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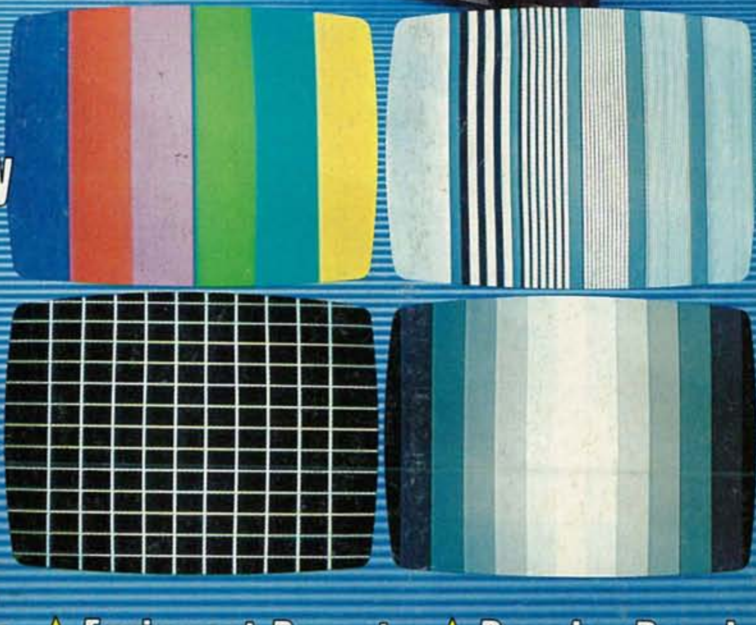

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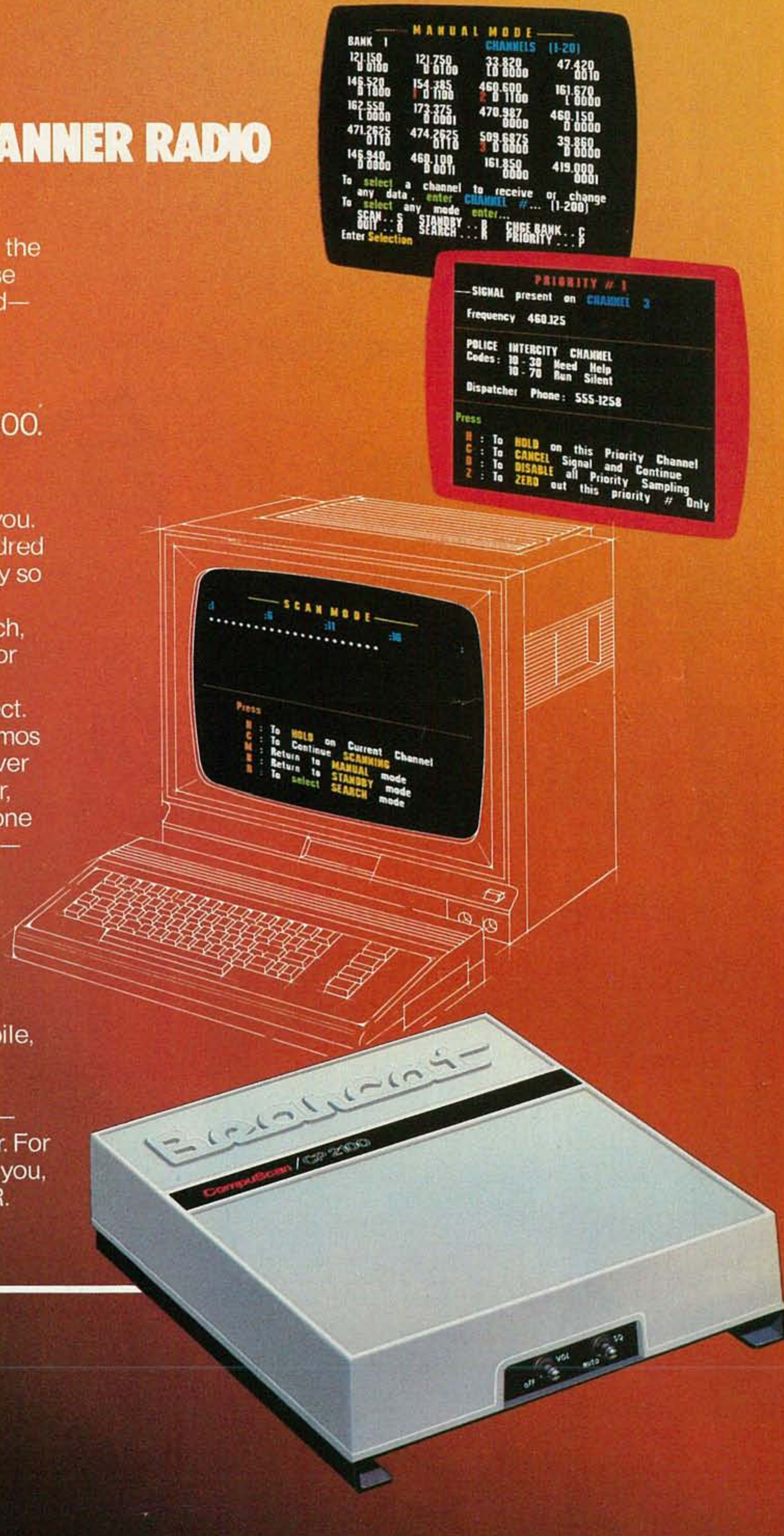

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Frequency range: 30-50, 144-174, 440-512 MHz.
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RRF Railroad Frequency Directory $10.00
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Radio-Electronics

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MARCH 1984 Vol. 55 No. 3

ON THE COVER

There are many manufacturers who sell TV-test equipment such as dot-pattern generators. But if you want to service video equipment other than TV's, then you need something more. This month we'll describe how to build and how to use a full-feature video test generator. You can use it to test VCR's, monitors, video amplifiers—just about any video equipment. It not only generates standard test patterns. It even has provision for external inputs (from a computer, for example) so that you can create your own test patterns for your own specific purpose. The story begins on page 43.

ANNUAL INDEX JANUARY—DECEMBER 1983

To present the maximum number of articles to our readers, we have not published the Annual Index as part of this issue. A 4-page brochure containing this index is available for those who need one. To get your free copy, send a *stamped self-addressed envelope (legal size) to:*

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Radio-Electronics, (ISSN 0033-7862) Published monthly by Gernsback Publications, Inc., 200 Park Avenue South, New York, NY 10003. Second-Class Postage Paid at New York, N.Y. and additional mailing offices. One-year subscription rate: U.S.A. and U.S. possessions, $14.97. Canada, $17.97. Other countries, $22.47 (cash orders only, payable in U.S.A. currency). Single copies $1.75. © 1984 by Gernsback Publications, Inc. All rights reserved. Printed in U.S.A.

