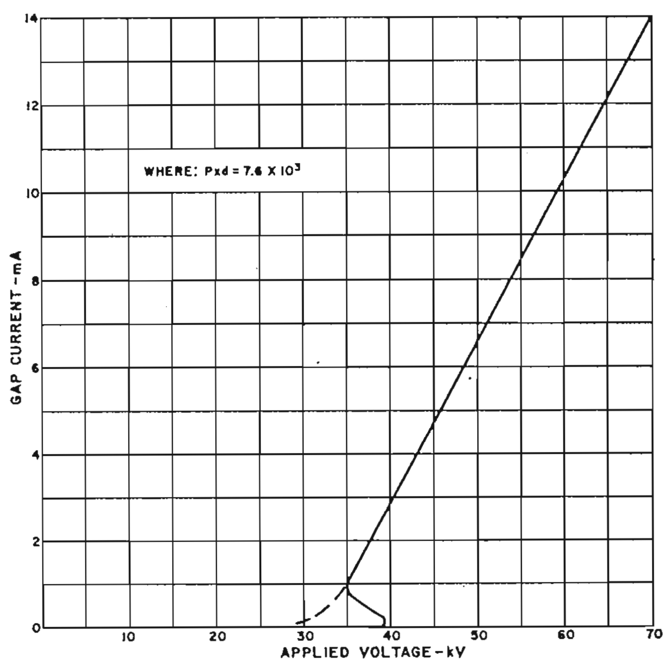


Fig. 1. Ionization potential of dry air rises with an increase in the pressure and the separation of the electrodes.

Fig. 2. The current in the air gap increases linearly above the voltage potential at which arcover condition takes place.



takes about 40 kV to operate the spark plugs. This 40 kV should be considered a minimum requirement. To assure complete combustion, this value should be exceeded if possible. Theoretically the more molecules of gas ionized, the greater the probability of complete combustion. At a given $P \times d$, current is proportional to the number of ionized molecules. Fig. 2 shows typical *I-V* characteristics of an air-gap discharge for a constant $P \times d$ of 7.6×10^3.

Let us look at the basic circuits to be considered.

Ignition-Coil Function

There are two ways to use an ignition coil to produce high-voltage pulses. First is the rate-of-change of current, or inductive mode, and the second is the transformer mode. The circuits shown in Figs. 3A and 3B use the first means mainly, while the circuit of Fig. 3C uses the second. The principal functional difference between the conventional system and the transistor system is that the latter is capable of switching higher currents.

Obviously both have limitations. Our purpose is to analyze circuit operation and determine whether or not circuit limitations occur at some point well beyond the maximum practical operating point of the car's engine.

In the transformer mode, the coil performs only one function—that of a voltage amplifier. However, the inductive mode requires two coil properties to produce high voltages: it must inductively "create" a high primary voltage and then amplify this self-induced voltage by transformer action. The amplification factor is common to both modes.

The voltage amplification factor is given by:

$$V_{out} = k \times V_{in}\ N1/N2 \qquad (3)$$

where: V_{out} is the output or secondary voltage; V_{in} is the input or primary voltage; $N1$ is the number of secondary turns; $N2$ is the number of primary turns; and k is the coefficient of coupling, a figure of merit relating to the coil's efficiency. Its maximum value is 1. With almost all coils and transformers, it is fairly safe to assume that $k = 1$.

Most engineers agree that 30 millijoules of energy must be stored in an ignition coil to fire the spark plugs reliably. This figure should be kept in mind when comparing the different systems.

A current is passed in the primary of the coil and then the current flow is interrupted abruptly. This creates a short-duration inductive voltage of from 100 to 300 volts, depending on the inductance of the coil itself and the amount of current being switched. This voltage is coupled, *via* the core flux, to the secondary of the coil and thence to the spark plug in the form of a high-voltage pulse. This method is simple and reliable, but less efficient, typically 15 to 50% less. In this mode energy is given by:

$$W = (\tfrac{1}{2})\ LI^2 \qquad (4)$$

where: W is energy in watt-seconds (joules); L is inductance in henrys; and I is current in amperes.

Here we sense the problem. We cannot have both high inductance and high current simultaneously since high inductance requires more turns of wire, with its attendant resistance. Also, it is easy enough to store 30 millijoules in the coil at low frequencies, but it becomes more difficult as the engine rpm is increased.

For convenience in making calculations, assume the following: battery voltage, 12 V negative ground; engine, 8 cylinders, which has four firing pulses per revolution; operating range, "cranking" speed to 6000 rpm or 12 to 400 Hz; conventional coil, 100:1 turns ratio, primary inductance 6 to 10 millihenrys; transistor ignition system coil, may vary, but typically 250:1 to 500:1 turns ratio. However, this is not as important as the lower primary inductance of 1 to 2 millihenrys.

The Duty Cycle

The systems shown in Figs. 3A and 3B have two operating conditions: a "on" time and an "off" time. The "on" time is when the distributor points are carrying direct current, *i.e.*, a closed circuit. The "off" time is when the distributor points are an open circuit to the direct current. It is at the beginning of the "off" time that the high-voltage pulse is produced.

The times mentioned above will be designated as t_{on} and t_{off}, respectively. Typically, these times are related as follows.

$$t_{on} = 2t_{off} \qquad (5)$$

and

$$t_{cycle} = t_{on} + t_{off} \qquad (6)$$

where: t_{cycle} is the duration of one electrical cycle.

This duty cycle is in accordance with almost all auto manufacturers' specifications no matter what the number of cylinders. It corresponds to a dwell or "on" time setting of about 40 degrees for a 6-cylinder engine or 30 degrees for an 8-cylinder engine.

In order to relate these times to the operating ranges, we will use the formula:

$$f = 1/t_{cycle} \qquad (7)$$

where: f is frequency in hertz; t is time in seconds.

To express f for an eight-cylinder engine in rpm:

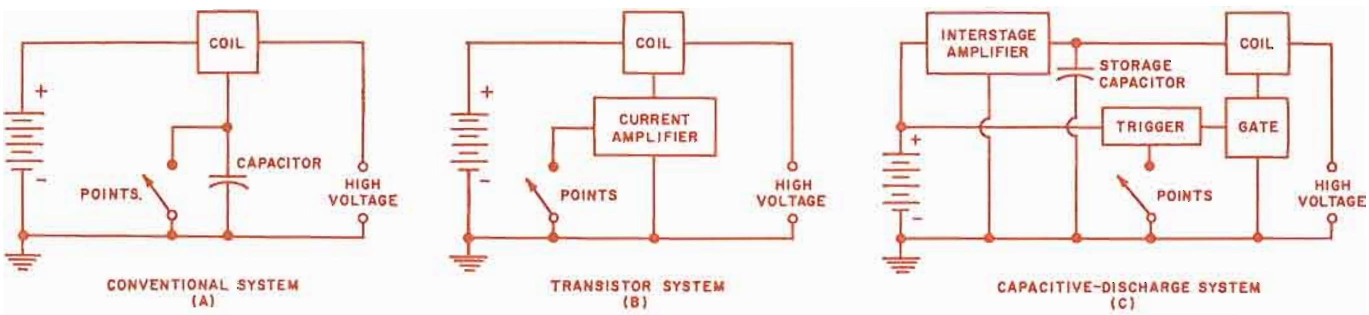
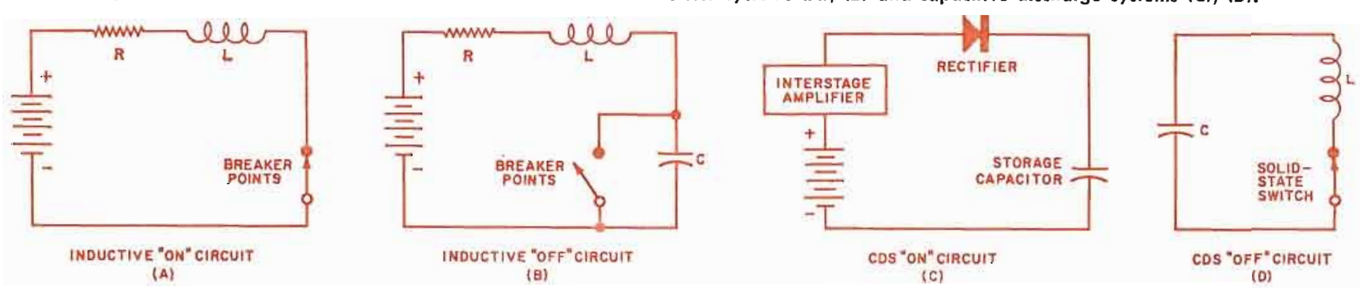


Fig. 3. Basic circuit arrangements that are employed in the conventional, transistor, and capacitive-discharge ignition systems.

Fig. 4. The "on" and "off" circuits for conventional and transistor systems (A), (B) and capacitive-discharge systems (C), (D).



$$f = rpm/15 \quad (8)$$

or:

$$rpm = 15\ f \quad (9)$$

Now let us examine closely what an induction coil looks like electrically. Since little can be done with the k and turns ratio of the coil (assuming both are reasonable), we can deal with the primary of the coil and the energy that can be stored in it as if it were a simple inductor.

Fig. 4A shows the simplest case of the "on" circuit and Fig. 4B, the "off" circuit.

The time constant for the "on" period is:

$$T_{on} = L/R \quad (10)$$

The time constant for the "off" period is:

$$T_{off} = \sqrt{LC} \quad (11)$$

Actually the "off" period time constant amounts to about one-sixth of one cycle of oscillation of the series resonant circuit and T_{on} is the time constant of the damping factor. R is the total d.c. resistance of the circuit, in ohms; L is the inductance of the coil primary windings, in henrys; while C is damping capacitance, optimized experimentally at 2×10^{-7} farad or 0.2 μF.

System limitations arise during one or both periods.

Let's discuss the "off" cycle first. Keeping eq. 11 in mind, we have found that the optimum t_{off} is about 20 μsec no matter which system is used. A faster system must be damped by addition of some capacitance. Since induced primary voltage is determined from the formula:

$$V_p = L\frac{\Delta I}{\Delta t} \approx L\frac{I}{t_{off}} \quad (12)$$

our first thought would be to turn off a large current as rapidly as possible, since V_p obviously approaches infinity as t_{off} approaches zero. However, this doesn't take into account the coil's ability to transform the voltage as a function of frequency since the coil's efficiency drops off drastically above 50 kHz. Hence, a system which switches much faster than 20 μsec must be damped to about this value by additional capacitance, or suffer a large output loss.

Using the 20-μsec optimum t_{off} in eqs. 7 and 9, we find that we would have to approach 250,000 rpm in order for the established "off" cycle to impair system performance. Thus we can disregard the possibility of t_{off} affecting an actual engine's performance.

Let us next consider the "on" time and its effect on operation. First, we will assign values to the parts in Fig. 4A.

For a typical transistor ignition system (#1), R is 1.2 ohms, L is 1 millihenry, and T_{on} is 0.83 millisecond; for a second typical transistor ignition system (#2), R is 1.2 ohms, L is 2 mH, and T_{on} is 1.67 msec; for an optimized conventional system (#3), R is 2 ohms, L is 6 mH, and T_{on} is 3 msec; for a second optimized conventional system (#4), R is 2 ohms, L is 10 mH, and T_{on} is 5 msec.

Note that systems #1 and #2 are typical transistor-coil circuits with component values equivalent to those you would purchase, *i.e.*, there was no attempt on the part of the author to enhance system performance.

This is not the case with systems #3 and #4. These are conventional systems optimized above their design limitations: they will not perform indefinitely at the V/R value of 6 peak amperes. Excessive heat generated by this current will eventually burn out these systems.

Fig. 5 shows actual current *vs* time for the four circuits being discussed. From this we can see that insufficient "on" time will impair system performance at the higher engine speeds, especially with the conventional ignition systems #3 and #4. With insufficient time for current build-up to occur, less energy is stored in the coil and the high voltage drops off.

Capacitive-Discharge System

Fig. 3C diagrams the transformer mode in a capacitive-discharge ignition system. In these circuits an intermediate stage of amplification charges a storage capacitor to several hundred volts, which is then discharged through the ignition coil primary, thus producing the desired high output voltage. This method is very efficient, typically 75% to 90%, and gives faster rise and fall times than the other methods. However, the cost will be usually about two to three times higher.

Although these systems use many more components, their basic operation is fairly straightforward. The battery voltage is converted into alternating current by means of an oscillator. This a.c. is transformed to several hundred volts, then rectified and stored in the storage capacitor. The points, when open, now trigger a silicon controlled rectifier or gate controlled switch which rapidly discharges the capacitor through the ignition coil primary, producing the spark. (*Continued on page* 83)

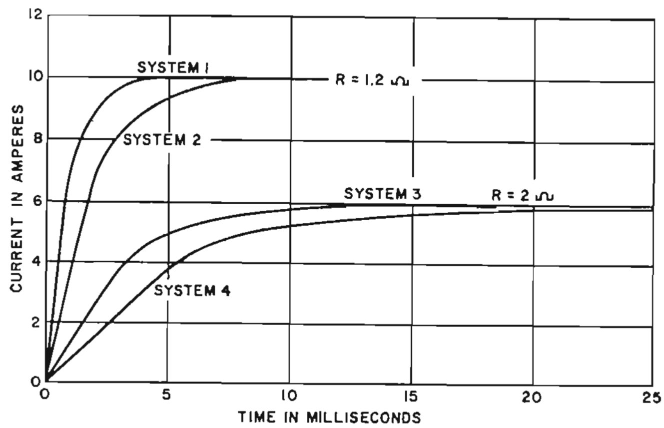
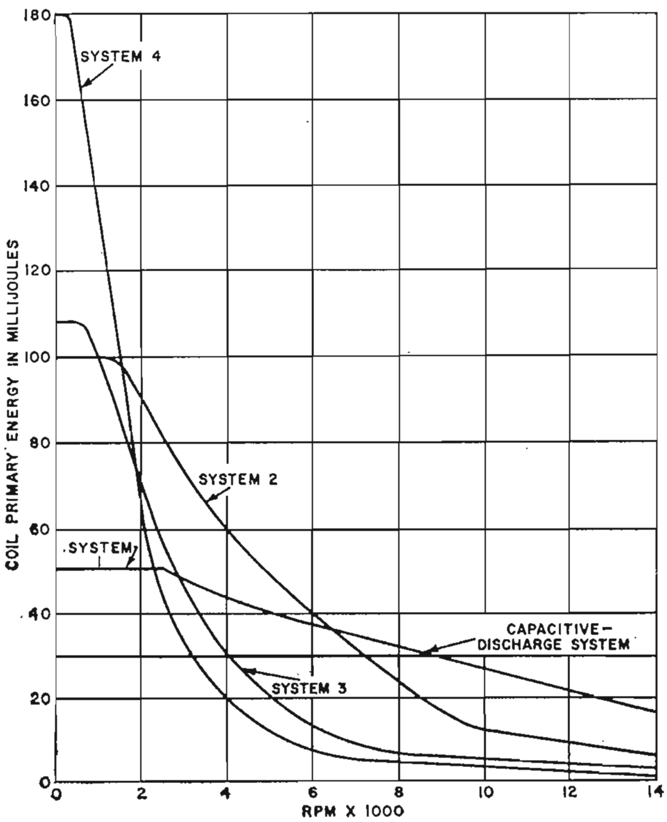


Fig. 5. Current build-up in two transistor ignition systems (1 and 2) and in two optimized conventional systems (3 and 4). Although the transistor systems have faster rise times, even they may prevent optimum engine performance at very high speeds.

Fig. 6. Coil primary energy should be above 30 millijoules at all times. Note that systems 1 and 2 are transistorized ignitions, while systems 3 and 4 are optimized conventional ignitions. The capacitive-discharge ignition system is shown to produce the same coil primary energy at all engine speeds.



Communicating with Computers

By JIM KYLE

Alphabetic and numeric symbols must be converted into a binary number code which can be operated on by a computer. In order to communicate back to the operator, reverse procedure is followed.

FROM a television network's studios on election night to the payroll department of most large companies, computers have moved into commanding positions. Thousands of words have been printed concerning the functioning of computer circuits—yet all these circuits are valueless until a means is provided for communication between the computer and its user.

It is obvious that communications are necessary, if for no other reason than to provide a way of determining the output of the computer. And since output implies that some input was provided, a second need for communications capability arises. Finally, the computer must be "programmed" to solve any problem given it, and the third communications requirement is for a manner of feeding the program into the machine.

While it might appear that communications techniques would be different for each different model of computer, actually the basic principles are almost identical for all models in current production. In fact, many of the techniques have been standardized within the computing industry, allowing interchangeability from one make of machine to another. This interchangeability has led to development of nationwide hookups between computers and users.

Table 1. Comparison of symbolic codes. Note that both Hollerith and ASCII are in order to allow direct sorting (the irregularity in the left digit for ASCII is due to the parity bit); Baudot is not. Baudot uses same codes for both letters and figures, transmitting a "37" or "33" to indicate which is meant. Once "33" is sent, all codes are interpreted as figures until "37" is sent. Punctuation differs from machine to machine.

CHARACTER	BAUDOT	HOLLERITH	ASCII (incl. parity)
0	26	0	260
1	27	1	061
2	23	2	062
3	01	3	263
4	12	4	064
5	20	5	265
6	25	6	266
7	07	7	067
8	06	8	070
9	30	9	271
A	03	12-1	301
B	31	12-2	302
C	16	12-3	103
D	11	12-4	304
E	01	12-5	105
F	15	12-6	106
G	32	12-7	307
H	21	12-8	310
I	06	12-9	111
J	13	11-1	112
K	17	11-2	313
L	22	11-3	114
M	34	11-4	315
N	14	11-5	316
O	30	11-6	117
P	26	11-7	320
Q	27	11-8	121
R	12	11-9	122
S	05	0-2	323
T	20	0-3	124
U	07	0-4	325
V	36	0-5	326
W	23	0-6	127
X	35	0-7	130
Y	25	0-8	331
Z	21	0-9	332
LTRS	37	not used	not used
FIGS	33	not used	not used
Car. Return	10	not used	015
Line Feed	02	not used	212

Machine-Language Communications

The majority of today's computers use the binary number system for all internal communications. Binary numbers consist of only two digits, 1 and 0. The base of the system is two; and two is written (in binary) as 10. Three would be 11, four is 100, and so forth. Computers use this system because the two digits (1 and 0) lend themselves ideally to electrical representation as high or low voltage levels; if "high" is defined as meaning "1", then four wires can represent up to 16 different numbers. The first wire would contain the lowest binary digit, the second the next lowest, and so forth, so that if the voltages were "high", "low", "high", and "low" (in order) the binary number contained would be 0101, which is equal to five.

A binary digit is known as a "bit" in the computer industry and a group of bits which are associated with each other is called a "word". The previous paragraph contains an example of a four-bit word, 0101.

One key specification of a computer is its "word length", since this is a measure of the largest binary number the machine is capable of processing. Word length in modern computers ranges from 8 bits to more than 40 bits; many general-purpose machines operate in the 20-bit to 30-bit range.

A 20-bit computer word is a difficult item to read or remember since each of the 20 bits must be correct. A typical such word might be "01011001111100100101". To aid in the reading and use of such words, both programmers and technicians make use of *octal* numbers.

Where binary numbers use *two* as a base and have only the two digits 1 and 0, octal numbers use *eight* for their base and have the *eight* digits from 0 through 7. Thus an octal number bears a close resemblance to the familiar decimal number and is easy to remember. The resemblance is only superficial; octal 100 is equal to decimal 64, and decimal 100 equals octal 144.

The only purpose for which octal is commonly used is to aid in the use of binary numbers; no computation is actually performed using the octal numbers.

The usefulness of octal stems from the easy mental conversion which may be made between binary and octal, or *vice versa.* To make the conversion from binary to octal, simply group the bits by threes, beginning at the right. Next, convert each group of three bits to decimal (001 = 1, 010 = 2, 011 = 3, 100 = 4, 101 = 5, 110 = 6, 111 = 7, and 000 = 0). "Push" the resulting decimal digits back together to obtain the octal equivalent for the binary numbers.

As an example, the 20-bit word cited previously is converted as follows:

01011001111100100101	original binary
001 011 001 111 100 100 101	grouped by threes
1 3 1 7 4 4 5	converted by threes
1317445	octal equivalent

Note that an extra zero had to be added on the left (underlined) to fill the last group out to three bits. "Leading zeros" have no effect on the value of a number; 001 is the same as 1.