POSTMASTER: Please send address changes to RADIO-ELECTRONICS, Subscription Dept., Box 2520, Boulder, CO 80322.

VIDEO ELECTRONICS

DAVID LACHENBRUCH
CONTRIBUTING EDITOR

NEW PICTURE TUBES

TV picture tubes will get bigger later this year, when American manufacturers adopt the next generation of square-cornered designs. Unlike some Japanese manufacturers, who already are substituting the so-called FST (*F*lat *S*quare *T*ubes) in the smaller sizes (**Radio-Electronics,** October 1983), American TV makers have decided to retain the same faceplate curvature as at present in their new squarish models—at least for the time being. All four American picture-tube manufacturers have finalized their plans. Three of those manufacturers—General Electric, Philips and RCA—will offer new 26-inch tubes while the fourth manufacturer, Zenith, has decided to adopt the 27-inch size as offering a noticeably larger picture than the current 25-inch tube.

Zenith's 27-inch tube will have a 340-square-inch viewable picture, 7.9% larger than a 25-inch (which measures 315 square inches) and 4.5% larger than the the 324 square inches of the 26-inch version. All of the manufacturers will continue to offer 25-inch tubes, at least for a time, for use in lower-priced big-screen models. In 1985 or 1986, RCA plans to add a premium flat-faced tube of completely new design, which it calls the SP (for *S*quare *P*lanar). That new tube is expected to measure 27-inches.

American manufacturers are expected to follow the Japanese later into new 20-inch and 14-inch square-cornered versions of the current 19- and 13-inch tubes, but it's doubtful that they'll adopt the flat face, with which Japanese manufacturers are said to be having difficulty in production.

LASERVISION GOES SOLID-STATE

The first laser disc-player using a solid-state laser pickup has been introduced in Japan by Pioneer. By eliminating the complex power-supply system formerly required by the tube laser, size and cost have been reduced. The random-access programmable player with wireless remote control is priced in Japan at about $825, or $125 below the original model. Its size also has been sharply reduced—it's smaller than RCA's random-access CED player. In another innovation, the player is simpler to use because it is slot-loaded from the front, eliminating the requirement of lifting the lid and placing the disc on a turntable. A similar model is expected in the U.S. this winter.

JAPAN ELECTRONICS SHOW

The Japan Electronics Show is usually a preview of what Americans will see in the following year, but the Fall 1983 show was lacking in any major excitement. The expected hit of the show—the new 8-mm video format—was completely missing, in line with our report that it has been shelved in Japan (**Radio-Electronics,** December 1983). In its place was the JVC-developed VHS Video Movie, the compact camera-recorder using the small VHS-C cassette. The show demonstrated that solid-state cameras are well on the way—with CCD (*C*harge-*C*oupled *D*evice) models from Sony (already introduced in the U.S.), Mitsubishi, and Sanyo, along with a new version of Hitachi's MOS camera. Sanyo demonstrated a pocket LCD color set with three-inch screen, scheduled for the second half of 1984 at about $425 in Japan. Prototype digital-TV sets were shown by Panasonic, NEC, Sharp, Sony, and Toshiba, but it now seems unlikely that any of those will reach the American market in 1984.

VIDEODISC GAMES

The coin-operated videodisc games, which have been nabbing quarters at a smart pace in amusement arcades, may be coming into the home. And they may come in two different versions—Laservision and CED. Although the first arcade videodisc games have involved the use of laser optical discs, Bally Manufacturing Co. chose the new RCA interactive CED disc system for its NFL football game. The game involves two players, repesenting offensive and defensive teams, who choose plays that are enacted in actual film footage. RCA has been talking with home-computer and videogame manufacturers about introducing home versions combining the CED disc system with game hardware and software. The company is expected to introduce a new version of its interactive videodisc system later this year with specific ports for home computers and videogames. Also, RCA recently reduced the prices of its videodisc players and discs to enhance the sales rate. **R-E**

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Gated measurements. Use the scope's intensified marker to measure frequency, period, width and to count events within specified portions of the signal.

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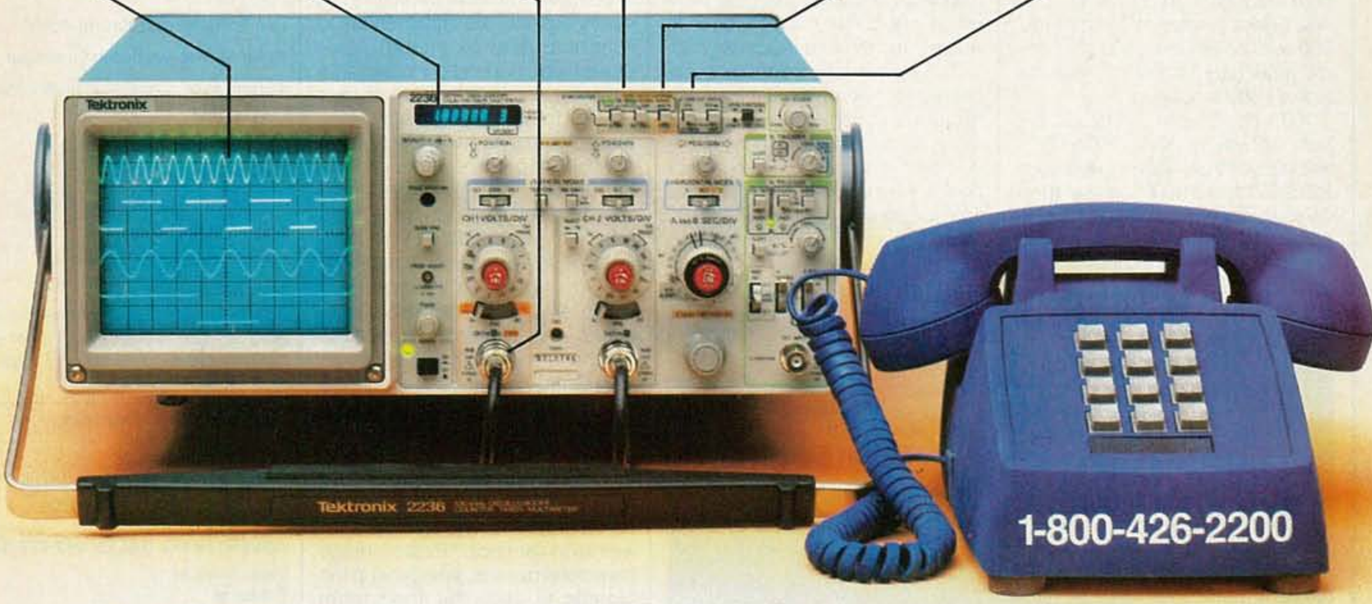

Now make measurements faster, easier, with greater accuracy and user confidence. The Tek 2236 makes gated counter measurements, temperature, time, frequency, resistance and voltage measurements push-button easy. You see results concurrently on the 9-digit numeric readout and CRT display.

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WHAT'S NEWS

New solid-state switch handles 12,000 watts

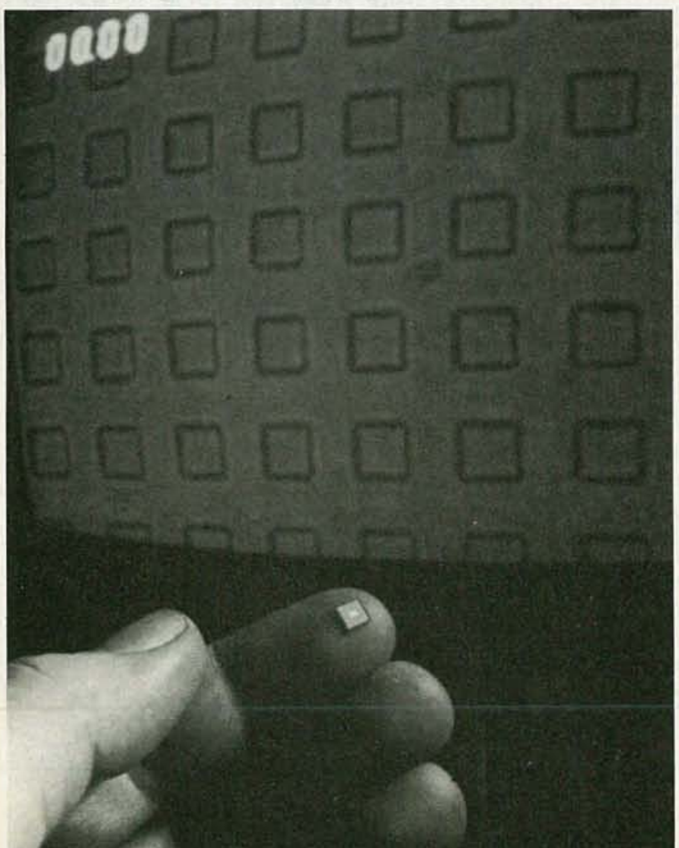
A new semiconductor switch was described by scientists of General Electric to the recent International Electron Devices Meeting in Washington, DC. It has the highest power-handling capacity so far attained in power metal-oxide-semiconductor (MOS) devices.

A second-generation insulated gate transistor (IGT) switch, the new device is rated at 25 amperes, 500 volts continuous, and can handle peak gate turn-off currents as high as 150 amperes.

IGT's combine in a single IC the best features of power MOSFET's and bipolar transistors. Like power MOSFET's, the IGT has low turn-on power requirements; and like bipolar transistors, the new device can handle high currents.

The first-generation IGT was rated at 10 amperes and 500 volts. To increase the power rating, the GE researchers made it larger and more densely packed. The 25-ampere device measures 200 by 200 mils and contains 16,000 interconnected cells, as against the 140 by 140 mils and 6,500 cells of the older unit. The research and development team also inproved the device by reducing the gate turn-off time from four microseconds to approximately one microsecond.

Those improvements are expected to extend the device's applications considerably, making it highly suitable, for instance, for the drives of motors up to five horsepower, whereas the older IGT was limited to only half-horsepower devices.



THE NEW IGT SWITCH HANDLES 12,000 WATTS. Though it measures less than a quarter inch square, it contains 16,000 interconnected cells, and is rated at 25 amperes, 500 volts.

Foreign "pirates" steal US satellite programs

The American film industry is becoming greatly concerned about the interception by foreign concerns of American satellite programs intended for U.S. cable TV. Those programs are then being rebroadcast for their own clients—or for the viewing public—in their own countries.

Losses, the motion-picture industry asserts, are often serious to American motion-picture companies who depend on foreign film sales for a critical portion of their profits. In Jamaica, for example, the government-owned broadcast administration showed four important films not yet released to Jamaican theaters. Coincidentally, there was a 50 percent drop in the revenues of Jamaican movie theaters.

(The Jamaican government, which says it is making arrangements with American interests to purchase the rights to use American films, has since stopped the broadcasts.)

According to the Motion Picture Association of America, the pirating takes place in most of the Central American countries, in the Bahamas, Haiti, and Dominica, as well as in Jamaica. "Pirates" range from hotel owners, who pick up the signals to show for their room guests, to major television companies that cover a whole country. Most of them insist that their actions are legal—that copyright laws covering such transmissions are either ambiguous or nonexistent in their countries.

More than a quarter million Americans are also watching satellite television programs picked up from their own backyard antennas. The legality of that action is in dispute, though persons who use such reception for profit can be prosecuted immediately; and usually, that is what happens.

The problem is expected to increase greatly as France, Germany, Brazil, Japan, and Saudi Arabia launch satellites for television programming. Those satellites will broadcast a tremendous amount of copyrighted material over practically the whole populated earth. **R-E**

Radio-Electronics

Cover photo by Robert Lewis
Radio-Electronics is indexed in *Applied Science & Technology Index* and *Readers Guide to Periodical Literature.*

Gernsback Publications, Inc.
200 Park Ave. South
New York, NY 10003
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SATELLITE/TELETEXT NEWS

GARY ARLEN
CONTRIBUTING EDITOR

CBS, COMSAT TEAM UP

Two of the largest companies readying direct-broadcast satellite services are consolidating their plans—and it's possible that other major organizations will affiliate with this "joint effort." Comsat (through its Satellite TV Corp. DBS subsidiary) and CBS Inc., which are among the eight DBS applicants, will work together on video-program development and acquisition, equipment and technical design, financing, and other factors. It's unclear what the new teaming will do to the plans of each company: Comsat had intended to launch its East Coast direct-to-home service this fall (1984). CBS's proposal includes high-definition TV features, such as 1125-line video, wide-screen display, and stereo sound.