Conversion from octal to binary is the reverse process. When the binary equivalents of the eight octal digits are memorized, either method may be done mentally.

Since the conversion is so simple, virtually all operating manuals, reference books, etc., for any computer give *octal* numbers for "machine language" communications. It is important to keep in mind that this is for human convenience; the machine uses only *binary* numbers and the octal numbers must be converted before the machine can use them.

All three of the main communications requirements of the machine are accomplished through binary numbers, composed of bits grouped in words of the length specified by the machine's design. Certain bit combinations are defined by the designers as "machine instructions" (frequently called "operation codes" or simply "op codes"). When the computer's control circuits detect these combinations on the input lines, specified machine actions result. For instance, if octal 7200000 is the op code for "add" in some machine, and the 21 input lines contain binary 11101-0000000000000000, the machine will perform an addition.

The op codes provide the machine-language means of programming, since the programmer may arrange the various operations in any sequence he finds necessary to solve a particular problem. The choice of sequence to be followed consitututes the art of programming, which is an entire subject in itself.

It might appear that the op codes prevent the machine from processing certain numbers, since octal 7200000 also represents a number. This does not occur, however, since *all* input is assumed to consist of op codes unless otherwise specified. The specification of input as data rather than as instructions is usually accomplished by storing data in a different part of the computer's memory than that used by the program. Thus the *location* of the number determines its meaning.

Of course, communications are necessary for the storage of the numbers in the memory in the first place. The op codes which command storage of a number usually contain certain spaces to be filled by the "memory address" of the number to be stored, and the address in which it is to be stored. If the basic "store" op code were 6300000, for instance, the two digits immediately following the "63" might specify the source address, and the final two digits specify the storage location. Thus, instead of sending the op code as "6300000", the programmer might send "6325050". This would cause the machine to take the number presently located in memory address "25" (010101, since all op codes are assumed to be in octal) and store it in address "50" (101000). If the first number sent to the machine is automatically placed in location "00" and each subsequent number is placed in the next higher numbered location, then the source location for each number is known. Input data can be transferred to the higher numbered portion of the memory, leaving only op codes in the low numbered part, and the separation is accomplished.

Output communication is usually by separate lines or indicators. Essentially the only machine-language output communication in most machines is the bank of indicator lights on the operator's console. Each light indicates a "1" binary value, in the corresponding bit position of the register to which the light is connected. Some machines have only one indicating register, while others have huge banks of lights. However, machine-language output is usually used only while troubleshooting the computer in case of breakdown.

The machine-language input communications provided for most computers consists of one or more banks of switches, either push-button or toggle, located (like the output indicators) on the operator's console. These switches are similar to the output lights; each switch controls the value of a single bit, with one switch position representing "1" and the other "0". After all switches are set, operating another switch inserts the setting into the associated computer register.

While it is possible to load a complete program and all its input into a machine in this manner (and a few machines exist which make no other provisions for program inputs), it is a slow and tedious process, open to many errors. For these reasons, direct switch-input communications are usually used only in troubleshooting or during initial "debugging" of new programs.

The "normal" input communications paths, like normal outputs, operate with other than machine language, through intermediate means. Usually one of several of the "symbolic codes" is employed. They will be discussed below.

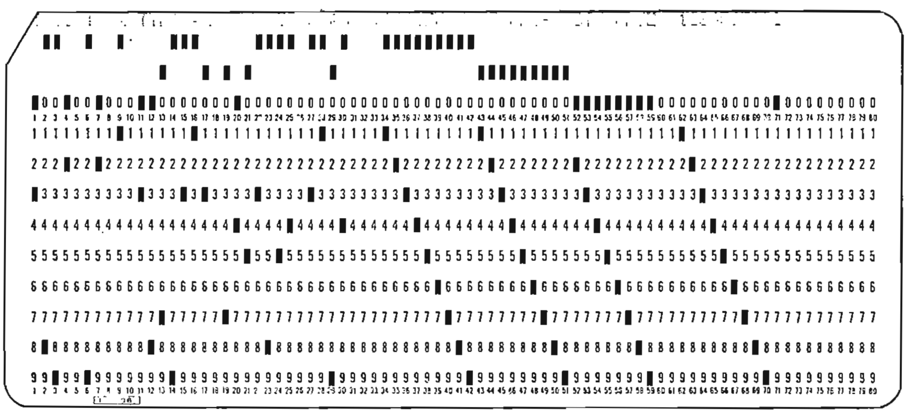
Symbolic Codes

A code is merely a table which matches two sets of symbols, so that one is understood to have the meaning normally attached to the other. Thus it appears that a "symbolic code" is a redundancy; the term is used in the computer industry to emphasize that one set of symbols in the code is the conventional set consisting of the alphabet, the decimal digits, and required punctuation marks, while the other set of symbols is a series of binary (usually written in octal) numbers.

The symbolic code most familiar to communications-oriented personnel outside the computer industry is the "7-unit teleprinter code" frequently called "Teletype® code". This code represents the letters of the alphabet, the numerals, the punctuation marks, and the various control functions necessary on a teleprinter (such as line feed, carriage return, upshift, and downshift) by 5-unit combinations of "mark" and "space" conditions. In addition to the five units which indicate the letter or other data, the code contains a "start" unit which is always a "space" and a "stop" unit which is always a "mark" to indicate the beginning and ending of each character.

Merely replacing the terms "mark" and "space" with "1" and "0" respec-

Fig. 1. Typical punched card, produced on IBM Model 026 key-punch machine with printing attachment. Printed line across top of card is for convenience of users only. Two unmarked rows between printing and row "0" are called "12" (upper row) and "11" (lower row) and are so identified under the Hollerith column in Table 1.



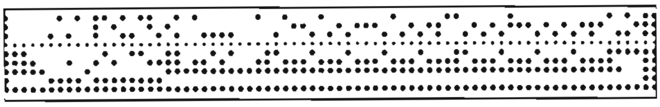


Fig. 2. Typical punched paper tape as produced by Model 33 Teletype equipped with tape-punch attachment. This tape was punched under computer control as part of output; computer was programmed not to produce parity bits. Normally, outside hole on wide side of tape (bottom)) would be parity. Each hole that has been punched indicates binary "1", lack of hole a "0".

tively changes the teleprinter code into a binary symbolic code in which every character begins with a "0" and ends with a "1". The five intervening bits determine the character.

When this change in terminology is made, the code becomes the *Baudot* code widely used by computers. Frequently a sixth "data" bit, called the "parity bit", is added to assist in determining the correctness of each character. The parity bit may be either a "1" or a "0", whichever is necessary to make the total number of "1's" in the six bits together an even number. Then a lost bit may be detected by counting "1's" in each character; if the total is odd, a bit has been lost from that character.

Baudot code may be used with punched-tape reading devices or with teleprinters connected to special "input buffer units" on a computer for either input or output. The conversion from Baudot code to the machine's language is accomplished by special circuits in the reading device or buffer unit; the conversion from alphabetic, numeric symbols to Baudot is accomplished by the teleprinter or tape punch. By this means, the user may type in data directly and need not have any concept of the computer's own internal language.

A code used even more widely than Baudot is that known as Hollerith code. This code is based on the punching of holes in cards at specified locations. From one to three punches may be made in each column of the card, and up to 80 columns may be punched in each card. Each column corresponds to one character; the specific character is determined by the number and location of the punches in that column. For instance, a single punch in row 9 designates the decimal digit 9. Two punches, one in row 11 and the other in row 5, designate the letter "E".

The familiar "IBM card" is a typical example of a Hollerith-coded card. These cards may be read into the computer by special card-reading machines which sense the presence and locations of the holes and convert the code into its binary equivalent for the specific computer with which they are used.

Since each card contains up to 80 characters and cards may be read at rates up to and exceeding 300 cards per minute, the punched-card communications channel is widely used for mass input of programs and data. The computer may also drive a card punch, producing new punched cards as output. This is a frequently used output channel, since many other business machines operate with punched-card data. Additionally, the output obtained during one pass through the computer may be used as input for a later pass if it is taken in the form of punched cards.

A relatively recent symbolic code which is, however, gaining almost industry-wide acceptance is the American Standard Code for Interchange of Information (ASCII). This code provides for 32 control characters and 96 data characters, allowing both capital letters and lower-case letters to be included in the alphabet along with all digits and punctuation marks.

ASCII is especially well suited to some of the more recent applications of computers in the areas of typesetting for printing plants; it remains compatible with all previous codes as well. This code is presently in use (completely, or in part) on punched-tape devices, teleprinters, video-display units, and for communications between remotely located computers. One of its major features is that any ASCII-coded device can communicate with any other, as long as both operate at the same speed. Data transmission speeds are standardized as well, with a choice ranging from 45 bits per second up to 2400 bits per second (equivalent to 40-w.p.m. telegraphy at the low speed up to approximately 200 w.p.m.).

Table 1 compares the three symbolic codes discussed here. Baudot and ASCII are shown in octal notation. The listing for ASCII includes the parity bit, since ASCII includes "odd parity" as part of its standardization. Hollerith code is shown in decimal notation; the hyphen indicates an additional punch location.

The communications channels with which these symbolic codes are usually used have already been mentioned briefly in the discussion of the codes. Now, let us take a more detailed look at each medium.

A typical Hollerith-coded card is shown in Fig. 1. To punch the card, a special key-punch machine is used. This machine has a keyboard similar to that of a typewriter, although the arrangement is sufficiently different from a typewriter that special training is required to operate the key punch.

To input information *via* punched cards, it is necessary to write out the information first, then deliver it to a key-punch operator to be punched into cards. After the initial punching, a second operator "verifies" each card by "re-punching" it in a different machine, from the same copy. If the data on the card is not identical to that indicated by the verifier's keying, an alarm light indicates the error. After verification and correction of any errors, the card is ready for loading into the computer's reader for input.

The verification step is essential; in a recent election tally in the Midwest, key-punch operators attempted to speed their output by accepting vote totals by telephone and punching without verification. The resulting unofficial returns contained errors of as much as 12,000 votes, which were traced in every case to single-digit key-punch errors on the cards. One "lucky" candidate discovered to his dismay when the official returns were posted that he had lost what had been declared unofficially an easy victory.

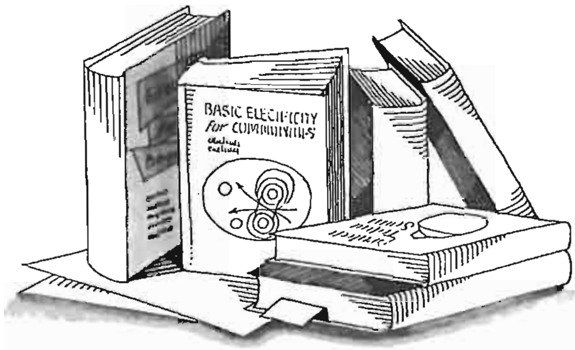
Because of the special additional equipment and trained operators required, card input is usually used only for large computer installations which process data in vast quantities.

Punched paper tape is similar in many ways to the card process but provides slower input rates since only one character is read into the computer at a time. The tape may be punched with teleprinter equipment, separate special tape punches, or by a tape punch connected to the computer output terminals. Fig. 2 shows a typical punched-tape input, in modified ASCII code, as produced by a Model 33 Teletype machine.

Output from a computer is frequently obtained by means of a "high-speed printer" unit, which is a special kind of typewriter that prints an entire line of data at once. These printers can produce output at rates greater than 800 lines per minute, gobbling stacks of continuous-form paper. These printers do not usually use a symbolic code which is one of the standard varieties; instead, they take binary output directly from the computer and convert it to symbols as determined by the computer's built-in "character set" (which is a special symbolic code of the specific computer, and normally is used only with the corresponding printer units). Frequently the printer's design and that of the computer are so closely related that neither can operate without the other.

Previous mention has been made of the similarity between teleprinter codes and symbolic codes and of the use of teleprinters for communication with computers. This means is one of the least expensive and simplest available for general input and output of data; its major disadvantage is its slow speed, in com- (*Continued on page* 77)

BOOK REVIEWS



"IONOSPHERIC RADIO PROPAGATION" by Kenneth Davies. Published by *Dover Publications, Inc.*, New York. 443 pages. Price $2.25. Soft cover.

This is an updated and unabridged edition of a National Bureau of Standards monograph (No. 80) originally published in 1965. It is designed for communications engineers and research workers who already have some background in radio propagation *via* the ionosphere.

The text is divided into nine chapters covering the earth's atmosphere, geomagnetism, and the sun; the theory of wave propagation; synoptic studies of the ionosphere; oblique propagation; signal strength; ionospheric disturbances; ionospheric propagation predictions; scatter propagation on very high frequencies; and propagation of low- and very-low-frequency waves.

The treatment is mathematical and the text is lavishly illustrated with graphs, charts, photographs, and ionograms. For those interested in ionospheric radio propagation and who have the requisite background, this volume is a real bargain.

* * *

"THE EFFICIENT GUIDE TO TECHNICAL WRITING" by Howard Whetsel. Published by *Techni-Riter Company*, Box 334, Oak Ridge, Tenn. 24 pages. Price $2.25. Soft cover.

This manual is addressed not only to those who prepare manuscripts for magazine or book publication but to the vast army of scientists, engineers, and technical personnel who are obliged to prepare technical reports as a part of their day-to-day job.

The first section explains the mechanics of report preparation, helping to solve many of the problems involved in the preparation of graphs, tables, etc. and the presentation of references. The second section explains how to write clearly, concisely, and coherently. Examples of the various points the author covers are given where required.

* * *

"ELECTRON TUBES" by R. G. Kloeffler. Published by *John Wiley & Sons, Inc.*, New York, N.Y. 10016. 258 pages. Price $5.95.

This volume has been written for the technical institute or junior college student and is intended to serve as an introduction to the study of electronics. Only a basic understanding of d.c. theory is prerequisite.

After a basic coverage of construction and characteristics of tubes, the text goes on to basic rectifier and amplifier analysis and equivalent circuits. Reference is also made to equivalent semiconductor devices to familiarize the student with terms he will encounter in later courses. The ten chapters cover electron emission, simple graphical circuit analysis, vacuum diodes, vacuum triodes, multi-electrode vacuum tubes, single-stage amplifiers, multi-stage vacuum-tube amplifiers, power amplifiers, gaseous tubes, electrical power supplies, and special electron tubes.

Like most textbooks, this has problems appended to each chapter.

* * *

"THE SEMICONDUCTOR DATA BOOK" compiled and published by *Motorola*. 1500 pages. Price $3.95. Available from Technical Information Center, *Motorola Semiconductor Products, Inc.*, Box 955, Phoenix, Arizona 85001.

Anyone who works with semiconductor devices—ranging from diodes to integrated circuits—will find this volume invaluable. In 16 edge-referenced sections, this book contains complete data sheets on more than 2800 devices.

The data book serves as a handy reference source for design engineers, component engineers, and purchasing agents to help in narrowing down the broad categories of potentially usable components to those best suited for a specific application.

In addition, the General Information section contains short-form specs on more than 10,500 EIA-registered semiconductor devices in the 1N, 2N and 3N categories. The data sheets are arranged in twelve sections, each prefaced by application-oriented Quick Section Guides. The Integrated Circuit section contains complete data specifications on over 200 digital and linear IC's.

The application notes in the last section are outlines of general procedures rather than specific circuits to provide useful information on device parameters. A numerical index of the various semiconductor devices and certain of their parameters is an especially useful feature of this volume.

All-in-all, this is an excellent reference book of its type

* * *

"SPECIAL PURPOSE TRANSISTORS" by *Federal Electric Corp.* Published by *Prentice-Hall Inc.*, Englewood Cliffs, N. J. 129 pages. Price $9.00.

This is a self-instructional programmed manual covering the newer and more sophisticated semiconductor devices. The format is such that the user can work at his own speed in learning about the new semiconductors and the circuits in which they are employed.

The eleven sections of the book cover *p-n* junction diodes, zener diodes, varactor diodes, tunnel diodes, unijunction transistors, field-effect transistors, Shockley diodes and SCR's, tetrode transistors, spacistors, phototransistors, and Hall generators. The book is slanted toward the professional.

* * *

"MATHEMATICS FOR ELECTRONICS TECHNICIANS" by Paul L. Evans. Published by *John Wiley & Sons, Inc.*, New York. 392 pages. Price $7.00.

This text presents the basic principles of mathematics commonly used by electronics technicians and their applications to electrical and electronic circuits. Designed for the technician in training, it will also be useful in industrial training courses and as an introduction to circuit analysis in engineering.

The author reviews high-school algebra and basic trigonometry and points out how these principles are applied in the solution of series, parallel, series-parallel, and network circuits. Quadratic and simultaneous equations are covered, as are the uses of the slide rule, scientific notation, determinants, imaginary and complex numbers, and the use of Thevenin's and Norton's theorems.

* * *

"MUSICAL INSTRUMENTS AND AUDIO" by G. A. Briggs. Published by *Wharfedale Wireless Works Limited.* Available from *Herman Publishing Svce., Inc.*, 755 Boylston St., Boston, Mass. 02116. 238 pages. Price $5.95.

Both the audiophile and the concert-goer are sure to be interested in this latest book to come from the prolific pen of G. A. Briggs. Entertainingly written as well as informative, this fascinating volume covers the cause and effect of musical sounds, the characteristics of various instruments and the human voice, and distortion in reproduction. Interesting chapters on organs, electronic organs, and pianos are included along with a large number of scope traces of musical sounds that were taken especially for the book. Briggs has made an attempt along with the poet Milton at: *Untwisting all the chains that tie / The hidden soul of harmony.* ▲

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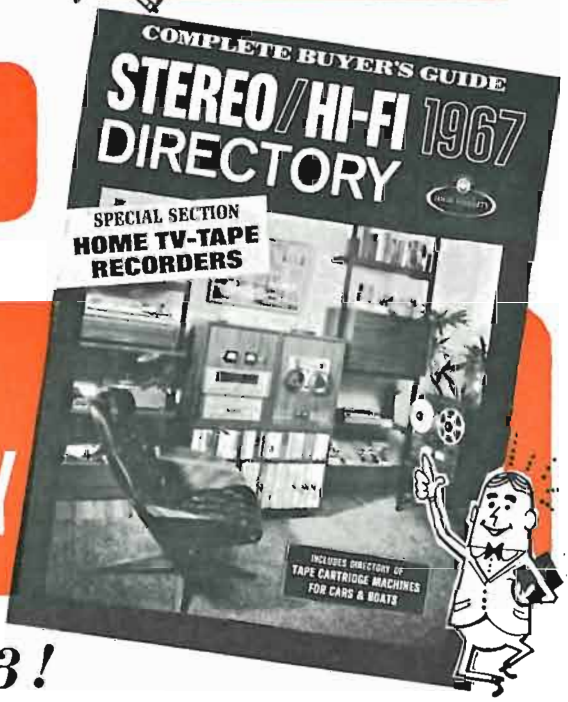

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JOHN FRYE

Numerous special devices have been developed to help make life easier for those with severe physical disabilities.

ELECTRONICS AND THE HANDICAPPED

IT was a slushy mess outside as a February thaw temporarily loosened the icy grip of winter; but, even though real spring weather was still many weeks away, there was something heart-lifting about the tinkling sound of running water undermining the rotten ice and snow packed in the gutters.

Perhaps that is why both Mac and Barney hummed happily to themselves as they worked at the service bench. Finally Mac finished checking out the new TV tuner he had installed and lit his pipe for a few moments of relaxation.

"Barney," he said to the younger man, "did you ever notice that after you learn the meaning of a new word, you're almost certain to run across that word again in a short time?"

"Sure, Boss; but what brings this up?"

"I had never heard the term 'respo' until you told me about a month ago it was the nickname for a victim of respiratory polio. But last week, when I was installing a pillow speaker for a bedridden shut-in so that she might watch the late-late shows without disturbing the rest of the household, I noticed on her bedside table a stack of magazines bearing the unlikely title of the *Toomey j. Gazette*. At her invitation, I leafed through a copy and discovered the non-profit magazine was published once a year in Chagrin Falls, Ohio by a group of 'horizontal,' or severely disabled people, and their 'vertical,' non-disabled, volunteering friends. Mrs. Gini Laurie is the vertical editor, and the magazine is distributed free to 'respos,' other 'quads' (those having four useless limbs), and to 'multiplegics' (those having two or more useless limbs). Donations are invited from the non-disabled.

"I became so interested I borrowed a couple of copies. This is not one of those spiritual-uplift publications that try to tell the handicapped how to *endure* their burdens. Instead, it encourages the readers to *do* something about their difficulties and concerns itself chiefly with disseminating practical information on how particular people have succeeded in overcoming their own severe handicaps so that they might earn a living and lead useful, productive lives."