EQUIPMENT HIGHLIGHTS

The *Nova SS* satellite-receiving dish—made of stainless steel—comes in 7.5- and 9-foot sizes with prime focus feed or subreflector feed. Steel construction is said to have greater tensile strength than aluminum. (Kaul-Tronics, PO Box 292, Lone Rock, WI 63556.)

Norsat 3000 satellite receiver is a fifth-generation unit with dual downconversion, continuous tuning, active limiting and clamping, ultra-linear low-noise oscillators, and digital metering. (Norsat International Inc., 205-19425 Langley Bypass, Surrey, British Columbia V3S 4N9 Canada.)

HBO STARTS SCRAMBLING

Home Box Office has begun its large-scale testing of "VideoCipher," the signal-scrambling system it has developed with M/A-Com. Both the regular HBO and the Cinemax feeds are being scrambled on HBO East transponders aboard Hughes' Galaxy Satellite. HBO says that new refinements in the scrambling technology have greatly reduced the price for cable-TV headend equipment—suggesting that the timetable for scrambling of all HBO service may be speeded up.

DBS AROUND THE WORLD

Another all-European direct-broadcasting-satellite plan has emerged from Luxembourg—this one coordinated by the government of that small country. The new proposal envisions a 16-channel system, using a modified 50-watt satellite now under construction; service would start by 1986. An earlier "Luxsat" plan using a high-powered 200-watt bird, proposed by Radio Tele-Luxembourg, has run into political problems because other countries fret about implications of programs being transmitted across national borders. Under the new plan, electronics companies in each European country would build and install small-diameter DBS dishes—costing the equivalent of about $500—to pick up the signals.

The British Broadcasting Corp. has begun negotiations with U.S. programmers for shows to be used on their proposed two-channel DBS system that is expected to use the new C-Mac technical format. However, delays may push British DBS back from the targetted 1986 launch; by target date, there may not be enough homes equipped with appropriate reception equipment to pick up C-Mac signals.

China may develop a Ku-band DBS service for education and community information. Since only 30% of the Chinese population has access to conventional TV signals, DBS is seen as a way to expand service nationwide; China has three orbital slots for domestic service. No timetable has been established for the low-powered DBS service.

HYBRID INTERACTIVE SYSTEM

Cox Cable Communications, a leading cable-TV operator, will team up with Chase Manhattan Bank, Jerrold Electronics (a major cable equipment firm), and other partners to develop an innovative hybrid teletext/videotex service by 1985. The system will use cable TV as well as telephone lines to deliver information, education, data processing, banking, and other interactive services through Jerrold's Communicom terminals. The Communicom cable-TV converters use a NAPLPS teletext-standard system for high-resolution graphics and will be installed on new Cox cable systems. In non-cable homes the same device—stripped of its cable channel-selector components and fitted with a phone modem—will be installed, making it possible to offer the information/banking/shopping service to homes that will connect to the system through a conventional phone-TV setup. **R-E**

LETTERS

Address your comments to: Letters, **Radio-Electronics,** 200 Park Avenue South, New York, NY 10003

OOOOPS!

We've noticed an error in the parts-placement diagrams that appeared in January's cover story "Build This C-QUAM AM Stereo Converter." The part labeled Q1 in Figs 7, 9, and 11 should be labeled IC2 (the LM317LZ voltage regulator). We're sorry for any confusion that oversight might have caused.

We also neglected to mention that C-QUAM is a registered trademark of Motorola, Inc. Our apologies.—*Editor*

CORRECTION

This is in response to the brief item in the "What's News" department of **Radio-Electronics** for September 1983. The writeup was accurate except for one very important point: Neither AT&T nor Motorola Corporation have posed any objections to Geostar's FCC filing. In fact, Geostar's filing has received overwhelming support. The one objection registered was by a small Gulf Coast microwave-communications firm, whose markets would be placed in severe jeopardy by Geostar's technology.

I believe that the Motorola and AT&T objections that you were referring to were directed at Mobilsat, which is a voice-communications system also under review by the FCC. The *New York Times* published an article in which the author erroneously mixed public reaction to Geostar with that of Mobilsat. Perhaps the error in your writeup was due to the misinformation in that article.

I would appreciate it very much if you would publish this correction, because such misinformation could be injurious to Geostar.
T. STEPHEN CHESTON,
Vice President for Administration,
Geostar Corp.

TRANSIENT SUPPRESSOR

I would like to comment on Herb Friedman's fine article, "Build This Powerline Transient Suppressor," in the September 1983 **Radio-Electronics**. Last spring, I realized my need for such a device and set about designing and building one. The design I came up with was very similar to Mr. Friedman's. There are, however, a few differences worth noting.

Fuse F1 in Mr. Friedman's circuit is a failsafe device for the varistor, and is a good idea; but it will not act as a protective fuse for the unit itself, or for any device plugged into it. A protective fuse must be added to the hot powerline entering the unit. Because the filter used (Radio Shack 273-100) has a 5-amp current rating, that fuse must be rated for 5 amps or less. If your computer system requires more power, filters with a higher rating may be purchased from electronics supply houses.

I built my unit completely inside a power strip. A heavy-duty, six-outlet, metal cabinet power strip was purchased. By removing two of the outlets (there are three standard AC household receptacles inside) there was enough room for all the components. It was a tight fit that required careful construction, but I was able to build it without any problems. Another difference in my design was that I placed the filter between the relay and the power outlets to filter any possible noise generated by the relay coil. The net result was a compact, easy-to-mount power source that protected up to four computer components against all three powerline problems outlined in the article.

The total cost for the unit was about $35—quite a saving over the $100 to $200 charged for equivalent commercial suppressors.
GARY E. WHITNEY
Portland, OR

WHICH IS RIGHT?

In reference to page 45 of the November 1983 **Radio-Electronics**, in the article, "Hi-Fi Sound Converter for Your TV", refer to page 47, Fig 2. Resistor R18 is connected directly to the emitters of Q1 and Q2 and R19 via C23.

However, the printed-circuit board shows R18 and R19 (on page 48, Fig 4) both directly connected to Q1 and Q2's emitters.

Please tell me which is correct—the schematic or the board.
JAMES C. MORALL
Baldwin, NY

The parts-placement diagram is correct—but so is the schematic. To make both match, simply reverse the positions of R19 and C23 on the schematic. (For those of you who can't find R18, it's the resistor labeled R13, right on top of R19.)—Editor.

STAY AS YOU ARE

Please add my name to the growing list of those who have either canceled or refused to renew their subscriptions to that electronics magazine which converted itself into just another trendy all-computer publication in 1982. **Radio-Electronics** is now the last remaining magazine that authoritatively covers all aspects of electronics. I have benefited immeasurably for the past three decades from your fine instructional and construction articles, especially those on test instruments. Please, please stay as you are now and have been in the past. Viva **Radio-Electronics**!
BERNARD J. FINNEGAN
Los Angeles, CA

NOT PROPRIETARY

I would like to point out an error involving our listing in your recent computer buying-guide issue (October 1983, **Radio-Electronics**).

The 16-bit operating system listed (Z-DOS) is not proprietary, as indicated. Rather, it is our version of Microsoft's MS-DOS, and thus is compatible with much of the software written for IBM, TI, and other system using MS-DOS or a variation.
ROBERT L. WINTER
Zenith Data Systems

THE SANDCASTLE PULSE

I just received your September 1983 issue of **Radio-Electronics**, and read in the "Service Questions" section on page 99 a "good question." (What is a sandcastle generator and where did it get that name?) I think I have sort of an answer to it.

The sandcastle pulse is a complex waveform with a repetition rate of the horizontal frequency. It looks like the waveform shown in Fig. 1-a.

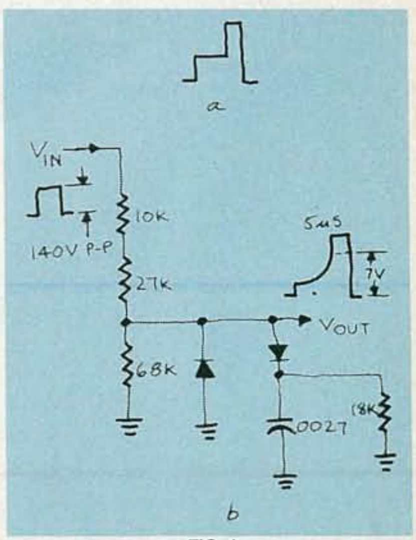

FIG. 1

The displacement of the upper part allows the separation of the burst signal. Sandcastle pulses are used in color-TV sets for the following purposes: (1) black-level clamping of lumi-
continued on page 20

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2V, 20V, 200V	±(0.7% rdg + 4d)
1000V	+(1% rdg + 4d)

AC Volts

RANGE	ACCURACY 40-500 Hz
2V, 20V, 200V	±(1% rdg + 8d)
600V	±(1.2% rdg + 8d)

DC Current

RANGE	ACCURACY
200mA	±(1.5% rdg + 4d)
10A	±(1.7% rdg + 4d)

AC Current

RANGE	ACCURACY 40-500 Hz
200mA	±(2% rdg + 8d)
10A	±(2.2% rdg + 8d)

Resistance

RANGE	ACCURACY	SHORT CIRCUIT CURRENT (approx.) Hi	Lo
200		1.5mA	—
2K	±(0.8% rdg + 5d) Hi	300μA	150μA
20K	±(1% rdg + 10d) Lo	30μA	15μA
200K		3μA	1.5μA
2000K	±(2% rdg + 10d)	0.3μA	0.15μA

DM-6590

$63.75

RANGES

DC VOLTS

RANGE	ACCURACY
2V	±0.5% rdg ±4 dgt
20V, 200V	±0.7% rdg ±4 dgt
500V	±1.0% rdg ±4 dgt

AC VOLTS

RANGE	ACCURACY
2V, 20V, 200V, 500V	±1.0% rdg ±8 dgt

RESISTANCE

RANGE	ACCURACY
2KΩ, 20KΩ, 200KΩ	±0.7% rdg ±4 dgt
2000KΩ	±1.2% rdg ±4 dgt

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Sensitivity	5mV/div to 5V/div ±5%, 10 calibrated steps 1mV/div to 1V/div ±6% (When using x5 amplifier) Uncalibrated continuous control between steps 1: < 2.5 (provided with click-positioning function)
Bandwidth	DC to 15MHz, –3dB (at 4 div) DC to 7MHz, –3dB (at 4 div) (When using x5 amplifier)
Rise Time	24ns, (for x5) 70ns typ
Signal Delay Line	—
Max. Input Voltage	600Vp-p or 300V (DC + AC peak, at 1kHz)
Input Coupling	AC, GND, DC
Input Impedance	Direct 1M ohm, approx. 30pF
Operating Modes	Single-trace
X-Y Operation	External trigger Input: X axis, Vertical Input: Y axis
Sensitivity	X axis: approx. 200mV/div. Y axis: same as Vertical input
Phase Difference	DC to 10kHz within 3°
X Bandwidth	DC to 500kHz, –3dB
Dynamic Range	4 div or more
Vertical Output	
Output Voltage	20mV/div or more (terminated into 50Ω)
Bandwidth	50Hz to 5MHz, –3dB
Output Impedance	Approx. 50Ω
Horizontal Deflection	
Trigger Modes	AUTO, NORM, TV (+), TV (–)
Trigger Source	LINE, EXT
Trigger Coupling	AC
TV Sync	TV sync-separation circuit
Internal	1 div or more (V sync-signal)
External	1Vp-p or more (V sync-signal)
Trigger Sensitivity	