"Where did it get that oddball name?"

"The magazine is named in memory of the late Dr. J. Toomey, director of Toomey Pavilion, Cleveland's former Respiratory Care and Rehabilitation Center.

"My first reaction on reading the magazine was to feel appalled at how severely many people were disabled. I think of a crippled person as one who must use crutches or even a wheelchair to get about, but many of the people in the *TjG* would be tickled pink if they could push themselves around in a wheelchair. Some cannot feed themselves or turn the pages of a book; others are entirely paralyzed except for being able to move their tongues or roll their eyes; still others cannot even breathe without mechanical help. Yet they are painting by holding a brush in their teeth; they are conducting a phone-answering service through the use of special telephone attachments; they are studying with an electric page-turner to turn the pages of their books; and they are writing by using their breath and solenoids to operate an electric typewriter."

"Those guys must have lots of guts," Barney said in a husky voice.

"That was my second reaction," Mac admitted; "and then came a desire to help. As I've mentioned before, I believe anyone given a supply of specialized knowledge, such as we have in electronics, also has an obligation to use that knowledge for the benefit of others. If all a man can do with his knowledge is make money, he has furnished his mind with pretty shoddy material.

"We are in a particularly fortunate position to help. When I was a kid growing up in a little Arkansas town, I knew a crippled boy whose dad ran the local garage. This mechanic father was always making things to help his crippled son get about better and do things for himself, and I often thought to myself that the best friend a crippled person could have was a good mechanic. Now I believe an electronic technician is the best friend a severely handicapped person can have. Most of the helpless person's needs are concerned with communication, remote control, and power amplification, and those are fields in which we shine."

"Surely some big companies must feel as you do and are already busy."

"I'm proud to say that those in electronics, big *and* little, are showing a desire to help. The *3M Company* over the last three years has quietly developed their Community Business Service Associates aimed at bringing self-employment and independence to severely disabled persons. They equip and train such a person to perform such services as copying, sending out monthly statements, and making up mailing lists; and they do everything they can to help him launch that business and keep it going.

"The Technical Utilization program of NASA has come up with several devices and ideas that can be used almost 'as-is' by the severely disabled. Their 'lunar walker' designed for remote-controlled moving about on the surface of the moon is being evaluated at the University of California's rehabilitation center as a possible means of locomotion for limbless or crippled individuals. Powered by battery motors, its mechanical legs are operated by hand or foot and can actually climb steps. Then a slightly modified wireless telemetering system developed for astronauts is now being used in one hospital's intensive-care cardiac-monitoring unit.

"The 'Sight Switch' developed by NASA to aid an astronaut in space who finds his arms pinned useless at his sides seems a natural for use by the completely paralyzed. In this device, a tiny cylinder mounted on the earpiece of an eyeglass frame contains an infrared light source, an infrared sensor, and an amplifier. Inconspicuous wires lead to a battery pack and a control relay. The 'Sight Switch' is operated simply by looking at it. The iris of the human eye is an excellent absorber—and therefore a nonreflector—of infrared energy, absorbing up to 80% of such energy striking it. Light from the infrared source is directed toward the eye and is reflected back to the sensor—*unless* the iris is *the only comprehensive guide to consumer electronics servicing!*

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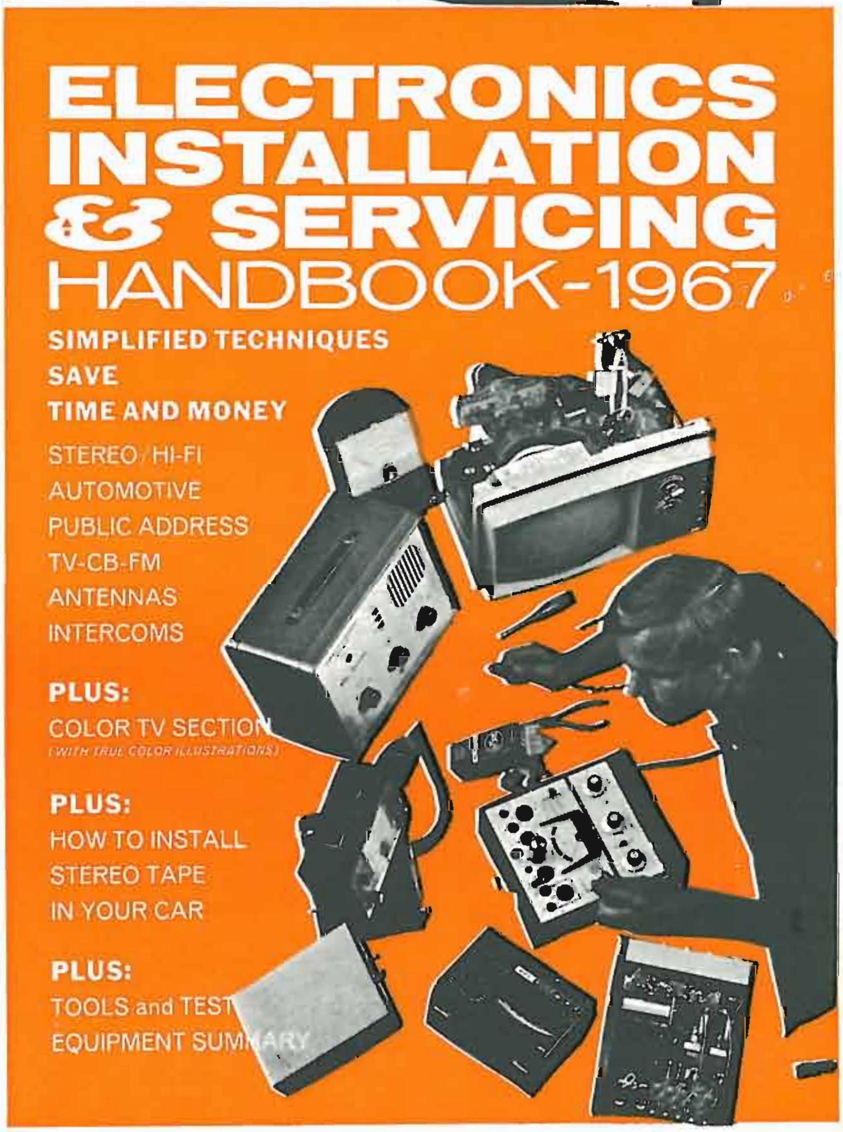

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turned toward that source. When this happens, the decrease in infrared energy reflected to the sensor causes it to close the associated relay and actuate an electric motor or other device.

"Two of these units, one mounted on either earpiece, permitted the wearer in a demonstration to completely control the movements of an electric wheelchair simply by moving his eyes right or left. Other exciting possibilities of the 'Sight Switch' include raising or lowering a hospital bed or typing on an electric typewriter.

"Getting down to a more individual basis, non-handicapped Bill Orr has collaborated with his handicapped friend Don Rugg, a research engineer in the Electromagnetic Propagation Division of the Denver Research Institute, in the development of a self-propelling, self-reclining wheelchair that is in current production. Dr. Vernon Nickel and his associates at the Rancho Los Amigos Hospital in California, operating under a grant from the Vocational Rehabilitation Administration for investigating 'externally powered orthotitic devices,' have developed an electrically powered mechanical arm that permits an otherwise helpless feminine wearer to feed herself, put on make-up, control her electric wheelchair, hold letters and papers, turn pages, lift and replace a telephone receiver, salt food, turn light switches on and off, and even throw dice and play cards. And she does all this by operating seven switches with her tongue!"

"It certainly shakes you up to be made to think of these taken-for-granted movements as highly prized and painfully achieved privileges," Barney commented. "But what can a lowly electronic technician do to help?"

"He can do a lot," Mac answered quickly. "You see, every one of these severely handicapped people is unique. No two persons suffer precisely the same kind of paralysis or have exactly the same needs. A knowledgeable technician working with the handicapped person can tailor various kinds of electronic equipment to the peculiar needs of the handicapped person. The technician does not necessarily have to invent the equipment, but often he can alter existing equipment slightly or combine various pieces of apparatus so as to adapt them to the physical limitations of his customer.

"Here's an example," he said, taking two little white plastic cases, each about the size of a shirt-pocket transistor radio, from a drawer. Each had an a.c. cord coming out the bottom and a tiny pilot-light jewel at the top. Otherwise they were identical except that one had a standard a.c. plug receptacle beneath the pilot light, while the other had a rocker-type on-off switch in the same location. Mac took the one with the receptacle into the front office and plugged it into a wall socket and plugged a desk lamp into the receptacle. Back in the service department he plugged the other unit into a socket and pushed the rocker switch to 'On.' The lamp in the other room came on instantly but went off when the rocker switch was pushed the other way. Both pilot lights went on and off with the light.

"This," Mac explained, "is *Lafayette's* new 'Wire-Less' remote control. In this unit a step-down transformer, rectifier, and filter furnish 14 volts d.c. for a transistorized r.f. oscillator operating at around 80 kHz. The output of the oscillator is capacitively coupled to the a.c. line.

"The receiver out there has a similar power supply. The r.f. signal from the a.c. line is picked off with capacitors and fed through a tuned circuit to an amplifying transistor. The tuned output of this transistor feeds a rectifying diode, and the d.c. voltage thus developed changes bias on a second transistor whose collector circuit contains a relay that closes when a signal is being received. Relay contacts feed the line voltage to anything plugged into the a.c. receptacle. Neon pilot lights show when the transmitter is turned on and when power is applied to the receiver receptacle.

"A bedridden person can use this wired, wireless control to turn on and off a radio, TV, lamp, hi-fi, *etc.* anywhere in the house without running unsightly and dangerous wires across the floor. The receiver plugged in anywhere in the house, basement, or yard can be made to sound a bell, buzzer, or Sonalert® when the bedridden person needs help."

"Hey! I can use it to start the coffee perking before I get out of bed!"

"The receiver unit is only rated for devices drawing up to 300 watts," Mac warned, "but you could use it to control a heavy-duty relay to operate such things as coffee makers or air conditioners. Also, a stepper relay controlled by the receiver would permit several different devices to be operated with the remote control."

"How far will it work?"

"I don't know, but it works beautifully from our house to the one next door, a wire distance of at least 400 feet. Of course, transmitter and receiver must both be connected to the same secondary winding of the pole transformer."

"Well," Barney said, "I'll do a little brainstorming and see what I can dream up with selsyns, photocells, light-activated switches, magnetic reed switches, grid-controlled rectifiers, and even garage-door controls to help these people be a little more independent. Courage deserves help." ▲

FET VOLTMETER

By JAMES RANDALL

THE circuit diagrammed in Fig. 1 is a transistorized version of the popular vacuum-tube voltmeter circuit and uses an inexpensive field-effect transistor (FET) to obtain an input impedance of 10 megohms. The novel design shown emphasizes simplicity and economy of construction while sacrificing nothing in performance. The over-all scale accuracy of the FET voltmeter is at least as good as most commercially available d.c. v.t.v.m.'s, and the linear response of this circuit permits direct use of the scale markings on the 50-microampere meter. An additional advantage is the low power consumption; the FET voltmeter draws only 1 mA at 4.5 volts, thereby providing long battery life.

The d.c. voltage to be measured is attenuated by the divider made up of *R*1, *R*2, and *R*3, so that a maximum of --0.5 volt is applied to the gate of the FET. The FET is connected in a source-follower arrangement directly coupled to *p-n-p* silicon transistor *Q*1. With no input, a quiescent voltage of approximately —1.6 volts will appear across load resistor *R*5. This voltage is balanced out by the divider made up of *R*7 and *R*8 so that no current flows through the meter. When a signal of —.05 volt d.c. is applied to the input, the increased current through the FET and *Q*1 causes the voltage across *R*5 to rise to approximately —2.1 volts. The resulting current which flows through the meter is controlled by calibration pot *R*6.

The selection of voltage scales and input impedance is at the discretion of the builder. The writer arbitrarily chose an an input impedance of 10 megohms ($R1 + R2 + R3$), although higher input impedances are easily possible. The voltage ranges shown in Fig. 1 were selected to provide measurement from .05 volt to 50 volts using the scale markings of the 50-microampere meter directly. Many builders will probably want to include additional voltage ranges. Any convenient arrangement will be satisfactory as long as it is remembered that the actual voltage at the gate of the FET must not exceed —.05 volt on any switch position. The resistors which make up the input attenuator should be precision types (1% accuracy or better), as these will affect the over-all accuracy of the voltmeter.

The *Siliconix* U147 FET and the 2N3638 transistor were chosen principally for reasons of economy. Both of these are new types which are not yet listed in the current catalogues. However, they are available in single-unit lots from authorized *Siliconix* and *Motorola* distributors. Actually, any available *p*-channel FET may be used to replace the U147, and a 2N1309 makes a good substitute for the 2N3638. The use of a silicon transistor as *Q*1 will reduce drift caused by temperature effects.

Construction of the FET voltmeter is extremely simple and lends itself readily to miniaturization.

Power switch S2 may either be an integral part of *R*7 or a part of S1, if a two-pole switch is used.

The input connector should be selected to accommodate whatever type of probe is going to be used with the volt-

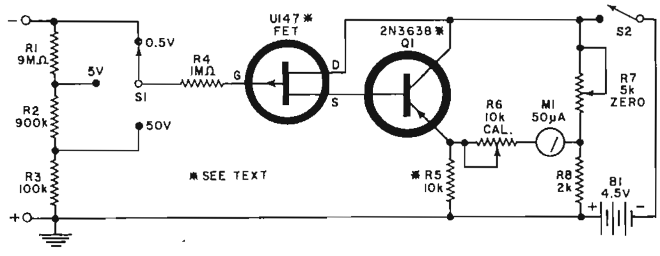


Fig. 1. Circuit of the FET voltmeter shows basic simplicity.

meter. Many different types of probes for measuring r.f., modulated r.f., audio, or d.c. voltages are available in kit form or can easily be constructed by the builder. Probes used for d.c. voltage measurements should not contain an isolating resistor as none is required.

Adjustment & Calibration

The linearity of response is dependent upon selection of the right value for $R5$. With range switch $S1$ set to the 0.5-volt scale, turn the voltmeter on (close $S2$) and adjust zero control $R7$

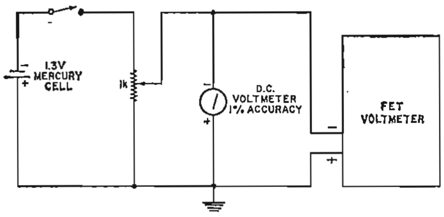
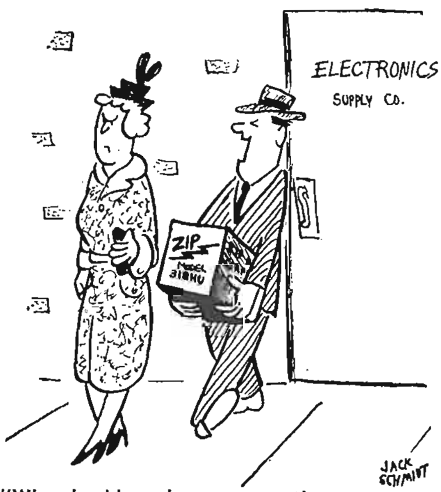


Fig. 2. Calibrating circuit for FET meter.

until the meter reads exactly zero. Apply an accurately known —0.5-volt signal to the input and adjust calibration pot $R6$ until the meter reads precisely 50 on the microampere scale. Remove the input voltage and recheck the zero setting, repeating this process three or four times until the meter readings are exact at zero and full scale.

To determine the linearity, reduce the input voltage from 0.5 volt to 0.1 volt in steps of 0.1 volt successively. If the meter reads less than 10 microamperes with 0.1 volt applied to the input, increase the value of $R5$ slightly (in 100-ohm steps) until a reading of 10 microamperes is obtained. Then readjust $R6$ for a full-scale reading with —0.5-volt input.

Fig. 2 shows a simple arrangement for providing calibrating voltages. After the meter has been calibrated on the 0.5-volt scale, it is not necessary to repeat the calibration procedure for the other voltage ranges if the values of $R1$, $R2$, and $R3$ are precise to at least 1%. ▲



"Why should we buy a carpet that covers one room when for the same amount of money we can buy a radio that covers the whole world?"

THE GUITAR-ORGAN

Unusual instrument combines electronic guitar and organ.

THE *Vox* (a division of *Thomas Organ Co.*) guitar-organ, shown on this month's cover at the extreme right, is a combination of a six-string guitar and a miniaturized electronic organ that will operate with any amplifier with at least two inputs. It can also be used as a stereo unit if it has the guitar portion plugged into one amplifier and the organ portion plugged into another.

The instrument can be played as an ordinary electronic guitar, and the usual volume and tone controls are provided. An on-off side control brings in or cuts out the organ section. The organ can be played by depressing a string or strings, using one or both hands. It is not necessary to use the right hand unless it is desired to add some guitar melody or background. The organ sound is created when a string touches a fret (which acts as a contact) and sends the signal down the neck to the components inside the guitar body. *(Technical details on exactly what the operation and circuitry are for accomplishing the organ effect are not available at this time.—Editor)*

The guitar-organ has two sets of tuning slots located on the back. One set is composed of six potentiometers which may be adjusted for fine tuning of the instrument. The other set of pots is used to fine tune the octaves.

The guitar portion has three controls which are for volume, bass, and treble. The organ portion has fifteen controls which are for volume, repeat percussion, sustain, basic flute, and octaves, including six open-string buttons. These open-string buttons do three things. They can tune the organ to the guitar, supply a simple bass line, and sound the notes of the open strings. The guitar portion is powered by two six-pole magnetic pickups located between the neck and bridge.

The guitar-organ can duplicate such tones and sounds as a church organ, rock and roll organ, baritone saxophone, low and high clarinets, bagpipes, flute, banjo, chimes, harpsichord, zither, and an oriental effect.

The instrument requires no special technique except for the operation of some additional controls.

The amplifier and speaker system shown directly behind the guitar on this month's cover is a 200-watt peak power unit with four 12-in. heavy-duty speakers and two high-frequency exponential horns. ▲

EW Lab Tested

(*Continued from page* 16)

output to a velocity basis at a level suitable for driving any standard preamplifier magnetic phono input. The rated output is 6 millivolts.

The "Sono-Flex" stylus, used on the 9T series, is unique among high-quality styli in being virtually indestructible. A flexible portion of the stylus cantilever allows flexing up to 180° without damage. This feature should appeal to anyone who has had an expensive stylus damaged by careless handling.

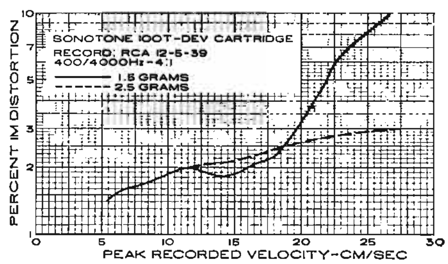
The lack of a magnetic structure allows the cartridge to weigh in at only 1.5 grams, compared with the 10- or 12-gram weight of the typical magnetic cartridge. In a lightweight arm, this permits an over-all mass reduction which is beneficial from the standpoint of record wear and ability to track warped records. In arms designed for heavy cartridges, additional weight may be necessary in the cartridge shell to provide proper balancing.

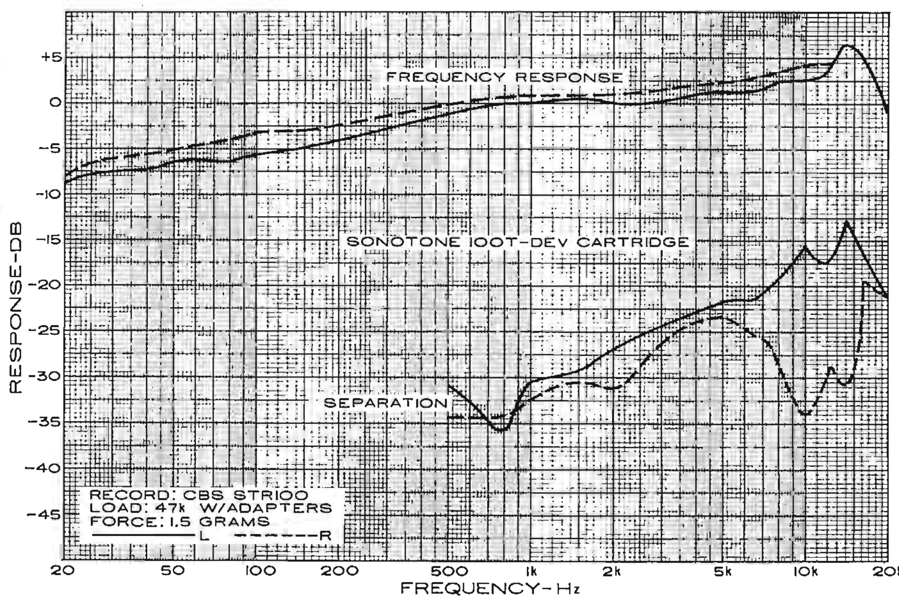
The cartridge we tested was the 100T-DEV, fitted with the elliptical diamond stylus. With the *Cook* Series 60 and *Fairchild* 101 test records, containing unusually high recorded velocities at low and middle frequencies, the cartridge required less than 1.5 grams for tracking. We used that force throughout our tests. Using the *CBS Labs* STR-100 record, the frequency response sloped upward at about 4 dB/decade from 20 Hz to over 10,000 Hz. There was a peak of about +6 dB at 14,000 Hz, and the 20,000-Hz output was at the mid-range level. Channel separation was better than 30 dB at middle frequencies and better than 12 dB at all frequencies up to 20,000 Hz. The measured output was 6.2 millivolts at 3.54 cm/sec, and the vertical stylus angle was 16°. Like all ceramic cartridges, the 100T had no susceptibility to magnetic hum.

Playing the *RCA* 12-5-39 IM test record, we found the cartridge to have IM less than 2% at 17 cm/sec and lesser velocities, using its minimum tracking force of 1.5 grams. This is excellent performance, and the 1.5-gram force should be adequate for the vast majority of music records. For the most critical tracking requirements, increasing the force to 2.5 grams reduces the IM to 3% at the 27.1 cm/sec maximum velocity on the test record. This rivals the lowest distortion cartridges we have measured and is far better than most cartridges of any type or price.

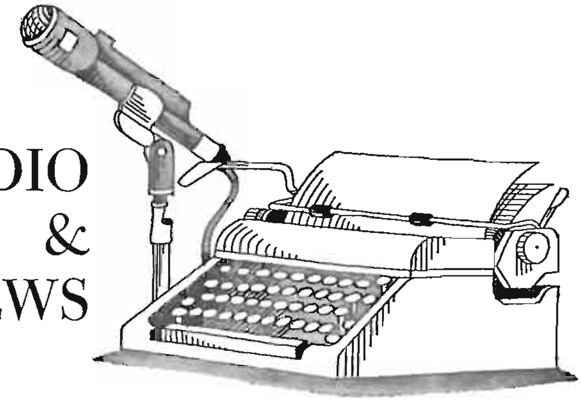
In listening tests, the cartridge produced sound that was exceptionally pleasing. It had a slightly bright, clean, and very well defined sound. In comparison with some other cartridges, its slight lack of low bass response could be heard, but this probably would not be noticed in ordinary listening since it is less than the normal variation in bass response from one speaker type to another. A slight amount of amplifier bass boost can easily flatten out the over-all response, making the 100T-DEV, in sheer listening quality, easily the equal of any magnetic cartridge in its price class.

The *Sonotone* 100T-DEV cartridge, with the elliptical stylus, sells for $39.50. With the 0.5-mil stylus it is $34.50; with the 0.7-mil stylus it is $32.50. ▲





RADIO & TV NEWS



After several years of reading and writing about such exotic electronic developments as satellite communications, you can get pretty blasé about subjects like this.

It is only at those times when you get a chance to actually use the equipment that the reality of it really hits home. So it happened to this editor a few weeks back.

While covering the story on the latest SATCOM acquisition, the AN/TSC-54 highly portable (two relatively small trailers, each about the size of a 1½-ton panel truck) satellite communications system made by *Radiation Inc.*, we watched a six-man crew assemble the complete system in a matter of an hour or so, plug it into a diesel generator, and start the system up; within a few moments, we were in telephone contact with another ground station many thousands of miles away *via* a repeater satellite orbiting far above the earth.

Although this type of communication could have been performed with any shortwave transmitter, the unit we were using operated at microwave frequencies. It has enough bandwidth for multiplexed telephone, Teletype, or facsimile signals, is virtually jam-proof, and provides an enormous degree of communications security because it is not susceptible to electronic eavesdropping. Also, because of the bandwidth available at these frequencies and the total lack of fading, the voice signals were far better than those from a commercial wire telephone or from most radio-telephone links.

Because of the number of SATCOM communications satellites now strung around the earth, coupled with the fact that this ground station could work through any one of them, this type of communications could be performed from almost any place on earth to almost any other place in a minimum of time with a maximum of communication efficiency.

A Vote for the VTR

Video tape recorders (VTR's) are now coming into prominence in the political arena. Several aspirants for public office have been using CCTV and a portable VTR during some of their speeches so that they could see how they appeared to their audience and then make any necessary posture, speech, or makeup changes in order to improve their visual impact.

The portable VTR is also being used to make on-the-spot commercials for politicians; then the tapes are sent to a processing center where they are re-recorded on broadcast-type VTR's for use by commercial TV stations. Some politicians use the VTR to cover the opposition so that they have a record of what was said by their opponents at all times.

The portable VTR is also playing an increasingly important role in the Navy. While at sea, classified intelligence information is recorded on video tape for playback to newly arrived pilots and other affected personnel. Also, crewmen are given preport briefings on matters of interest to the ship's entire complement. Presentations by local authorities are recorded on the video tape and played back over the CCTV system, enabling all crewmen to receive the information.

However, all is not work for the ubiquitous VTR. In the entertainment area, live performances by visiting USO troupes, talent shows put on by members of the ship's complement, and many popular commercial TV shows are recorded (when the vessel is within TV range of the transmitters) for future playback on the system.

In some cases, certain educational services for on-board schooling are being supplied *via* the VTR.

How Many?

We all know that a large number of semiconductors of all varieties are used in modern digital computers. However, if you had to guess, how many devices do you think are used by any one company in the creation of its computers?

Well, according to a release from *Fairchild Semiconductor,* it is shipping over 20 million silicon integrated circuits, transistors, and diodes to the *Burroughs Corporation* over the next two years for use in its B2500, B3500, B6500, and B8500 general-purpose digital computers. ▲

IC's and the Automobile

(Continued from page 33)

Traffic signals in congested areas are already becoming computer controlled. While some have advocated an interface between the computer and the individual automobile, one of the thus far insurmountable problems has been the cost of such a standardized system. Integrated circuits bring this concept a step closer to reality. Systems proposed for this purpose include passive indicators, alerting the driver *via* radio or inductive coils set in the roadway of impending signal changes, of ice, an accident or temporary detour ahead, or the approach of an emergency vehicle, such as an ambulance. One form of this system is a warning lamp; a more sophisticated version would override the car's radio loudspeaker, giving verbal warning either from a pre-taped vocabulary in the vehicle or directly from the roadside station.

If mass-produced, simple "radar" systems, either microwave or ultrasonic, could continuously monitor the distance between the car and the one in front. This information could be combined with speedometer readings to warn the driver if he is following too close for a given speed or to forewarn him of obstacles in heavy fog. The self-contained radar could also be tied into "auto pilot" speed control systems such as those available today.

Standardized two-way emergency radio has also been considered by the auto industry; whether it takes the form of bandwidth-consuming voice communications or digitally encoded distress signals, integrated circuits with their capability of replacing entire subsystems in radio equipment, are the logical choice.

Because of the popularity of auto rallying, many exotic driver aids are already in experimental use, requiring only the economies of mass production to adapt them to all automobiles. For example, employees of a Scotch avionics firm adapted a moving-map display, designed for aircraft, to their competition car. The hand-made unit contained microfilmed maps showing fine details of all routes within a certain area, with an optical display moved by an analog position computer. Receiving instantaneous direction information from a gyro-compass, velocity and distance inputs from the speedometer, the computer (given the starting point) continuously shows the driver exactly where he is. If the mechanical components of the display were cast in plastic, the computing and servo motor drive performed by integrated circuits, and a complete set of road map "films" made available, the moving map display could become a useful navigation aid on tomorrow's automobile.

Passenger Services

Many of the accessories which enhance the comfort and convenience of the passenger compartment are as complex as those essential to operation of the car. What was previously a heater and air-conditioner has become a "climate control". Just as integrated circuit controls can improve engine efficiency, they can make this system more sensitive to human needs.

Perhaps the most obvious application of the integrated circuit is in replacing existing electronics in car radios, tape players, even mobile television receivers. While these entertainment functions are already performed by sophisticated circuitry, standardized integrated circuits can make them less expensive and can allow them to perform multiple functions, such as the verbal warning system described earlier.

Conclusion

It is, of course, difficult to predict the future course of automotive development. Some of the specific suggestions in this article would be inapplicable if, for example, a radically different power plant came into general use. But the basic attractiveness of a low-cost, mass-produced electronic control system remains and integrated circuits appear to be the logical solution to many projected future requirements.

While the exact shape of tomorrow's automobile may be uncertain, the greater quality and performance standards that will be required are clear. Far-sighted designers who are now working on plans for the next generation of automobiles, must consider the integrated circuit as economically essential to building a better car. ▲

TINY RADIO USES IC

SOON to make its appearance on the market is a new Sony radio using a combination of IC and discrete components and having an over-all physical size less than half of that of a pack of cigarettes.

The IC contains nine transistors, four diodes, and 14 resistors and works in conjunction with three outboard transistors—the converter stage and a pair of complementary symmetry germanium output transistors.

Containing a 2.44-volt rechargeable cell, the set can run for six hours.

Germanium output transistors are used as they have a lower emitter-to-base voltage as compared with silicon devices, thus producing a higher output for the same inputs.

The converter transistor was not included on the chip as it would have meant more connections on an already crowded IC package. ▲

Portable Satellite Communications Link

WHEN one thinks of a satellite communications station, what usually comes to mind is a massive parabolic antenna coupled to a large structure housing a formidable complex of electronics. During the past couple of years, however, many companies have succeeded in putting together a highly sophisticated satellite communicator in a very small package. In many cases, these stations are capable of being transported by conventional cargo aircraft to the desired site and then being set up and placed into operation within a few hours by a crew of only half a dozen men. Such a typical station is the Mark V AN/TSC-54 Satellite Communications Link Terminal developed by *Radiation Incorporated* and shown in the photo.

The entire system consists of the antenna portion, which is capable of collapsing down into a small package on its own trailer; an electronics shelter containing all the operating equipment; and a lightweight 45-kW, 400-Hz diesel generator. Total over-all road weight, including crew and sufficient fuel for 72 hours of operation, is 12 tons, which, if desired, can be broken down into discrete 3-ton packages for air transport. Set-up by the six-man crew, time from arrival at the site to actual communications is two hours.

The unusual-looking antenna has four 10-foot Cassagrain aluminum reflectors, with the outboard section of each vertical pair of dishes capable of folding laterally on hinges to make the antenna transportable.

Each feed emits its energy through a cone-shaped foam dielectric material extending out to a small sub-reflector at the end of the feed. Because of the guiding effect of the foam material, signal losses to the sub-reflector dish are reduced and over-all antenna efficiency is improved. Gain is 52 dB at 8 GHz transmit and 51 dB at 7.25 GHz receive.

The antenna is a phase-monopulse type using a special phase shifter which adds and subtracts azimuth and elevation error signals with the sum signal in such a way as to permit the use of conical-scan signal processing in the receiver. These signals are used to drive servo motors which control the tracking movements.

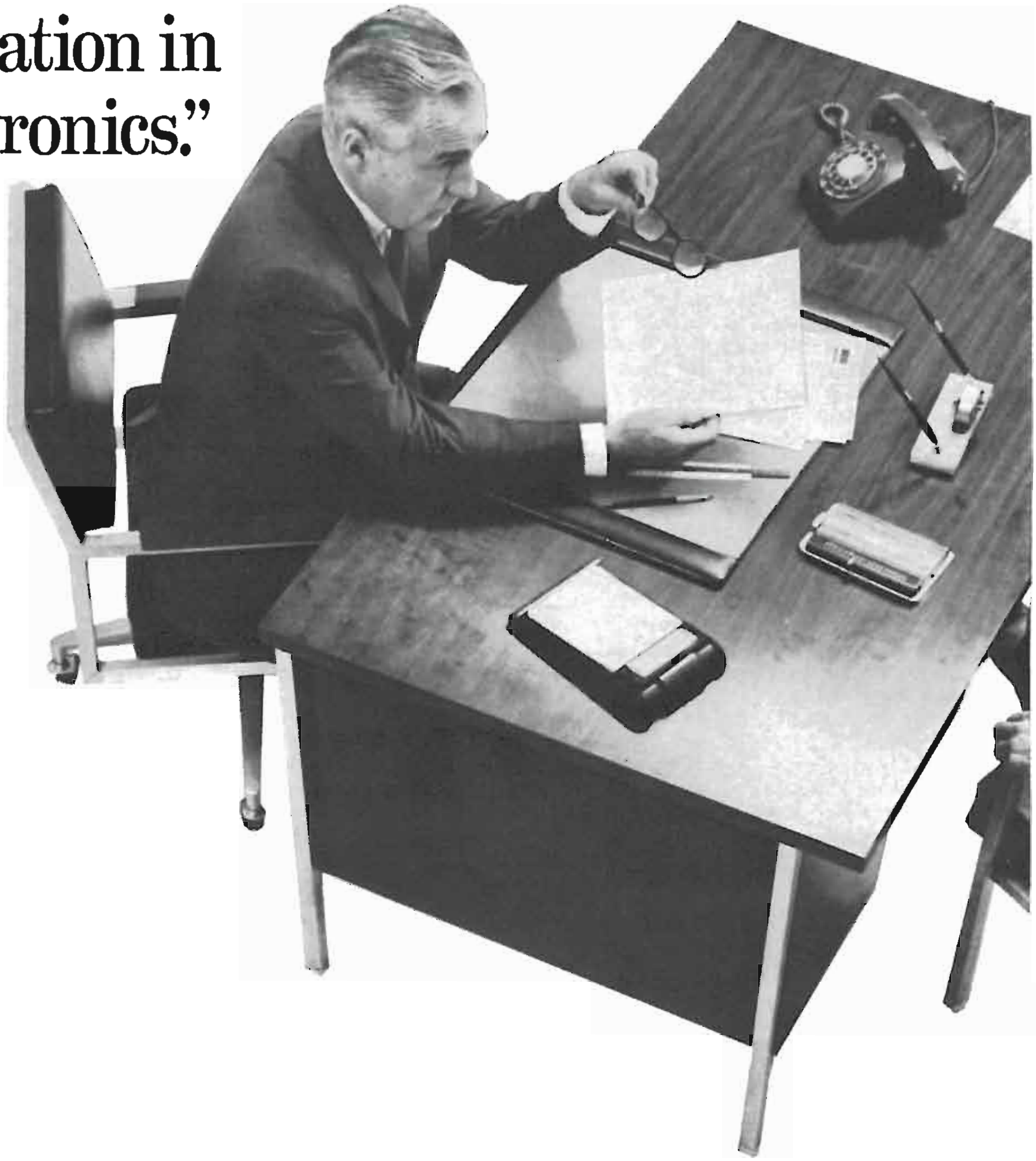
The air-conditioned electronics shelter can handle multiplexed voice, Teletype, and facsimile, either directly from on-board equipment or from remote field equipment linked to the terminal by an appropriate communications system.

The desired combination of signals is achieved using frequency-division multiplex; this combination is then employed to frequency modulate a 70-MHz carrier, which is passed to the electronic equipment in the antenna pedestal base. The signal is next up-converted to a specific frequency in the 8-GHz band and amplified to 7 kW by a klystron.

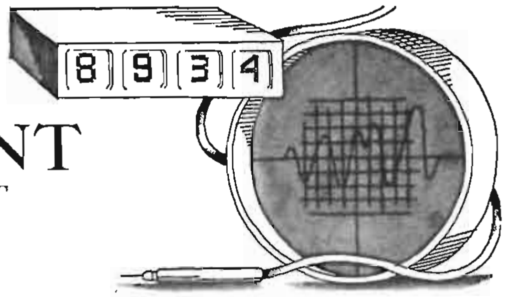
In the receive mode, the antenna electronics converts the 7.25-GHz input signal to the i.f. and then passes this down to the remainder of the receiver in the electronics shelter.

When the equipment is set up and under power, the operator must then locate a satellite. The problem of locking onto a satellite is intensified by the relatively narrow beam width of the antenna (0.3°) and by the fact that the ground terminal's exact location may be unknown. When the operator presses a button, the antenna begins to follow a programmed scan pattern very rapidly. Each satellite is identified by means of a coded beacon signal. If, during the antenna scan, the ground system intercepts a satellite beacon, a relay closes and an integrator (position memory) directs the antenna to the position where the signal was spotted. If the beacon signal is not detected within two minutes, the automatic scan is resumed. If it is detected, automatic tracking begins. The received beacon signature first identifies the particular satellite; then the ground operator selects the appropriate frequencies to be used for that satellite and proceeds to transmit and receive messages. ▲

"He's a good worker. I'd promote him right now if he had more education in electronics."



TEST EQUIPMENT
PRODUCT REPORT



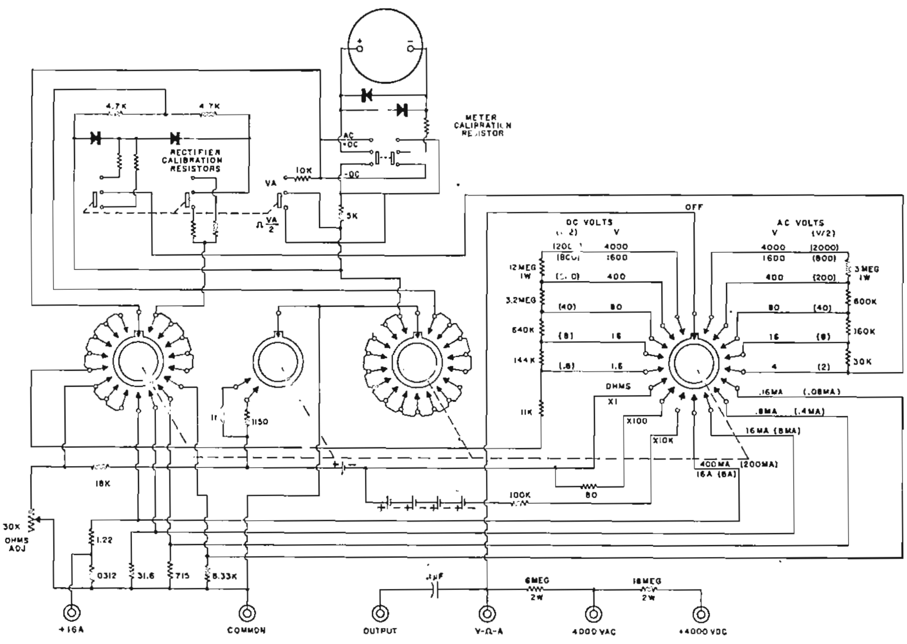
"Knight-Kit" Model KG-640 V.O.M.

For copy of manufacturer's brochure, circle No. 27 on Reader Service Card.

THE new "Knight-Kit" Model KG-640 is this kit manufacturer's finest volt-ohm-milliammeter. This is the first v.o.m. in kit form that we have seen that uses an excellent mirrored-scale taut-band meter movement instead of the more common pivot, bearing, and hairspring suspension system for the moving coil and pointer assembly. The taut-band movement will withstand severe shocks and has excellent repeatability of meter readings over very long periods of time. What is more, the movement is protected against overloads of more than 1000 times by the pair of diodes shunted across it (see diagram).

Another unique feature of the instrument is the very large number of ranges available for use. There are no less than 57 ranges in all. These are made possible by the use of a "VA/2" switch that cuts in half the full-scale readings on the various d.c. voltage and current ranges and a.c. voltage ranges. This effectively doubles the number of these ranges. The lowest d.c. voltage range is only 0.8 volt full scale, which permits the user to measure the low emitter-to-base voltages in transistor circuits. The highest voltage range is 4000 volts, a.c. or d.c., while the highest current range is 16 amperes d.c.

The sensitivity of the v.o.m. is 20,000 ohms/volt on d.c. and 10,000 ohms/volt on a.c. All the multiplier resistors used are 1% carbon-film types and the over-all meter accuracy is rated as within 3% of full-scale on d.c. and within 5% of full-scale on a.c. A standard "C" cell and four standard penlight cells are used for the ohmmeter circuits.