Frequency	Internal	External
20Hz to 2MHz	0.5div	200mV
2 to 15MHz	1.5div	800mV

AUTO Low Bandwidth	30Hz
Trigger Slope	±
External Trigger Input	Input impedance: approx. 1M ohm, 30pF or less Max. input voltage: 100V (DC + AC peak at 1kHz)
Sweep Time	0.2μs/div to 0.2s/div. ±5% 19 calibrated steps Uncalibrated continuous control between steps 1: < 2.5 (provided with click-positioning function)
Sweep Time Magnifier	10 times (±7%)
Max. Sweep Time	100ns/div (20ns/div and 50ns/div. not calibrated)
Amplitude Calibrator	
Waveform	Approx. 1kHz ±10% (typ), square wave
Voltage	0.5V ±5%
Power Requirements	100/120/220/240V ±10% 50 to 60Hz. approx. 40W
Dimensions	Approx. 275(W) x 190(H) x 400(D) mm
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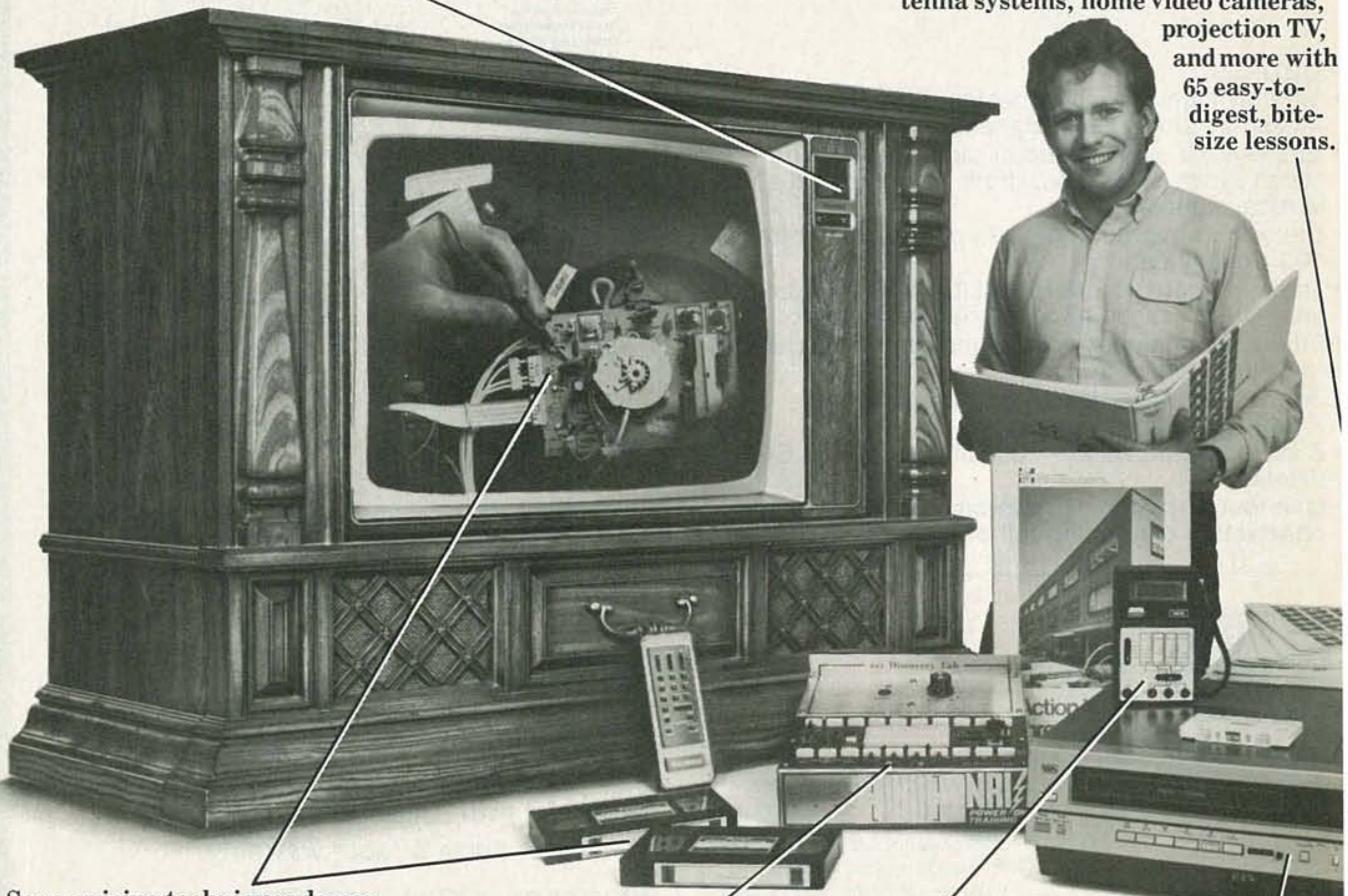

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continued from page 10

nance signals (2) burst keying (3) blanking (horizontal and vertical) (4) chrominance channel gating.

The sandcastle pulse can be generated by any of the following integrated circuits and many others generally used in the horizontal oscillator and/or sync section, such as: TDA 2573A and TDA 2575A for 525-line systems; TDA 2576A for 625-line systems; TDA 2571, TDA 2590, TDA 2591, TDA 2593, et al. The sandcastle pulse is required in several luminance and chromonance processors, mostly one-chip systems, such as TA 10313 (by RCA), TDA 3300 (by Motorola), TDA 3560 (PAL-decoder by Philips), TDA 3570 (NTSC decoder, by Philips) to name just a few of the better-known types. There are many other IC's that use a sandcastle pulse or generate one.

If you don't have a sandcastle pulse, but need one, you can generate it from a horizontal flyback pulse by means of the circuit shown in Fig. 1-b.

EGON STRAUSS
Buenos Aires, Argentina

ON TESLA'S PATENTS

It is quite refreshing to see the amount of interest generated from your articles on Nikola Tesla. All too often, we tend to take for granted the goods and services that make our lives comfortable, with little or no regard for the price paid by the originators of those goods or services.

In your recent article, the departure of Tesla might induce a sense of pity in the reader, because for one to be penniless and at the mercies of others after having contributed so much to the entire world is a sad epilogue. On the other hand, it seems that a great majority of geniuses get a tremendous sense of satisfaction from the work itself, and not necessarily the financial rewards. We might ask who determines what yardstick is used to measure rewards.

That brings us to the important matter—the subject of patents. The general assumption is that as long as one owns a patent, one is guaranteed financial success; but Tesla owned hundreds of them. That did not make him rich, which says that the invention itself and the marketing of the invention are two different and often unrelated subjects. Most inventors are not able to handle or are even concerned with the latter. Then the question is: Why go through all the trouble and expense to obtain letters of patent in the first place? It must be for the same reason that people climb Pike's Peak, hang glide, watch birds, etc: to obtain the rewards therefrom, using their own personal yardsticks.

As a patent researcher, I have assembled a list of Nikola Tesla's patents. It is available to your readers from the address below at $3.50 for mailing and handling.

A complete set of copies of all 113 patents (full disclosure), enclosed in a binder and fully indexed, is also available from the same address: $79.95. (Patents may also be ordered directly from the US Patent and Trademark Office by sending each individual patent number, along with $1 for each patent. The total, then, comes to $113.00 for the set, unbound and not indexed.)

DR. ETHAN KING
EDG Enterprises
Box 5155
Washington, DC 20019

LOTTO DEVICE

I am writing in regard to "Hobby Corner," in the November 1983 issue of **Radio-Electronics**. That is the column in which a lotto device was featured.