As an indication of the simplicity of construction and the accuracy of the assembly instructions, the writer's 13-year-old son was able to put the kit together in just under 8 hours and end up with a perfectly functioning instrument. The accuracy of the completed v.o.m., incidentally, was found to be far better than the manufacturer's specs given above.

The price of the "Knight-Kit" KG-640 is $39.95 in kit form or $59.95 fully assembled. The instrument is available from *Allied Radio.* ▲

Dynamics Model 501 D.C.-A.C. Millivoltmeter

For copy of manufacturer's brochure, circle No. 161 on Reader Service Card.

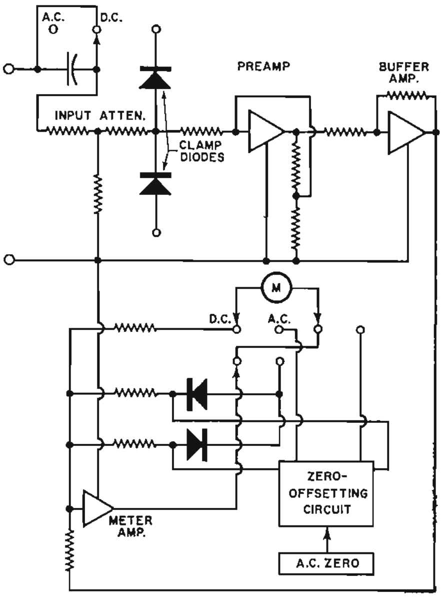
A NEW solid-state instrument for laboratory and field use is the Model 501 portable d.c.-a.c. millivoltmeter just introduced by *Dynamics Instrumentation Co.* Full-scale ranges from as low as 1 mV to 1000 volts are

provided at an accuracy of 1% on all d.c. ranges and 2% on a.c. The meter movement used is a 7.2-inch mirror-backed, taut-band *Weston.* Frequency response on a.c. is from 1 Hz to 100 kHz and there is a panel-mounted meter-damping switch to facilitate readings below 10 Hz. Without the use of this switch, the meter pointer would try to follow the incoming low-frequency a.c. wave and reading would be difficult.

Since the instrument operates on six ordinary "D" cells, preferably of the heavy-duty type, it is completely portable and ideal for field use. At least 500 hours of operation are obtained from the batteries which operate at an 8-mA discharge rate.

The d.c. scales are all zero-center types while the a.c. scales are the usual left-zero types. The input impedance is 1 megohm and the input terminals are fully isolated for two-terminal or fully guarded differential voltage readings. Output terminals are provided at low impedance so that an external recorder can be readily driven by the instrument.

The basic block diagram of the unit is shown here. The clamp diodes protect the amplifier circuit against damage if excessive input voltages are applied. The preamp circuit consists of three cascaded differential gain transistor stages which drive a class-B output stage. The input stage is driven by a source follower consisting of a dual field-effect transistor. The buffer amplifier contains two cascaded differential gain stages which drive another class-B output stage. The circuit of the meter amplifier is similar except for the feedback arrangement which includes the meter itself in the d.c. function. Four a.c. crystal diodes are inserted into the meter circuit.



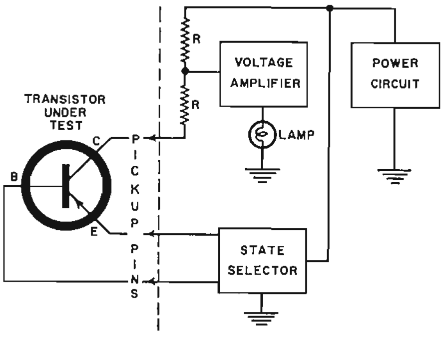
The Model 501 millivoltmeter is the first of a new line of instruments being introduced by the company. Other models will permit measurement of microvolts, microamperes, and ohms. All units are designed to operate on both line power as well as on batteries and to provide ±1% accuracies using the same basic meter movement. The Model 501 is priced at $395 and is available directly from the manufacturer. ▲

Jensen Tools Model SC-4 Transistor Tester

For copy of manufacturer's brochure, circle No. 28 on Reader Service Card.

THIS new test instrument is for the circuit designer, test technician, or service engineer who must make rapid "go/no-go" evaluations of semiconductors while they are still in the circuit. The *Jensen Tools & Alloys* SC-4 hand-held tester checks cut-off and conduction characteristics of *p-n-p* and *n-p-n* transistors and all diodes.

The SC-4 consists of three parts—a battery holder at the rear; a central housing incorporating the electronic circuitry, indicator light, and selector switches; and a forward pickup section consisting of three spring-loaded pins with TO-5 spacing. The entire unit weighs only 6 ounces and measures 9″ long by 1¼″ diameter. All power is provided by an inexpensive 3-volt dry battery built into the tester.



To use the tester, the operator presses the sharp spring-loaded contact pins against the transistor's printed-circuit connections. Cut-off is determined by simply noting the pilot light on the tester (light off, transistor cut off properly; light on, transistor shorted emitter to collector). Conduction is then tested by pressing the tester's push-button and again noting the pilot light (light on, transistor conducting properly; light off, transistor shorted emitter to base). Thus, each transistor is made to cut off and conduct without being removed from its circuit. A special extending lead and set of clips are furnished to make the connections to transistors not using TO-5 pin spacing.

Diodes are tested in a similar fashion

and are made to conduct and cut off in their circuits in order to determine their condition. A special diode adapter is provided with the tester.

The tester may be used with any transistor capable of withstanding a collector current of 10 mA, a collector-emitter potential of 3 volts, and an emitter-base potential of 1 volt. It may be used with any diode capable of withstanding a forward current of 10 mA and a reverse potential of 3 volts. When checking transistors mounted in the circuit, the external resistance of the emitter-base circuit must exceed 1000 ohms for silicon transistors and 600 ohms for germanium devices. Total resistance of the emitter-collector and base-collector external circuits (taken as being in parallel) must exceed 1000 ohms. When checking diodes connected in-circuit, the external resistance of the circuit must exceed 1000 ohms.

The SC-4 transistor tester is priced at $89. ▲

NEW SOUND PICKUP FOR WIND INSTRUMENTS

DESIGNED for use with most wind and brass instruments, the new sound pickup shown below on the bell of a saxophone, is plugged directly into a musical instrument amplifier. In this way, the output of alto or tenor saxophones, trumpets, cornets, and trombones can be electronically amplified to produce greater sound volume. The pickup is especially effective in small combos.

The pickup consists of a specially mounted crystal microphone element with a 1-meg volume control connected across it. Because of the mounting and grille that are used, the very high frequencies are filtered out so that the mechanical sounds of the instrument's keys are not amplified.

To use the pickup, which is manufactured by Koss, it is only necessary to hang the felt-covered ends of the frame over the instrument bell; the bottom leg of the frame is simply bent back to hold the pickup securely in place. It is not necessary to drill or otherwise damage the musical instrument. ▲

(Continued from page 52)

parison with other input-output devices.

Teleprinters, operating with either Baudot or ASCII codes, may be connected to computers either directly or through standard telephone lines (by use of special digital data sets at each end of the line). Thus they allow a user in New York to communicate with a computer in Los Angeles and permit nationwide networks of users to share a single computer. With special controller units at the computer, all users may communicate at apparently the same time (actually, the computer communicates with only one at a time but switches from one to another so rapidly that the users are not aware of the changing).

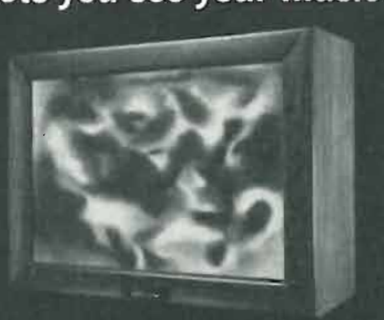
The teleprinter keyboard is virtually identical to that of a typewriter, so that anyone can provide computer input through this channel. The printout provided is also similar to that of a typewriter except that only capital letters are used.

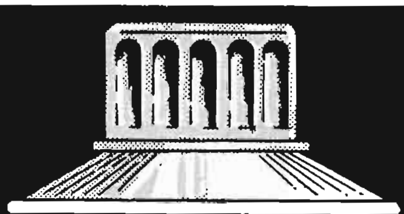
Aside from the slow speed, the second greatest disadvantage of the teleprinter as a communications device is the vast amount of paper consumed (which must be disposed of in some manner). Even a brief bout with a program can result in a printout five to ten feet in length—before any usable results are obtained.

To overcome this problem, a number of manufacturers have developed "buffer displays" or "video display units" which operate in essentially the same manner as a teleprinter, except that the output is shown on a CRT screen rather than being printed on paper. This is known in the computer industry as "soft copy" (a paper print is "hard copy"). When the screen becomes cluttered with data, it can be erased and communication continues with a clear screen. Among industry leaders offering such units are *IBM, RCA, General Electric, Raytheon,* and *Stromberg-Carlson.*

Summary

Essentially, then, communication with a computer is accomplished by first coding alphabetic and numeric symbols into binary numbers so that the computer can make use of it. Within the computer, certain numbers in the "program" part of the memory cause similar numbers in the "data" portion to be manipulated. At the completion of the program, numbers in the "output" sub-part of the "data" portion of memory are either recorded into a symbolic code for most output devices, or transmitted directly to such devices as the printer and card punch. Finally, the all-number code (whether





in machine language or in symbolic code) is decoded back into alphabetic and numeric symbols for the benefit of the user.

While it is possible to communicate with a computer directly in its own binary language by use of the console switches and indicator lights, the multiple-coding communication techniques add vastly to the speed of operation. Since all the coding is accomplished by machine (or mechanical means such as the self-coding keyboard of a teleprinter or video-display unit), the user gains speed by being able to communicate in symbols which are familiar to him and the computer gains speed by not having to wait for the user.

Present communications techniques are still short of the ultimate. *Bell Telephone Labs* has demonstrated a device which recognizes spoken words and converts them into computer machine language. A number of firms make units which re-convert machine language into speech (most are based on the principle of the time-by-telephone machines used in all parts of the country). Perhaps the day will soon arrive when an article of this nature must be titled "How to Talk to a Computer—and How to Listen to Its Replies". ▲

Radar Signature Analysis

(*Continued from page* 25)

By using appropriate formulas and by counting the number of lobes in one period, one can find the length and radius of the object.

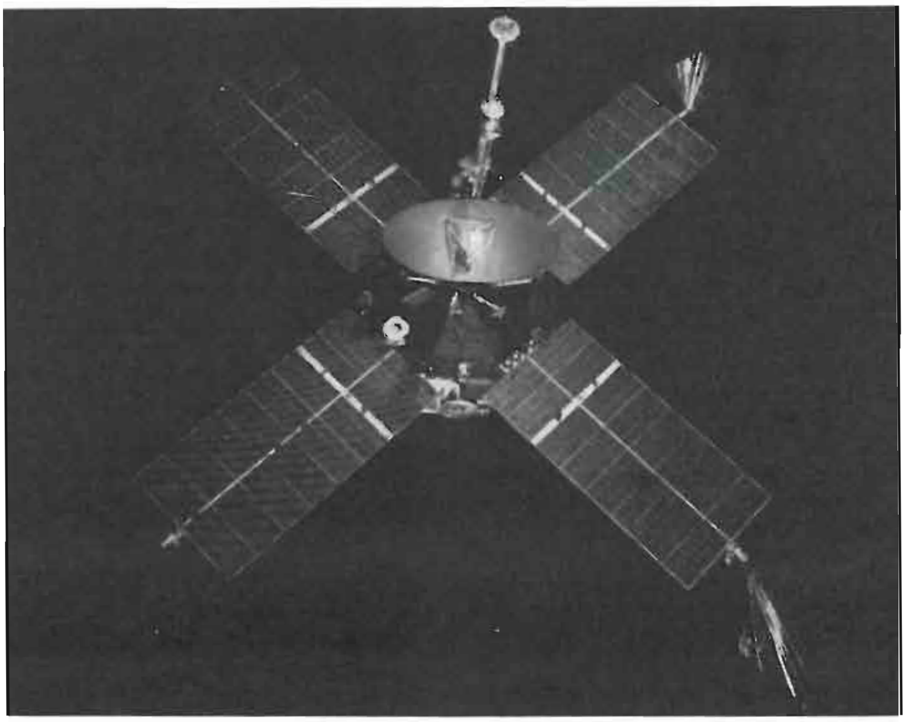
Reentry Body Study

Besides satellite target recognition, signature analysis is being used to study reentry bodies. When a reentry vehicle enters the atmosphere, the shock waves formed by the vehicle cause a plasma sheath—a concentrated layer of electrons—to be formed on the vehicle. The plasma sheath has a drastic effect on the cross-section—the reentry vehicle may show a significant increase or decrease in cross-section compared to its cross-section as measured in free space. The ionized field—called the "wake"—which trails behind the vehicle will show similar effects. Using signature analysis, we can then determine how the vehicle is being affected by reentry.

In the military area, anti-radar signature devices (decoys) use built-in electronics to reshape the returning radar echoes so that a small, inexpensive decoy can "look" like a larger reentering vehicle.

A more important use of signature analysis is to be able to determine which reentry bodies are enemy warheads and which are merely decoys in the mass of reentry bodies. Since the warhead must be identified in time for us to take defensive action, a computer is necessary. A computer, however, tends to take things too literally: if a return differs only slightly from the description which was given to it, the computer will not recognize the object. But with new computers which are capable of learning and with improved optical techniques for pattern recognition, perhaps this problem is closer to solution. ▲

Satellites such as Mariner IV have a more complicated radar signature on account of the solar-cell paddles that are used.



Electronic Guitar System

(Continued from page 26)

put, or 20 watts of continuous power output. The latter two figures are at the EIA standard of 5% harmonic distortion.

The unit employs two special-response twelve-inch speakers. The power supply can be wired for either domestic 120-volt 50- or 60-Hz sources, or for export 240-volt 50- or 60-Hz sources. A line-bypass reversing switch (which also acts as an on-off switch) can be used to select the side of the power line which provides the least hum—an important feature for electronic guitars with their magnetic pickups.

Tube amplifiers are still commonly offered in the guitar industry, but this amplifier is an all-solid-state design with a fail-safe complementary transistor output circuit. The dependability, cool operation, and low microphonics of transistors make them most desirable for rugged portable service.

Tremolo Circuit

The tremolo section of the TA-16 amplifier employs an interesting new circuit (Fig. 2). It uses a light-dependent resistor (LDR) which can be found in the lower right-hand corner of the amplifier schematic. The LDR unit consists of a low-current lamp and a light-dependent resistance element. The value of the resistance varies with the brightness of the lamp—as the lamp glows brighter, the resistance decreases; as the lamp dims, the resistance increases.

The basic tremolo frequency is developed in transistor $Q12$ which is connected as a subsonic phase-shift oscillator. The frequency can be varied from approximately 4 to 14 Hz by the rate control. The amplitude of the oscillator frequency can be varied by the depth control. The signal is then coupled through a 2-μF capacitor to the base of tremolo-modulator transistor $Q13$. Transistors $Q12$ and $Q13$ are connected to a common emitter resistor to provide additional positive feedback for sustaining oscillation.

Transistor $Q13$ draws collector current through the lamp element in the LDR unit, causing the lamp to glow. Since transistor $Q13$ is amplifying the tremolo oscillator signal, the collector current will follow this signal, causing the lamp in the LDR unit to glow correspondingly brighter or dimmer. The resistance of the LDR will vary in the same way, from a very low to a very high resistance. Since the LDR is connected between the reverb-channel signal path and ground, its resistance variations will modulate the signal with the low-frequency tremolo signal. ▲

Scope Sweep Generator

By ROBERT G. TEETER / RF Communications, Inc.

Construction details on an inexpensive time-mark generator for calibrating the horizontal sweep of an oscilloscope.

MEASURING time or frequency accurately with an oscilloscope is impossible if the scope's horizontal sweep (trace) is uncalibrated. The horizontal sweep can be calibrated by a time-mark generator. Although a professional time-mark generator costs about $300, the simple time-mark generator covered in this article can be built for substantially less than this amount.

This time-mark generator has outputs at known frequencies and when the frequency is accurately known, the period in microseconds along the scope trace can be calculated. Table 1 indicates the relationship between frequency and time for this generator.

A scope's horizontal sweep can be calibrated in one of three ways. The first and most useful is in microseconds-per-centimeter. Other, less-common markings, are microseconds-per-inch, or frequency, which is uncalibrated. With a known frequency signal any scope's horizontal sweep can be calibrated with great accuracy by merely adjusting the variable sweep speed until a known number of timing intervals occupies a specific distance on the screen. Any scope sweep non-linearity will also be displayed.

In this time-mark calibrator, thirteen transistors are used to provide accurate calibration points of 1, 5, 10, 100, 1000, and 10,000 microseconds duration.

As shown in Fig. 1, a 1-MHz crystal oscillator (*Q*1) furnishes an accurate 1-microsecond timing output *via* *Q*2 to point "A". A one-shot multivibrator (*Q*3-*Q*4), adjusted for a division of five, furnishes an accurate 5-μsec output at point "B". Division-by-two is accomplished in flip-flop *Q*5-*Q*6 to produce a 10-μsec output at point "C". Division-by-ten can now be accomplished with unijunction transistor stage *Q*7 to produce a 100-μsec output at point "D". Two more divide-by-ten circuits, *Q*8 and *Q*9, have outputs of 1000 μsecs at point "E" and 10,000 μsecs at point "F", respectively.

Accuracy is inherent in this design. The crystal provides the primary accuracy and any error is too small to be observed on a scope. All of the other outputs are obtained by division from this stable source. A word of caution—division in the last three stages will be correct only if the loading of the unijunction emitters remains constant. For this reason, an emitter follower, *Q*12 and *Q*13, has been added.

Table 1. The relationship between frequency and time for the various output waveforms of the simple scope sweep calibrator.

TEST POINT	FREQUENCY	TIME
"A"	1 MHz	1 μsec
"B"	200 kHz	5 μsecs
"C"	100 kHz	10 μsecs
"D"	10 kHz	100 μsecs
"E"	1 kHz	1000 μsecs
"F"	100 Hz	10,000 μsecs

If your scope does not have a 10-megohm vertical amplifier input impedance, then the emitter follower should be used as part of the testing procedure. The emitter follower is a Darlington configuration with a calculated input impedance of about 14 megohms. It exhibits no measurable loading to any of the circuits.

Parts required to build this generator are standard but a high-*beta*, high-f_t transistor should be used for the higher frequency circuits. Placement of the parts is not critical although short leads should be used.

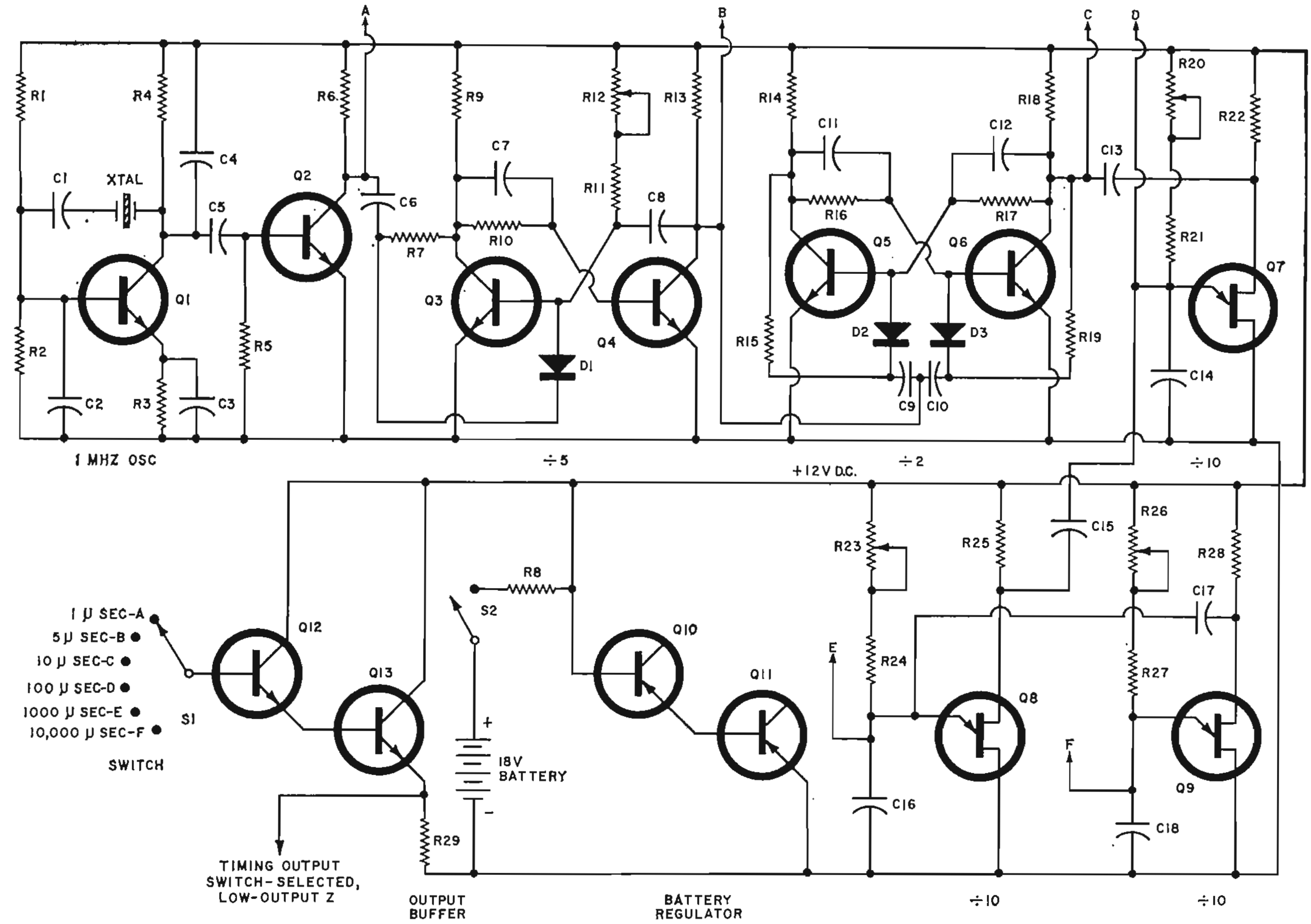
The addition of regulator *R*8 and *Q*10 and *Q*11 will result in greater stability. The emitter-base junctions of the 2N3638's are used as a low-cost zener diode. If a regulated supply or a mercury battery is used, the regulator would not be required, and could be omitted.

Waveforms

When power is applied, the waveform of Fig. 2A will be present at the collector of *Q*1. The purpose of buffer *Q*2 is to provide a sharp falling edge for triggering the following divide-by-five counter. The waveform of Fig. 2B will be present at the collector of *Q*2 and point "A". The trailing edges of this waveform are 1 μsec apart. Transistors *Q*3 and *Q*4 make up a one-shot, divide-by-five circuit. *Q*3 is normally "on" ("on" is defined as the transistor in conduction while "off" is when it is not). A negative pulse coupled through *C*6 and *D*1 turns *Q*3 "off" causing *Q*4 to go "on". Since the voltage across capacitor *C*8 cannot change instantaneously, the base of *Q*3 is forced approximately 10 volts below the emitter. Capacitor *C*8 is charged by *R*11 and *R*12 in series and, when approximately +0.6 volt is reached, *Q*3 turns "on" removing the base drive from *Q*4. Control *R*12 is adjusted so that the time required for this complete cycle is five pulses of the input. Fig. 2C shows the collector waveform of *Q*4 at point "B", while Fig. 2D shows the waveform at the base of *Q*3. The waveform at the collector of *Q*4 is 5 μsec per cycle.

Division-by-two is most easily accomplished with a flip-flop. Transistors *Q*5 and *Q*6 make a simple flip-flop, with *D*2 and *D*3, the triggering diodes. Since *R*16 and *R*17 form direct paths from opposite collectors to opposite bases, the flip-flop will remain stable until a change is triggered by the falling edge of the *Q*4 output waveform. The waveforms of this flip-flop will be affected by subsequent loading, so *C*13 and *R*22 should be connected before testing. Fig. 2E shows the waveform present at the *Q*6 collector and point "C". This waveform is 10 μsec per cycle, or 100 kHz.

Division-by-ten can be accomplished at lower frequencies using a unijunction transistor. Capacitor *C*13 couples the pulses from *Q*6 into base-2 of *Q*7. The combination of *C*14 and *R*20 and *R*21 form a time constant equivalent to a fre-



R1—27,000 ohm, ½ W res.
R2, R6, R13, R14, R18—10,000 ohm, ½ W res.
R3, R4—2200 ohm, ½ W res.
R5—100,000 ohm, ½ W res.
R7—15,000 ohm, ½ W res.
R8—100 ohm, ½ W res.
R9, R29—4700 ohm, ½ W res.
R10—39,000 ohm, ½ W res.
R11, R21, R24, R27—47,000 ohm, ½ W res.
R12, R20, R23, R26—100,000 ohm pot
R15, R16, R17, R19—22,000 ohm, ½ W res.
R22, R25, R28—470 ohm, ½ W res.
C1—220 pF capacitor
C2—82 pF capacitor
C3, C18—0.1 μF capacitor
C4, C6, C9, C10, C11, C12—100 pF capacitor
C5, C13, C14, C15, C17—1000 pF capacitor
C7—330 pF capacitor
C8—33 pF capacitor
C16—0.01 μF capacitor
S1—S.p.6-pos. rotary switch
S2—S.p.s.t. switch
Xtal—1 MHz crystal
D1, D2, D3—1N277 diode
Q1, Q2, Q3, Q4, Q5, Q6, Q12, Q13—2N3394 transistor
Q7, Q8, Q9—2N2646 transistor
Q10, Q11—2N3638 transistor

Fig. 1. Schematic and parts list for scope sweep calibrator. Regulator transistors Q10 and Q11 can be omitted if a regulated power supply or mercury battery is used. Each lettered output is connected to the appropriate terminal of switch S1.

quency of 10 kHz. Both C15 and R25 should be connected since they present a load to Q7. Potentiometer R20 is adjusted until 10 pulses at the Q6 collector result in one sawtooth at the emitter of Q7, as shown in Fig. 2F. This sawtooth is 100 μsec per cycle or 10 kHz.

Division-by-ten is accomplished twice more in exactly the same way by unijunction oscillators Q8 and Q9. Outputs are 1000 μsecs per cycle (1 kHz) and 10,000 μsecs per cycle (100 Hz), respectively. The waveform is identical to Fig. 2F except the μsec/cm scale becomes 100 and 1000 respectively. Fig. 2G shows the waveform at base-2 of each unijunction transistor.

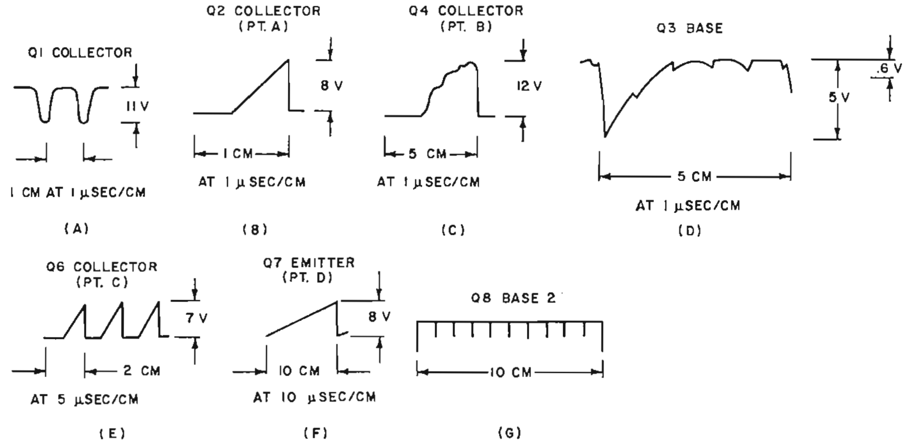
How to Use

The generator output is connected to the scope vertical input and the scope is set to trigger on negative peaks. If the scope has provisions for external triggering, then the generator output can also be connected (in parallel) to this terminal and the sweep set for negative triggering.

The scope graticule should be calibrated in centimeters along the horizontal axis (one centimeter equals 0.3937 inch).

Assume that it is desired to calibrate the scope to 1 μsec/cm. Set the generator S1 to position "A", and adjust the scope sweep until one complete waveform (Fig. 2B) occupies one centimeter division. This distance, and all equivalent marked distances along the sweep, are now calibrated at 1 μsec per centimeter. The same centimeter divisions can be used to set the sweep to any desired value as selected by S1, and the corresponding waveforms of Fig. 2. ▲

Fig. 2. Waveforms present in the generator. See text for explanation.



Electronic Saxophone
(Continued from page 30)

application were settled, the engineers turned their attention to control functions and the addition of the various "effects" so easily available through electronic circuitry. The control unit for the "Varitone" saxophone is mounted on the instrument for easy accessibility to the player's right hand. Controls can be adjusted without interrupting the performance while fingering with the left hand.

Controls include three knobs and four tab switches, similar in function to organ stop tabs. Rotating knobs vary over-all volume, echo, and loudness of the sub-octave. One of the switches is for tremolo on/off, and the other three control tone quality ("bright" for upper frequencies, "dark" for low frequencies, and "normal"). Upper and lower frequencies are boosted or cut approximately 10 dB in the corresponding switch positions. An increase in upper harmonic content adds a "reedy" quality to the tone, while in the "dark" position, the tone tends toward the sine wave, which is more characteristic of flute quality. The small control box also contains tone-shaping circuits to assure faithful reproduction of the saxophone sound.

The preamp, power amplifier, power supply, and speaker for the saxophone are built into a separate cabinet. This unit is placed on stage near the performer, a position similar to that of a guitar amp-speaker. The preamp includes circuitry for echo (reverb), tremolo, and sub-octave effects. Reverb and tremolo are produced by circuits utilized in electronic organs. Spring-type reverberation circuitry incorporates a time-delay network. Tremolo is based on an effect as close as possible to the performer's own natural tremolo of about 4 Hz (in contrast with the 7 Hz in organ designs) and may be varied from that frequency.

Sub-octave Effect

The most interesting and most difficult development associated with the instrument is the "Octamatic" or sub-octave effect, which allows the player to add a note one octave below the one he is playing at any desired volume level. In effect, he doubles with himself. This is accomplished by selecting the fundamental frequency of the note being played and, through a triggering and multivibrator circuit, adding a frequency half that of the original.

In designing the "Octamatic" circuit, care had to be taken to trigger this effect only with a fundamental tone within the saxophone's range. If triggered by an overtone, the sub-octave would not be half the frequency of the basic tone and could even be a strong discord. Therefore, the activating signal is processed to limit its frequency spectrum to the fundamental tones of the instrument. Also, the sub-octave tone itself is voiced so that it has its own distinctive sound identity, different than but complementary to normal saxophone quality.

A separate volume knob on the saxophone controls the loudness of the "Octamatic" output. Once set, the loudness of the sub-octave is constant regardless of how loudly or softly the saxophone is played. This enables the performer to create unusual and interesting effects. He can play loudly, almost drowning out the sub-octave, and then switch to a soft technique, letting the lower tone stand out. An optional foot-controlled switch permits the player to switch the effect in and out quickly as desired. The result is an interplay of sound approaching that of two different instruments.

Output of approximately one volt from the preamp is fed into the main amplifier, which incorporates a four-transistor bridge output circuit. The full bridge circuit develops 75 watts continuous sine-wave output at low distortion while having the advantage of requiring lower power-supply voltages. The entire circuit includes 21 transistors and 14 diodes. Silicon transistors are used throughout with the exception of four germanium output transistors.

Of supreme importance to the engineers involved was the integrity of sound produced by the instrument's electronic components. The speaker and enclosure design was a key factor in this area. No new developments were made, but we were surprised that many existing amplification systems for guitars or accordians completely overlook basic good-design principles in the speaker systems they use. Many amplification systems have a large speaker in too small an enclosure, or low-cost, low-sensitivity speakers mounted in open-back boxes.

The "Varitone" speaker is a specially designed 12-inch unit with a heavy ceramic magnet weighing over three pounds. It is high in sensitivity and is enclosed in a tuned box of proper size to attain maximum effective power and wide, balanced frequency range. Practical considerations of use and portability dictate limits on the size of the speaker/tone-unit enclosure. For this size enclosure and to properly reproduce the saxophone and sub-base tone, optimum speaker size is 12 inches. A larger speaker in this enclosure would not improve the sound but would actually degrade it. ▲

(Note: Several existing and pending patents apply to "Varitone" and "Octamatic" developments.)

Electronic Ignition Systems

(*Continued from page* 49)

It is fairly easy to see just why the capacitive discharge system (CDS) is more appealing since the energy is determined by the formula:

$$W = (\tfrac{1}{2})\,CV^2 \ldots\ldots\ldots\ldots\ldots (13)$$

where: W is energy in joules (watt-seconds); C is the storage capacitance in farads; and V is the voltage to which the storage capacitor is charged.

C and V assume quite reasonable values in order to produce the necessary 30 millijoules for the coil primary.

In analyzing the CDS, we again find the two time intervals, t_{off} and t_{on}, having the same relationship as in eqs. 5 and 6. During t_{on} the distributor points are closed while during t_{off} they are open. However, there is a difference between the CDS and two inductive circuits discussed. For a CDS, during t_{on} no current flows through the ignition coil since the trigger input pulse is shunted to ground, keeping the gate turned "off". At t_{off} a positive trigger pulse turns the gate "on", thus discharging the storage capacitor through the ignition coil.

Fig. 4D illustrates t_{off}, while Fig. 4C approximates the t_{on} circuit with the interstage amplifier actually consisting of an oscillator directly coupled to a step-up transformer. In most cases, these transformers are special low-inductance, high-"Q" components since they must operate at frequencies up to several hundred hertz.

Eq. 11 again is the time constant for t_{off}. However, there is little or no damping involved as is the case with the inductive system. For our calculations, we shall keep C constant at 1 μF, although the value of C may vary from 0.33 to 1 μF, depending on the manufacturer's circuit. For L we shall use the upper and lower limits of 10 and 1 mH, respectively. Using these values in the previous equations, we find that the electrical limitations of t_{off} far exceed the engine's operating range. For the 10-mH ignition coil we would have to exceed 50,000 rpm in order for the electronics to impair performance, and for the 1-mH ignition coil, this figure would be 160,000 rpm.

If the ability to discharge C through L is not limited, let's consider the problems of charging C to the required several hundred volts *via* the intermediate stage of amplification. All this must take place during t_{on} as seen in Fig. 4C. The rectifier shown is actually a full-wave bridge. The special transformer permits a maximum effective oscillation frequency of, typically, 400 Hz. Bearing in mind that the stepped-up oscillations are sinusoidal and full-wave rectified, we find that the capacitor reaches maximum voltage, V_{max}, in about one-fourth of a cycle or, in this case, about 0.6 millisecond. Using t_{on} = 0.6 msec in the previous equations, we arrive at a value of almost 17,000 rpm before the electronics circuit limits engine operation. This, too, is considerably above practical engine operating speeds.

Most of the CDS circuits used have charge-up oscillations somewhat proportional to rpm, as the oscillations themselves are triggered by the discharge of the storage capacitor. The efficiency of the system is improved since most of the input power is dissipated during capacitor charge-up, *i.e.*, one-fourth of the first oscillation. Subsequent oscillations merely maintain the capacitor's charge. This is not the case with the inductive systems since they constantly draw current during t_{on}.

Finally, Fig. 6 shows the effect of rpm on coil primary energy. Obviously, all systems exceed the two conventional systems #3 and #4 over most of an engine's operating range except for the lowest engine speeds. However, the transistor systems (#1 and #2) are consuming 120 peak watts against the conventional systems (#3 and #4) 72 peak watts. The CDS also requires about 72 watts, but in terms of average power, it draws considerably less. Even 120 watts is not appreciable when compared to the battery's almost 1 kW of available power, and is of even less concern once the engine is started and the generator or alternator is producing the required power. It is interesting to note that conventional system #3 is the optimized version of a system that is standard in a popular American racing car whose engine is designed to operate in the 7000-8000 rpm range.

Fig. 6 leads us to the conclusion that conventional systems do an adequate job up to the 3000-4000 range (65-85 mph for most cars). But remember that these are optimized results. In actual practice, the circuit energy would be about 20 to 50% less than the values shown. Also, by merely increasing the dwell angle, *i.e.*, altering the effective duty cycle, we can improve the transistor ignition system's performance. In this case, we could reasonably switch 12 amperes instead of 10 by reducing R from 1.2 ohms to 1 ohm, thus obtaining an average energy increase of around 20% for the same rpm. This assumes, of course, that the switching transistor and coil can handle the added current.

The CDS offers efficiency as well as performance. There seem to be only two drawbacks. Initial expense may run two to three times that of transistor ignition systems and reliability may be less since there are many more components involved. ▲

Electronic Music

(*Continued from page 46*)

be built for programmed composition is the *RCA* synthesizer, illustrated in Fig. 10. A punched paper tape, much like a piano roll, is used to specify a set of parameters every 1/30 second. The *RCA* synthesizer does not use voltage control but employs passive component switching to achieve the parameter variations. This device is located in one of the studios of the Columbia-Princeton Electronic Music Center and has been used for the realization of several important electronic-music compositions. The high cost of the instrument is one of the reasons why more devices of this particular type have not been built.

Using Voltage Variations

Instruments for programmed composition employing control-voltage variations are inherently less expensive than those employing component switching and consist of a modest collection of voltage-controlled devices and one or more programmable control-voltage generators. A simple programmable control-voltage generator, called a sequencer, is based on a ring counter. A block diagram of a typical sequencer is shown in Fig. 9. Only one stage of the ring counter is "on" at a time. A timing pulse turns that stage "off" and the next stage "on." When a given stage is "on," it applies a fixed direct voltage across one or more programming potentiometers associated with it; when it is "off," the voltage across the potentiometers falls to zero.

The voltages at the wiper arms of all the programming potentiometers are added by a d.c. adder circuit. All these voltages are zero except the voltage of the "on" stage; the sequencer output is thus a voltage which changes from one preset value to another upon receipt of a timing pulse. The composer is able to set the programming potentiometers in advance to produce a given sequence of parameter variations, and he can produce the sequence simply by initiating the timing pulses. A control-voltage sequence can further be used to control a v.c.o. which is connected so that it produces timing pulses, thus facilitating the programming of event timing as required.

Paper-Tape Programming

The sequencer can be pre-programmed for only as many events as the number of sequencer stages, after which it repeats the sequence. Thus, the sequencer can eliminate much, but not all, splicing. The next step in programming capability is the continuous

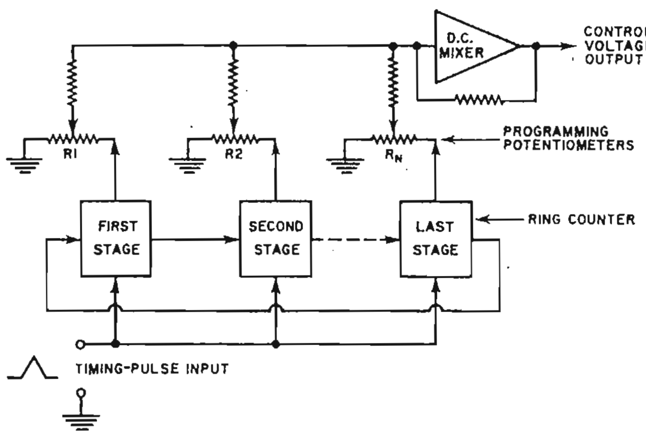
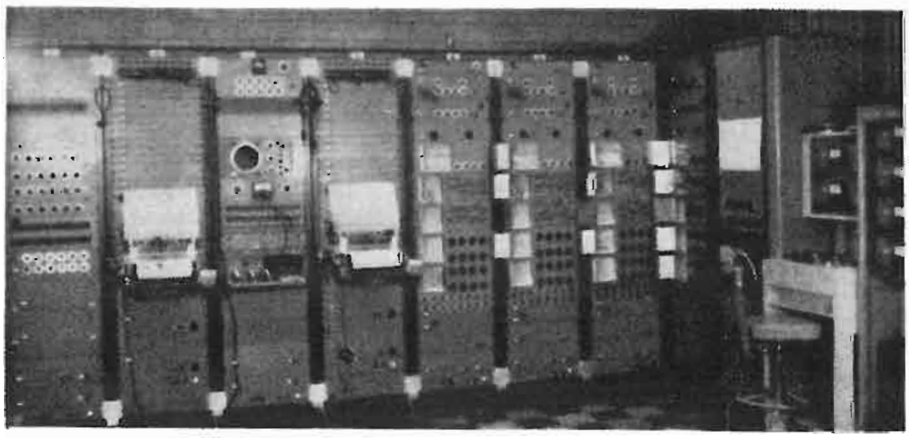


Fig. 9. Block diagram of a simple control-voltage sequencer.