In the schematic representation of Fig. 3, I've noticed a few errors concerning the pinouts of the IC's— 7404 (hex inverter) and the 74145 (BCD to decimal decoder). First, the V_{CC} for a 7404 is pin 14, not pin 5 as denoted (pin 14 is being used as a clock input here), and pin 16, not pin 6, for the 74145. Pin 6 is denoted twice here, so it's probably just a typographical error.

Also, numerous input pins of the 7404 (11, 9, 3, and 1) are tied to the A, B, C, and D inputs of the 74145. That's surely a no-no, considering how some of those pins are being used here.

TOM STACEY
Princeton, NJ

You're right, there are errors. The 7404 in Fig. 3 is mislabeled—it should be a 7490. A 7404 should be used to invert the A, B, C, *and* D *outputs of the 74145. Sorry for any inconvenience that error caused*—Editor. **R-E**

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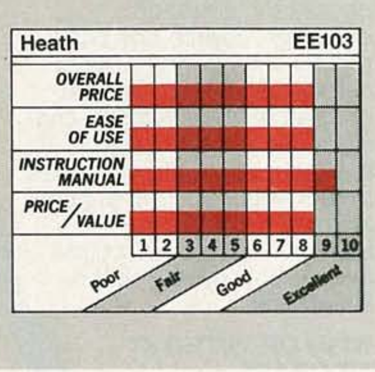

CIRCLE 101 ON FREE INFORMATION CARD

ONE OF THE MOST COMMONLY USED DEvices in modern electronics is the timer IC. Its use is so common that most of us have come to take it for granted. But, that hasn't always been the case; after all, the IC timer has only been around for a little more than 10 years. Previously, timer circuits had to be designed using discrete components.

Since its application is so widespread, a working knowledge of the inner workings of the timer IC is valuable. That's true not only for the newcomer, but even to the veteran service technician or advanced hobbyist. After all, we can all use a refresher now and then to keep our skills up to date.

That's why we recommend Heath's *EE-103* IC timer course so highly. At $44.95, that follow-up to Heath's *EE-3210A* digital-techniques course provides an economical yet effective way

to acquire or update knowledge about those important devices.

What's covered

Although it isn't the longest course that Heath (Benton Harbor, MI 49022) offers, its six units are packed with information whose aim is to give you a working knowledge of IC timers, their uses, and the various types of those devices available. For example, Unit One explores timer basics and goes into an explanation of the monostable multivibrator and the astable timer.

Unit Two introduces the types of timers you will find. It first explores the 555 timer and presents you with a functional diagram and schematic of that device; it also discusses such things as pin functions and the operating modes. Next, it moves to the 556 dual-unit general-purpose timer and then on to the 322 and 3905 timers.

Unit two also takes you through some timer-counters, such as the 2240 binary programmable timer/counter, the 2250 BCD programmable timer/counter, and the 8260 seconds-minutes-hours BCD programmable timer/counter. The unit also moves through a series of experiments with those devices in order to give you hands-on experience with them.

Unit Three covers operating procedures and some precautions to take with timer devices. Included in the discussion are such topics as the selection of external components that can be used with the various devices.

Moving on to Unit Four, the knowledge you have gained through the three previous units is expanded with a detailed discussion of monostable multivibrator (one-shot) circuits and some of their applications. For instance, it discusses the 555-based one-shot with an auxiliary output, the inverted one-shot, and manually triggered one-shot circuits. Other applications covered include pulse generators, programmable one-shots, extended-range one-shots, voltage-controlled one-shots, and a ratiometric voltage-to-pulse width converter. A series of experiments rounds out the unit; each one is designed to give you experience handling one-shot circuits.

Unit Five is an in-depth discussion of astable timer circuits. Included in that chapter are circuits based on a variety of IC timers. A series of experiments help insure that the information presented will be retained.

Unit Six turns its attention to practical applications. Among the circuits covered are the Schmitt trigger, inverting bi-stable buffer, RS flip-flop, voltage comparator, zero-crossing detector, window detector, differential line-driver, and opto-isolated data link.

The unit also discusses output-drive circuits and shows how LED's, as well as incandescent lamps, relays, and booster amplifiers can be driven. After that, the unit moves on to time-delay relay circuits and then on to function generators such as a CMOS function-generator, a wide-range tunable function-generator, a function generator with logarithmic-control characteristics, voltage-controlled oscillators, and triangular-wave-to-sinewave converters. Other applications include DC-DC converters, a precise clock source, a universal appliance-timer, a time-mark generator, phased-lock loops, a bipolar staircase generator, an A/D converter, a speed alarm, a power-monitor error detector and a burglar alarm. Finally, Unit six closes with a presentation of a series of experiments.

As you can see, the IC timer course is a thorough examination of timer circuits and it should easily give you the basic knowledge you need about them or refresh and update the knowledge you have. It will also serve as a good reference resource when you have finished the course, because it contains an appendix with manufacturer's data sheets, a second-source guide, and a list of timing-component manufacturers.

Overall, it's a good investment in your

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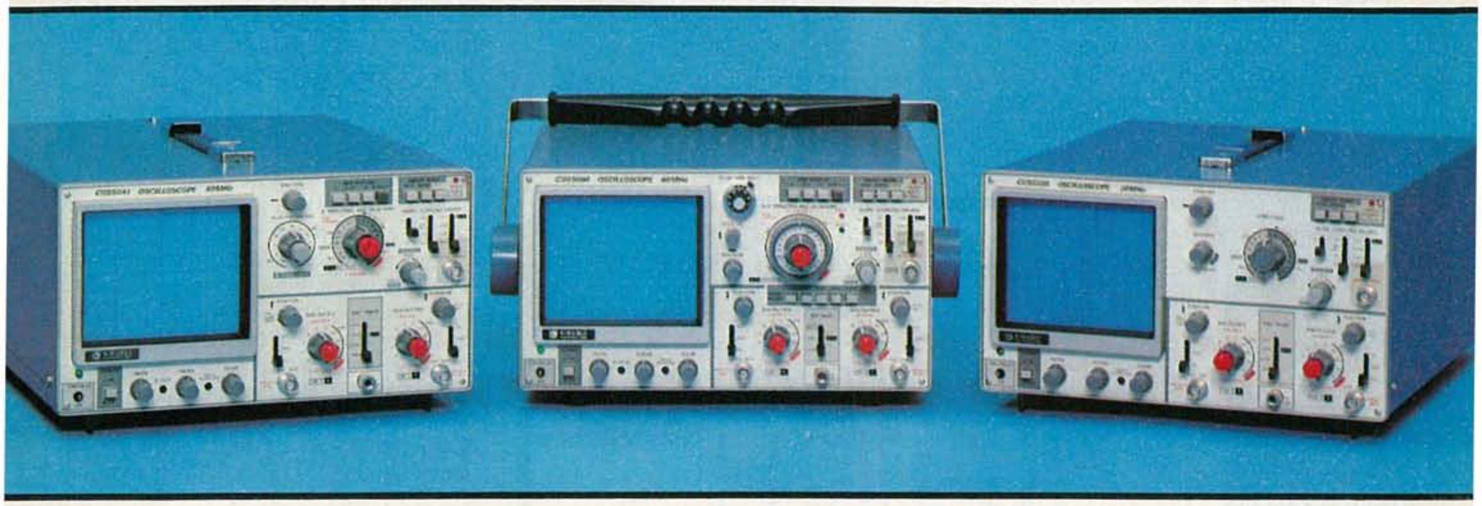