Fig. 10. The RCA synthesizer, located at the Columbia-Princeton Electronic Music Center. The rolls of paper at the center of the photograph are employed to program the entire instrument.



programming of control voltages *via* paper tape. We have used conventional 8-track paper-tape readers to program passages of several thousand sound events. The passage is recorded in real time in its entirety, and this almost completely eliminates the necessity of splicing. Programmed composition of fast, intricate passages *via* paper tape generally takes about one-tenth the time of classical studio composition and, because the program is in digital form, is inherently accurate. The lead photo illustrates a portion of a typical studio in which a simple paper-tape reader is being used to program a bank of voltage-controlled oscillators and voltage-controlled amplifiers.

Using Computers

A further increase in programming capability, which has recently been developed, is achieved by using a small digital computer and a digital-to-analog converter to produce the control voltages. The converter itself can be programmed to accept coded information from the computer and speeds the composition process to a point where it is nearly as fast as composing traditional music in conventional notation. Prices of small computers are now in a region such that programmed performances of electronic music without tape recorders are entirely feasible.

Real-time performance instruments based on voltage-controlled circuitry have also been developed in recent years and have been played in public concerts of new music. The "ultimate" performance instrument, on which the performer can produce any sound or combination of sounds in real time, is yet to be developed. The main problem is the design of manual-control devices which permit the performer to continuously specify all the parameters of the sounds. This problem is one of "human engineering" and will undoubtedly take years of experimentation, on the concert stage as well as in the laboratory, to solve completely. However, even the simple performance instruments which have already been built have opened new musical horizons to composers and performers alike, and a new type of electronic music, composed for live performance, may develop apart from recorded electronic music.

Note: The Independent Electronic Music Center, a non-profit educational membership corporation, engages in several activities related to electronic music. One of these is the publication of the Electronic Music Review, *a quarterly magazine devoted to matters of interest to electronic-music composers, engineers, performers, and listeners. Interested readers are invited to send for further information to the Independent Electronic Music Center, Trumansburg, New York 14886.* ▲

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TEMPERATURE-MEASURING KITS

The "Temp-Plate" is a unique temperature-recording decal which provides a permanent irreversible reading and record of peak temperatures. The product uses a spot of pastel-colored chemical which turns irreversibly black when the heat reaches the calibrated level of the temperatures specified on the indicator.

The range of temperatures available is from 100°F through 1100°F, or the centigrade equivalents. These are normally in 10°F gradients throughout the range, and all carry a ±1% accuracy factor. Complete kits are now available in a wide range of temperatures. William Wahl

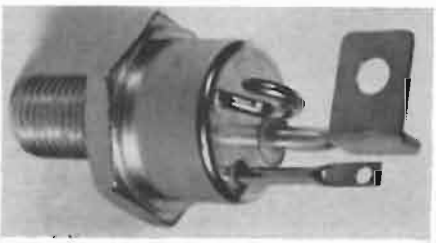
Circle No. 127 on Reader Service Card

HIGH-POWER TRANSISTORS

A new line of two JEDEC-registered high-current n-p-n silicon power transistors capable of controlling and/or switching a collector current of 100 amperes is now available in a 1 1/16" hex package, double-ended for stud mounting.

Combined with the 100-ampere current capability is the ability to dissipate up to 350 watts. The sustaining voltages are 80 V for the 2N4865 and 120 V for the 2N4866. Both devices have a minimum cut-off frequency of 10 MHz.

The transistors have an h_{FE} of 10 to 40 at 70 amperes and 5 at 90 amperes. Saturation voltage is less than 2.5 V (collector to emitter) at 70



amperes collector current with a base current of 7 amperes; it is less than 5 V at 90 amperes with a base current of 18 amps. Total switching speed at 70 amperes is 4 microseconds maximum. Both transistors meet or exceed MIL-S-19500. Solitron

Circle No. 128 on Reader Service Card

TRIMMING POTENTIOMETER

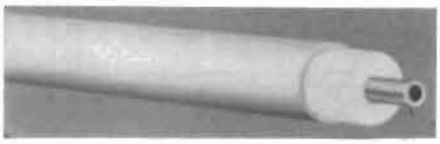
A new series of extremely rugged wirewound trimming potentiometers, designed with a ring of multiple contacts around the resistance element to provide smooth, light, and even contact pressure in all directions, is now available. During adjustment, the multiple contacts make many sequential contacts on each turn of the resistance wire as the line of contacts moves in a spiral motion. As a result, resolution is increased and wiper contact is less than 20 ohms at vibration levels in excess of 50 g's.

Physical size of the Model 3 series is 1 1/4" long by 5/16" high by [illegible]/16" deep. Resolution is better than 0.2%, power rating is 1 W at 70°C, temperature coefficient is better than 50 ppm/°C, and the units are available in a variety of case and lead configurations with resistance values ranging from 10 to 50,000 ohms. Newport Instrument

Circle No. 129 on Reader Service Card

LOW-LOSS COAXIAL CABLE

"Aircraft Foamflex" coaxial cable is now available to meet the needs of airborne applications. This cable has less than one-half the loss of RG-213/U or RG-214/U and is capable of handling more than twice the power with no increase in weight. An outer conductor of seamless aluminum tubing, a foam polyethylene dielectric, and



a smooth copper tube for the inner conductor result in 100% shielding and excellent uniformity.

Designated RG-231/U by the Air Force, the cable has an impedance of 50 ohms, capacitance of 25 pF per foot, and velocity of 81%, with a loss of 3.5 dB at 1 GHz. Weight is less than 11 pounds per 100 feet.

A full line of adapters matches this cable to UG-21, UG-23, type N, UG-572, UG-573, and type C as well as other interfaces such as General Radio 874 and HN. Phelps Dodge

Circle No. 130 on Reader Service Card

CLEAR EPOXY ADHESIVE

The new "Eccobond 24" is a two-part, general-purpose, low-viscosity, clear epoxy adhesive that will cure at room temperature. It will adhere to a wide variety of substrates and is particularly recommended for joining transparent materials such as glass where the clarity of the substrate is not affected by the adhesive. Because it contains no solvent, it is also useful for joining two impervious adherends.

The epoxy has been used successfully for bonding most metals and ceramics as well as many plastics, including polystyrene, polyacrylates, polysulfone, polycarbonate, rigid polyvinyl chloride, polyvinylidene chloride, and epoxies.

Sufficient cure takes place in 2 to 4 hours so that bonded articles may be handled. Complete cure requires about 24 hours at room temperature. Pot life is 30 minutes after mixing. Emerson & Cuming

Circle No. 131 on Reader Service Card

SOLID-STATE VTR

Using two rotary magnetic heads in a helical scanning system, the Model SV-700 solid-state video tape recorder provides a video response of 3 MHz or more with 300 lines horizontal resolution, plus 36 dB or more in signal-to-noise ratio.

Operation is simple. The video and audio lev-

els are set through a level meter indicator. The 1/2" wide tape permits 60 minutes of continuous recording on a 7" reel at 7.5 ips. Recording signals may be standard TV or CCTV outputs.

Audio response is 50 to 10,000 Hz with S/N ratio of 40 dB. The unit is 15 3/4" wide, 15 3/4" deep, and 9 1/2" high. Weight is 66 pounds. Shibaden Corp. of America

Circle No. 1 on Reader Service Card

SEMICONDUCTOR PACKAGE

The new plastic semiconductor "HANDYLab" contains 300 "Unibloc" plastic-packaged semiconductor devices and provides the circuit designer or experimenter with a wide selection of devices for prototype circuit development and experimental designing. This selection includes 11 different general-purpose n-p-n and p-n-p plastic transistor types. These transistors are the patented "Annular" structure and are encapsulated in a rugged one-piece, pressure-molded plastic case. In addition, 25 plastic dual switching diodes designed for use in high-speed switching applications are included. Motorola

Circle No. 2 on Reader Service Card

RADIOACTIVE LEAK TESTER

This new pre-registered leak test kit permits users of radioactive sealed sources to meet AEC leak test requirements easily and inexpensively. The kit contains protective equipment, a finger dosimeter, and complete leak test supplies and instructions. Test kits are returned to the company for analysis. Controls for Radiation

Circle No. 132 on Reader Service Card

HIGH-VOLTAGE SUPPLIES

A pair of high-voltage bench power supplies featuring all-silicon circuitry in a half-rack package has been announced. The Model 6515A, only 3 1/2" high, has an output of 0 to 1600 V d.c. at 0 to 5 mA; and the Model 6516A, 5 1/4" high, has an output of 0 to 3000 V d.c. at 0 to 6 mA. Load

and line regulation is 0.01% or 16 mV. The supplies have low ripple and noise and are short-circuit-proof. A 10-turn vernier permits full adjustment with 100-mV resolution over each voltage span with no blind spots. Hewlett-Packard/Harrison Division

Circle No. 133 on Reader Service Card

FAIL-SAFE POWER SYSTEM

The "All American Power Watch System" is a solid-state system designed to assure a constant flow of d.c. to operate laboratory equipment even if a complete power failure occurs. Heart of the system is a "Power Watch Battery Monitor" which automatically cuts in when the energy level in a storage battery drops down. When connected to a 120-V a.c. source, the monitors check the controlling battery voltage 120 times per second. Whenever the energy level drops, the monitor switches on to restore full charge and then cuts off completely until needed again. All American Engineering

Circle No. 134 on Reader Service Card

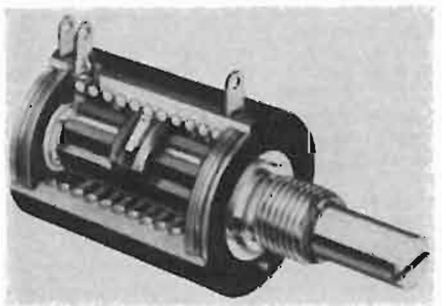
NEW UNIJUNCTIONS

A new line of improved unijunction transistors is now available. The immediately available 2N4851-53 Series of UJT's offer a combination of low emitter reverse current and low peak-point current, allowing the design of long time-delay circuits with smaller and less expensive capacitors than would ordinarily be required. The low input current demands also give these units exceptional capabilities in low-level sensing applications. In oscillator circuits, these devices are guaranteed to be capable of 1-MHz operation and to exhibit a more uniform interbase temperature coefficient. Motorola

Circle No. 135 on Reader Service Card

MULTI-TURN POTENTIOMETER

A new ⅞" diameter multi-turn precision wirewound potentiometer, the Type 8400, can be adjusted with either a knob or screwdriver, has resistance values from 100 to 100,000 ohms, ±5%



tolerance, 0.25% independent linearity, is rated at 2 watts at 25°C, and operates over a temperature range of —53 to 105°C. IRC

Circle No. 136 on Reader Service Card

COLOR-TV KIT

A 180-square-inch rectangular 19-inch color-TV kit, the Model GR-180, has been introduced. Total construction time is about 25 hours with all critical circuits prewired, aligned, and factory-tested.

The set includes a built-in dot generator for ease of service. The set may be installed either in a wall or in a custom cabinet.

The 26-vacuum-tube set uses a rare-earth 19-inch rectangular CRT and 10 diodes; it has a regulated 24-kV high-voltage supply, an automatic degaussing coil, a magnetic shield that covers the CRT, a "memory" fine tuning in the v.h.f. tuner, and a 2-speed transistor u.h.f. tuner. It features a cathode-follower output to drive an external hi-fi audio system. The CRT is guaranteed for one year. Heath

Circle No. 3 on Reader Service Card

TINY AUDIO TRANSISTORS

A new series of microminiature silicon planar epitaxial audio transistors (Types A151, A152, and A153) comes in a package size of 0.078" x 0.071" x 0.071" and features a noise figure of 1.5 dB, 10-nA leakage, with current gain characteristics maintained over a wide range of collector currents from 20 to 2000 μA.

Mounted on ceramic substrates, the units have extra-rigid leads. Amperex

Circle No. 137 on Reader Service Card

TRIMMING POTENTIOMETERS

The "Kwik-Trim" trimming potentiometers have triple-adjustment screwdriver slots and dual visual indicators. They come as ½" square, ½" round, or ¾" square with thicknesses ranging from 0.240" to 0.280". Either wire or dip solder leads are provided.

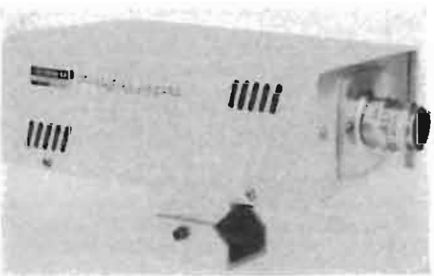
Temperature range is from —65 to 150°C (derating to zero watts at 150°C). Standard resistance values on ½" models run from 10 to 50,000 ohms, and from 100 ohms to 150,000 ohms on the ¾" models. Resistance tolerance is ±10% and linearity is ±5%. General Scientific

Circle No. 138 on Reader Service Card

CCTV CAMERA

The 4100 Series all-silicon solid-state-circuitry self-contained closed-circuit TV camera is available for use with either a conventional TV receiver or a video monitor. Both installations use a 75-ohm coaxial cable to connect the camera to the monitor.

Automatic adjustment of sensitivity provides



unattended operation over an illumination range of greater than 5000:1 with highlight intensities as low as 10 footlamberts. The camera housing is finished in mar-resistant, vinyl-clad aluminum and is 3¾" high, 7" wide, and 12" long. Weight is under 6 pounds, including the 1" lens and vidicon. Any standard TV 16-mm "C" mount lens may be used. The mounting base is tapped for standard ¼-20 camera tripod screws. Cohu

Circle No. 4 on Reader Service Card

CERAMIC CAPACITOR

A new radial-lead ceramic capacitor with 100 times more capacitance than previously available in a package as small as 0.3" x 0.3" x 0.15" has just been introduced. Called the "C12 Hi-D," it is offered in capacitance ranges from 0.18 to 1 μF. The capacitor case measures 0.3" x 0.3" x 0.1" up to 0.47 μF, and 0.3" x 0.3" x 0.15" up to 1 μF. Working voltages (d.c.) are 50 V at 125°C for values from 0.18 to 0.27 μF and 25 V at 125°C for values from 0.33 to 1 μF.

Operating temperature range is —55 to 125°C and capacitance tolerance is ±10% standard with 5% and 20% available. The units meet all applicable requirements of MIL-C-11015. U.S. Capacitor

Circle No. 139 on Reader Service Card

HEAT-SHRINKABLE TAPE

A new irradiated, heat-shrinkable tape with a meltable wall for use as insulation and protection in virtually all electrical and electronic applications is now available under the name "Insultape." In addition to serving as an electrical insulator, the tape also forms a watertight seal. The new tape is rated at 135°C continuous operating temperature, is flame-resistant, and exceeds federal and military specifications.

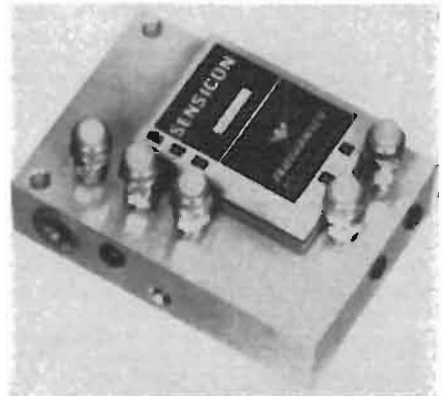
The tape is available in standard white and in widths of ¾" and 1½". The line will be expanded to include widths to 6". Electronized Chemicals

Circle No. 140 on Reader Service Card

FLUIDIC DEVICES

The first of a new line of fluidic devices for circuit sensing and control is now being made available under the name "Sensicon." These devices are compatible with any type of control system requiring a digital pressure output.

The initial unit uses an interruptible gap for



proximity sensing and emits a digital on-off signal. The device is composed of a special manifold to which an "or"/"nor" gate is bonded. Factory-set adjustable needle valves control sensing and digital output signals. The complete line will include devices for proximity, interruptible, temperature, noise, light, or magnetic sensing. Fluidonics Div., Imperial-Eastman

Circle No. 141 on Reader Service Card

FIBER OPTICS KIT

To help engineers and equipment designers in the data-processing, instrumentation, and control system fields determine whether fiber optic "light wires" can help solve their problems, a familiarization kit containing six sections of light wire varying from 1/16 to ¼ inch in diameter and from 6 to 48 inches in length is now available. Three of these units are sheathed in plastic and three in crush-resistant aluminum tubing. All are complete with appropriate end fittings, ready for use. Bausch & Lomb

Circle No. 142 on Reader Service Card

PRECISION TIMER

This completely transistorized electronic timer registers minutes, seconds, and tenths of a second to 99:59.9 minutes on a large conventional electromechanical counter. Hundredths and thousandths of seconds are indicated on an easily read illuminated binary-coded decimal (BCD) readout. These characteristics make the timer useful

in experimental timing of production and laboratory processes, human reactions, physics demonstrations, and related scientific applications.

The unit is powered by a 12-V source, is 8″ by 6″ by 8″, and weighs under 6 pounds. Heuer Time Corp.

Circle No. 143 on Reader Service Card

REPLACEMENT RESISTORS

The Type MV is an axial-lead, film-type color-TV replacement resistor rated at 6 kV. It is available in two ranges: MV47 at 4700 ohms and MV66 at 6600 ohms, both ±20%. Precise mechanical spacing of the helical resistance path allows a uniform voltage gradient throughout the resistor length. IRC

Circle No. 5 on Reader Service Card

1.5-KW DIMMER SWITCH

This 1500-watt incandescent dimmer switch operates on the 120-volt, 60-Hz power line, has one-piece construction, and will fit within a standard two-gang box. A new concept in face design allows maximum ventilation for cooler operation.

A silicon symmetrical switch and solid-state circuitry give full dimming control without flickering. An r.f. noise filter eliminates interference. Ideal

Circle No. 6 on Reader Service Card

SOLID-STATE FM/TV AMPLIFIER

The "Avante 20" is a solid-state TV FM amplifier for master antenna and home installations. It has a frequency response of ±1 dB and a gain of 20 dB across the frequencies from 50 through 220 MHz. Dual 75-to 300-ohm inputs and outputs use stripless screw terminals and MF61A

fittings. Matching MF59A coaxial connectors are included. The unit operates from a 117-V, 60-Hz power source, measures 3″ by 5″ by 4″, and has a shipping weight of 1½ pounds. Craftsman Electronic

Circle No. 7 on Reader Service Card

CONVERTER-BATTERY CHARGER

The "Safe-T-Plug Mark II" can be used to recharge ordinary carbon-zinc flashlight batteries and to convert ordinary house current to the low d.c. required by transistorized products and small motor-driven appliances. It can also be employed to recharge the nickel-cadmium batteries used in cordless rechargeable devices.

The plug is just slightly larger than a standard electrical plug and contains a transformer and rectifier. The cord emanating from the plug carries only low-voltage d.c. Dynamic Instrument

Circle No. 8 on Reader Service Card

HI-FI—AUDIO PRODUCTS

SHELF-TYPE SPEAKER

The new Model GK-100 speaker uses a 3″ tweeter and an efficient 6″ low- and mid-range woofer and has a built-in crossover network with an infinitely variable potentiometer to adjust response for best listening to compensate for room characteristics. Its beige grille cloth blends with any room decor. Response is from 40 to 16,000 Hz and impedance is 8 ohms. The solid oiled-walnut cabinet is 10½″ by 18″ by 6″. J. J. Kuscher

Circle No. 9 on Reader Service Card

SOLID-STATE AM/FM RECEIVER

The new SX-1000TA AM/FM solid-state receiver covers both AM and FM bands, has a 90-

watt output covering 30 to 20,000 Hz with distortion less than 1%, uses a time-switching stereo circuit providing 38-dB channel separation, has simultaneous tape-recording jacks and a tape monitor switch, and has an FM sensitivity of 2.2 μV. A muting circuit eliminates noise between stations. A sensitive tuning indicator and a stereo indicator lamp are also provided. In addition, the unit is supplied with an oiled-walnut cabinet at no extra charge. Pioneer

Circle No. 10 on Reader Service Card

SOUND RECORDER AIDS

Three new accessory items for tape recorders—an easier-to-use splicing tape, a tough leader and timing tape, and a unique tape timing guide—have been recently introduced.

The ¼-inch "Presstapes" are pre-cut splices which can be easily applied to recording tape with none of the customary trimming since they are identical in width to the recording tapes. They come in packets of 40 with complete instructions. The leader and timing tape has a matte, opaque surface that enables write-on identification and damage-free threading. The product is supplied in 150′ lengths on a 3″ tape reel in a dispenser box. The leader and timing tape is colored yellow to separate it from magnetic tape when it is used to identify recorded selections within a roll of tape.

The tape timing guide, measuring 5 by 1¾ inches, is notched at one end for use with any type of tape. Positioning a guide with its notched end against the reel spindle permits the number of minutes of playing time remaining on a reel to be read off directly on the proper scale of the guide. Each package contains two guides, one for 7½ ips and the other for 3¾ ips. Kodak

Circle No. 11 on Reader Service Card

SOLID-STATE CARTRIDGE UNIT

The new Model TM706S solid-state stereo cartridge player accepts eight-track tape cartridges which may be used interchangeably with home players built for this type of recorded unit.

Two 5½″ speakers are included with the unit. The system operates from a 12-volt negative-ground electrical system and uses 13 transistors and one diode. Designed for under-the-dash installation, the unit is 8½″ wide, 7½″ deep, and 3″ high. The dual-channel amplifier provides response from 50 Hz to 10 kHz. Motorola

Circle No. 12 on Reader Service Card

STEREO POWER AMPLIFIER

The TA-3120 stereo power amplifier uses silicon transistors throughout, 20 diodes, and one SCR. Power output is 120 watts ± 0.5 dB both channels at 8 ohms or 35 watts per channel ± 0.5 dB at 16 ohms.

Frequency response is 30-100,000 Hz +0, −1 dB at rated output while harmonic distortion is less than 0.1% at rated output and 1000

Hz. Damping factor is better than 70 at 1000 Hz (8 ohms) and sensitivity is 1 volt at rated output.

The unit is powered by 117 volt ± 10%, 60 Hz a.c. There are two switched and one unswitched a.c. outlets. The amplifier measures 7⅛″ w. x 5¾″ h. x 17½″ d. and weighs 17 pounds, 10 ounces. Sony

Circle No. 13 on Reader Service Card

ORGAN KIT

A new theater model organ, featuring the traditional horseshoe-shaped console, 25-note pedalboard, and two full 61-note keyboards, is now available in kit form. This fully transistorized organ also features 48 stop tablets, and pitch registrations from 1 foot to 16 feet are available.

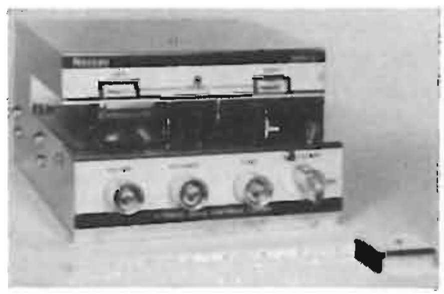
There are 35 speaking stops and 4 couplers. The 35 stops cover the gamut of true theater pipe-organ sound from the smooth round tibias to the most biting and blaring strings and reeds. There is also an optional combination action and an 8-voice percussion section available.

Printed circuits are used throughout, and it is estimated that it will take the average person 150 hours to assemble this organ. Schober

Circle No. 14 on Reader Service Card

CARTRIDGE TAPE RECORDER

The "Nassau Mark III" four-track stereo tape recorder accepts all standard 4-track stereo cartridges including Fidelpac 300, 600, and 1200 or Audiopac and allows high-fidelity recordings to be made through standard phono plug jack in-



puts. It operates from 117 V a.c. or 12 V d.c. and includes monitoring jacks and illuminated recording-level meters. Guesswork as to where the recording began is eliminated by an automatic shutoff after each recording cycle. The unit measures 7½″ wide by 8½″ deep by 5¼″ high. Telephone Dynamics

Circle No. 15 on Reader Service Card

ALL-SILICON STEREO TUNER

The new Model S-2300 stereo tuner uses 18 silicon transistors, 13 silicon diodes, and one silicon zener diode. It combines sensitive (2 μV), low-noise AM circuitry with FM circuitry rated at 1.6 μV (IHF) sensitivity and interchannel hush. A specially designed dual automatic gain control system maintains proper selectivity under the strongest signal conditions. This circuit uses reverse and amplified forward control for a.g.c. and is unique with this company's sets.

The Model S-2300 also features noise-threshold gated automatic FM-stereo, mono switching (35 dB separation), a d'Arsonval zero-center tuning meter, a front-panel level control, and professional rocker-action front-panel function switches. Hum and noise are 70 dB down for FM and 56 dB down for AM. The tuner is 14″ x 4″ x 10½″ and weighs 10½ pounds. Sherwood

Circle No. 16 on Reader Service Card

CB-HAM-COMMUNICATIONS

VOLTAGE REGULATOR

The ability to operate low-powered communications and other electronic equipment from practically any d.c. power source ranging from six to 32 volts is now possible with two new accessories. These units can be used with equipment drawing up to 14 watts and can correct improper input voltage or incorrect polarity.

The "In-Converter" accepts 6 or 12 V d.c. and delivers an output of 6 or 12 V d.c. of the polarity desired or an output of 18 or 24 V d.c. of the same polarity as the input.

The "Voltage Regulator" accepts any d.c. voltage from 24 to 32 volts and furnishes an output of 13 V d.c. at 14 W. E. F. Johnson

Circle No. 17 on Reader Service Card

SOLID-STATE FM MONITOR

This new solid-state FM monitor receiver for 25- to 50-MHz and 132- to 174-MHz communications systems has increased sensitivity for improved reception in weak signal areas and high selectivity for greater protection against interference.

The receiver may be used on 117 V a.c. or 12 V

d.c. Automatic standby power (optional) allows an internal nickel-cadmium battery supply to take over in the event of a.c. power failure.

Decoder options Type 90 or 99 may be mounted internally for signaling or alarm. This permits individual receivers to be called selectivity and allows activation of buzzers, lights, or bells. General Electric

Circle No. 18 on Reader Service Card

MARINE RADIOTELEPHONES

A new line of marine radiotelephones has been recently introduced. Among the new devices are: model 45, a 45-watt unit operating on 4 marine channels plus broadcast-band reception; model 75A, a 75-watt system operating on 6 marine channels plus broadcast-band reception; model 120A, a 120-watt unit operating on 6 marine channels plus broadcast-band reception; and the model 150A, a 150-watt unit operating on 8 marine channels plus broadcast-band reception. The VHF-50 is a 50-watt v.h.f. FM radiotelephone operating on 12 v.h.f. channels; it incorporates a dual-channel monitoring and low-power transmitting facility for short-range communications. Simpson

Circle No. 19 on Reader Service Card

MANUFACTURERS' LITERATURE

FREQUENCY COMPARISON

A new 9-page application note (No. 77-2) on the subject of precision frequency comparison with the company's Model 8405A vector voltmeter has been published.

The booklet describes how to use the voltmeter to plot phase difference between two signals and shows how the phase plots are employed to find frequency difference. Several examples are given, along with diagrams which illustrate how the equipment is calibrated and used. In addition, a number of graphs are supplied. Hewlett-Packard

Circle No. 144 on Reader Service Card

NUCLEAR ACCESSORIES

A new 50-page illustrated catalogue of nuclear accessories and detectors has been issued. More than 2000 items are listed in the catalogue, including x-ray dose indicators, remote handling tools, air samplers, warning signs, protective clothing, fume hoods, radioactive sources, and various types of detectors.

The publication is prefaced by an alphabetical index. Hamner

Circle No. 145 on Reader Service Card

POTENTIOMETERS

Technical data on more than 50 high-performance wirewound and non-wirewound, and general- and special-purpose adjustment potentiometers is contained in a new 8-page illustrated short-form catalogue (No. 14).

Other products described in the brochure include relays, counting dials, voltage sensors, and power supplies. Bourns, Trimpot Div.

Circle No. 146 on Reader Service Card

DRY TRANSFER PRODUCTS

A new, expanded 40-page catalogue covering the entire line of "Deca-Dry" dry transfer products for draftsmen and technical illustrators has been issued.

The fully illustrated, indexed publication features transfer lettering in a wide range of styles; number sheets; repetitive dry transfer letters, numbers, and symbols in handy dispensers; custom printed sheets; and an electronic marking kit. Chart-Pak

Circle No. 147 on Reader Service Card

MICROPHONE CONNECTION

A new 12-page pocket-sized booklet, which describes the proper method of connecting the company's "+2" Citizens Band microphone to more than 100 different CB and amateur radio sets, has been issued. Turner

Circle No. 20 on Reader Service Card

ACCELEROMETERS

A new 24-page handbook for users of piezoelectric accelerometers has been published. Bulletin 4200 covers piezoelectric vibration and shock transducers; and theory and application, including accelerometers, voltage amplifiers, source followers, charge amplifiers, low-impedance accelerometers, and calibration.

Also provided are associated diagrams and curves, helpful formulas, and a glossary of terms. Consolidated Electrodynamics

Circle No. 148 on Reader Service Card

MEASURING INSTRUMENTS

A wide variety of electrical measuring devices, including potentiometers and voltage standards, d.c. resistance bridges, galvanometers, magnetic flux meters, portable standards, and insulation and ground resistance testers, is offered in a new 4-page illustrated catalogue digest (No. C9-04). YEW

Circle No. 149 on Reader Service Card

POWER GENERATORS

A series of four "Mite-E-Lite" portable electric power generators is offered in a new 8-page illustrated brochure. Featuring barium-ferrite permanent magnets, the generators differ from conventional designs in that the magnets rotate and the coils remain stationary. McCulloch

Circle No. 21 on Reader Service Card

CALCULATING DEVICES

A new 16-page illustrated 1966-67 catalogue of special slide rules, calculators, and various engineering aids has been issued. The items listed in the booklet, which should be of interest to engineers, architects, draftsmen, machinists, and contractors, include a probability slide rule, a steel-sheet weight computer, a circular slide rule, and a handbook of electronic charts and nomograms. TAD

Circle No. 150 on Reader Service Card

TEST EQUIPMENT

Features and specifications of a line of professional test equipment for servicing radio, TV, hi-fi, and electronic communications equipment are outlined in a new 12-page illustrated brochure.

Instruments listed in the catalogue include an all-solid-state color generator, a CRT rejuvenator and checker, tube testers, a v.o.m., and a vacuum-tube voltmeter. B & K

Circle No. 22 on Reader Service Card

SPECTROPHOTOMETERS

Information on a complete line of spectrophotometric instruments and accessories is contained in a new 16-page illustrated catalogue. The booklet describes applications, specifications, instrument data, and spectra-demonstrating equipment capabilities and versatility. Cary

Circle No. 151 on Reader Service Card

ELECTRONIC COMPONENTS

A new 26-page illustrated catalogue describing the company's entire standard line of electronic components is now available. Prepared for design engineers, the booklet provides information on capacitors, tube sockets, connectors, terminals, insulators, pilot lights, inductors, and miscellaneous hardware. E. F. Johnson

Circle No. 152 on Reader Service Card

DIMMER SWITCHES

Described and illustrated in a new 4-page brochure is a line of electronically controlled incandescent dimmer switches. Bulletin 3A discusses 600-watt push-push types as well as 1000-, 1500-, and 2000-watt rotary devices. Ideal

Circle No. 23 on Reader Service Card

TOGGLE SWITCHES

A new technical data sheet (No. 244) covering the new "TW" series of miniature toggle switches has been published. Applications include aircraft panels, survival kits, portable communications equipment, data-processing equipment, and other areas where small size and light weight are required.

The data sheet gives complete mechanical and electrical specifications, outlines construction features, and supplies mounting and wiring information. Micro Switch

Circle No. 153 on Reader Service Card

TOOL CATALOGUE

A new 48-page illustrated catalogue covering a wide line of specialized microminiature tools and other equipment is now available.

Featured in the booklet is a complete selection of hand tools, including tweezers, pliers, scissors, and nippers. Also shown are miniature power tools, ultrasonic cleaning devices, various types of soldering equipment, magnifiers, and high-intensity lamps. Henry Mann

Circle No. 154 on Reader Service Card

MICROWAVE DIODES

A new 4-page condensed catalogue (No. D-1) describing a complete line of microwave diodes has been released. Tabulated electrical and mechanical data is provided on more than 100 models, including mixer and video detector diodes, general-purpose varactors, step-recovery diodes, parametric-amplifier varactor diodes, fast-switching devices, and PIN switching types. Alpha Industries, Micro Optics Div.

Circle No. 155 on Reader Service Card

SHIELDING PRODUCTS

A new 16-page illustrated design manual which discusses a variety of EMI/RFI shielding products, including strips, gaskets, and shielded cabinet components, has been made available.

Introduced in the booklet is a new gasket material, "Tecknit" SN/CU/FE, which offers improved shielding effectiveness in low-frequency magnetic fields and at low joint pressures. Technical Wire Products

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SCR BOOKLET

A complete line of silicon controlled rectifiers is described in a new catalogue, No. A-66. The booklet devotes 40 pages to the company's extensive line of alloyed diffused and epitaxial SCR's, providing application notes, charts, and graphs. International Rectifier

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INTEGRATED CIRCUITS

A new 16-page condensed catalogue featuring a broad line of digital and linear integrated circuits has been published. Listings for each element include typical performance characteristics, power-supply requirements, packaging, operating temperature range, and primary area of application.

In addition, the booklet supplies schematic diagrams and discusses in detail the company's systematic uniformity and reliability evaluation (SURE) program. Signetics

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SILICON TRANSISTORS

A new 8-page "Specs in Brief" booklet (No. SL1066) on silicon transistors for a.f., r.f., and switching applications is currently available.

The brochure covers in capsule format four recently announced families of silicon transistors, including six v.h.f./u.h.f. devices; the new 2N3241A family of high-current, high-dissipation types; a new MOSFET, 3N128, for critical front-end use in TV and v.h.f. communications equipment; and a high-performance, low-cost family of silicon power transistors. RCA Electronic Components and Devices

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OP AMP BOOKLET

A simplified introduction to operational amplifiers is presented in a new 20-page booklet entitled "Review of Operational Amplifier Principles."

Topics discussed include definitions of terms used in manufacturers' specifications, analysis of feedback amplifiers, and a comparison of performance characteristics for various operational amplifiers.

The report concludes with a 5-page summary of the most common applications for op amps. Fairchild Instrumentation

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ENGINEERING PLACEMENT

A 24-page survey, "The Placement of Engineering Graduates, 1966" has just been issued by the Engineering Manpower Commission of Engineers Joint Council.

According to the publication, the number of bachelor's degree engineers accepting employment dropped from 57.9% in 1965 to 53.9% in 1966. This number was largely offset by an increase in those considering employment who had not made commitments prior to graduation. There was only a slight increase in the percentage of graduates continuing directly on to full-time advanced degree studies. This appears to mark a slowdown in the rate of growth of advanced engineering degrees, which has been particularly strong in recent years.

Starting salary offers for 1966 averaged between $659 and $682 per month, making engineers among the highest paid of all categories of new college graduates.

Copies of this report may be ordered from the Commission, Department "P", 345 E. 47th St., New York, New York 10017 at $1.50 a copy.

BATTERY MANUAL

A new 68-page illustrated battery manual (BDG-111A) covering RCA's complete line of carbon-zinc, mercury, and alkaline batteries has been published.

Detailed electrical and mechanical characteristics, dimensional outlines, and terminal connections are given for each of the 156 battery types described in the handbook. In addition, an introductory section discusses basic cell and battery types, battery terminology, chemical composition, and testing methods.

The manual costs 50¢ and is available from Radio Corporation of America, Commercial Engineering Dept., Harrison, N.J. ▲

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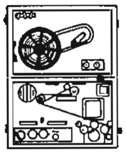

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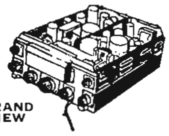

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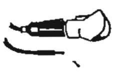

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200	.20	.60	1.20
400	.25	.80	2.00
600	.35	1.20	2.50
800	.45	1.50	2.75
1000	.65		3.00

5A Insul Base

PRV	
100	.20
200	.40
400	.60
600	.80
800	1.25
1000	1.40
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PRV	
100	.07
200	.09
400	.12
600	.20
800	.25
1000	.50
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300	1.60	2.45
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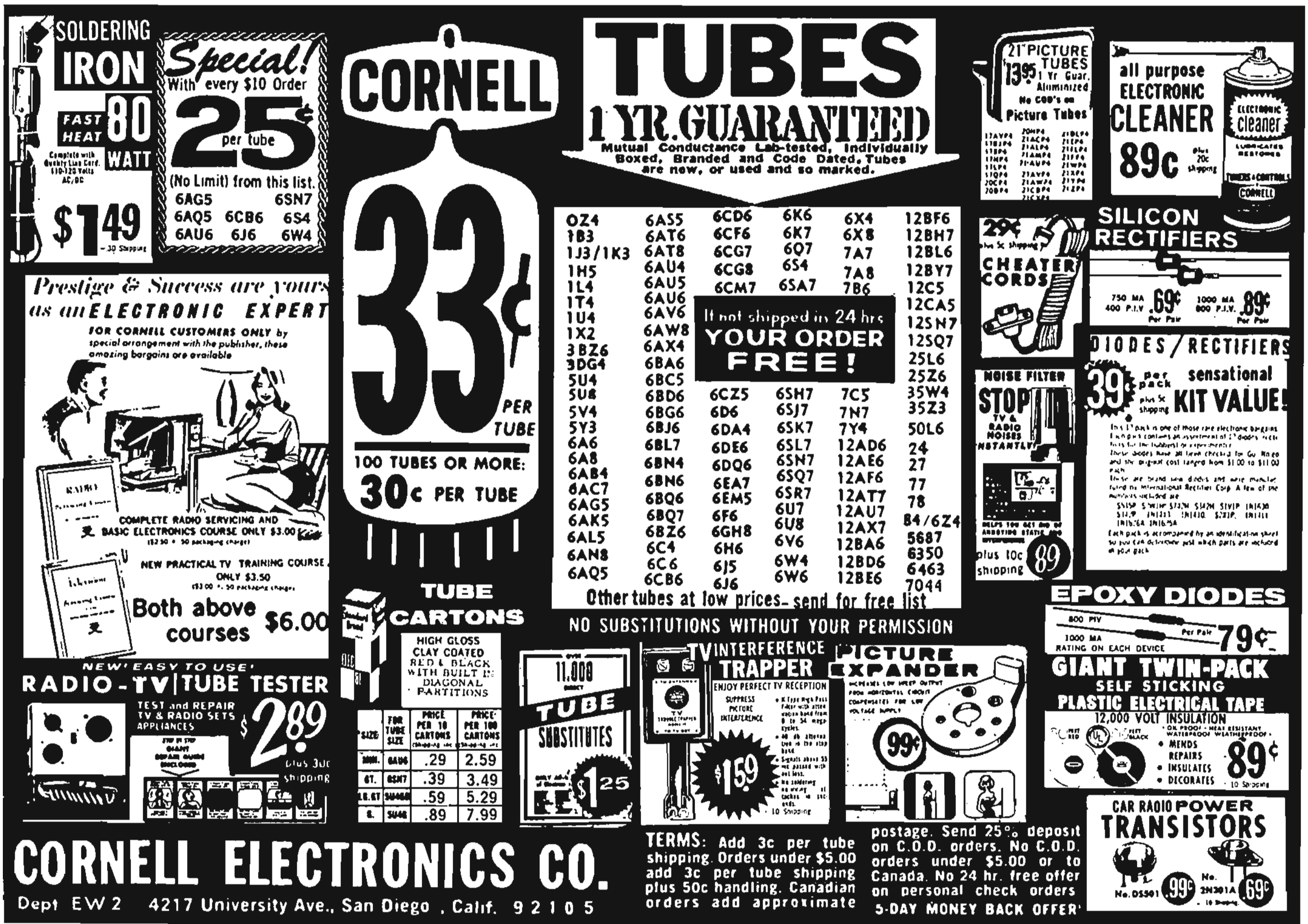

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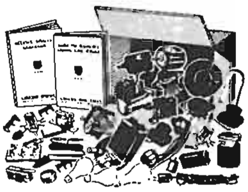

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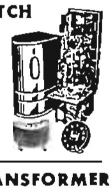

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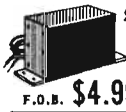

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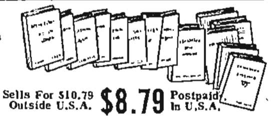

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