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Not only that, we're offering a two year warranty on each of them, compared to other big name companies' limited one year warranties.

When it comes to performance, our 5000 Series has the edge over the Tektronix 2200 Series in lab quality, chop frequency, and trigger view. Ours also have more display modes, higher acceleration for better brightness, and sharper focus for better resolution.

Each scope in our 5000 Series is crafted so that it can be used for production, field service, consumer electronics servicing, or even personal use. The 5060 is a 60MHz scope with 3 channels, eight traces, delayed sweep, delay line and alternate sweep, and priced at $1150. Models 5040 and 5041 are 40MHz, dual channel scopes, featuring peak-to-peak automatic triggering, automatic focus control and a delay line. If you're interested in a 20MHz scope, we have our 5020 and 5021 models with features similar to our 40MHz scopes. Both the 5041 and 5021 also have delayed sweep. Prices at $920 for the 5041, $795 for the 5040, $690 for the 5021 and $595 for the 5020. So, whatever model suits you best, you can't get a better scope for the money.

Of course, there's a reason we're able to offer these bargains and quality. We're one of the biggest manufacturers of scopes in the world, with over 30 years in the business. Another reason is KIK's nationwide network of lab quality maintenance facilities.

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future. Like other Heath courses, it contains all the parts needed to complete the series of experiments and is a complete unit. As with other Heath courses, you will need the *ET-3300B* breadboard or an equivalent to lay out the experiments, and you will also need access to a good oscilloscope and a digital multimeter. If you don't have access to those items, buying them can significantly increase the cost of the course. Heath offers a package of the *ET-3300B* breadboard and the *EE-103* course for $129.95. On the other hand, those additional items should be part of any reasonably equipped workbench. **R-E**

Tektronix Model 214 Storage Oscilloscope

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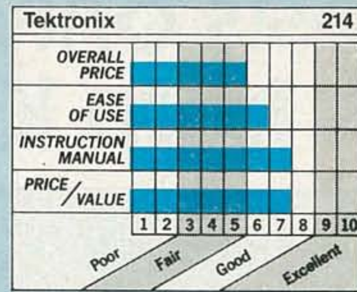

IF YOU DO MUCH WORK IN THE FIELD, YOU know the importance of having compact equipment that can stand up to the rigors of portable operation. We recently had a chance to review an oscilloscope that fills those requirements and adds some bonuses, including dual-trace capability, the ability to display one sweep at a time, and the ability to store a display. The unit is the model *214* storage oscilloscope from Tektronix (PO Box 500, Beaverton, OR, 97077).

To say that the unit is compact is an understatement. It would indeed be difficult to find an oscilloscope that was significantly smaller than this 3 × 5¼ × 9½-inch unit. The weight is a scant 3½ pounds. The graticule area is 6 divisions (vertical) by 10 divisions (horizontal), with each division being about ³⁄₁₀ inch.

The sturdy looking case is made from a high-impact plastic. At the rear of the case is a set of permanently attached high-impedance test probes. As you would expect of a portable scope, the unit can be operated either from the AC power line or from its built-in rechargable batteries.

Specifications

Turning to what the scope can do, it has a bandwidth of DC to 500-kHz. The vertical deflection can be set for anywhere between one-millivolt to 50-volts-per-division. The vertical deflection controls are set up in the familiar 1-2-5 sequence and the entire range is covered in 15 steps.

When the scope is in the dual-trace mode, the display will either be chopped or alternated, depending on the sweep rate (time base) selected. The display is chopped for sweep rates of 500-milliseconds-per-division to 2-milliseconds-per-division; the chopping rate is approximately 40 kHz. The display is alternated for sweep rates of 1-millisecond-per-division to 5-microseconds-per-division. A variable uncalibrated magnifier can increase the sweep rate by at least five times the setting, giving a maximum sweep-rate of 1-microsecond-per-division (uncalibrated). Either trace can be turned off by using its POSITION control.

The scope may be internally triggered (two modes) or externally triggered. In

performance by design

Folding Meters are Better

Not all multimeters fold. There's a reason. While other manufacturers were busy copying each others designs, BBC looked at where portable meters were used and how they could be improved.

The result is a unique approach. Folding meters with large displays (18 mm LCDs) and adjustable viewing angles. Now you can have high performance in a meter that excels in the field and on the bench.

Hands Free vs Handheld

In multimeters "hands free" is significantly better than "handheld." You need three hands to operate the typical "handheld" meter in the field. One for the meter and two for the probes. BBC's folding design lets you use a neck strap for the meter. This frees your hands for the probes.

On the bench, the large, adjustable displays pay off. It's a sensible design that lets you make measurements faster and more easily.

A Heritage of Precision

BBC's track record of expertise in precision engineering spans eight decades. All our meters are built to tough VDE and DIN safety standards. The 3½-digit DMM's feature 0.1% basic dc accuracy and externally accessible fuses for overload protection.

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Compact, Rugged and Affordable

To design the impact resistant case that protects these DMM's, BBC relied on the industrial design skills of the Porsche Design Studios.

When open, the display angle is easily adjustable. When closed, the display and the controls are protected, and the meters turn off automatically. Competitive pricing is another feature of BBC meters. Prices start at $193.00.

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BBC meters are available throughout the U.S. If your instrumentation supplier doesn't carry BBC yet, we'll gladly tell you who does. Call toll free:

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the COMP mode, the trigger signal is derived from the unit's vertical-deflection system after vertical switching has occurred. Note that when the COMP mode and dual-trace operation have both been selected, triggering will take place on the vertical chopping signal, and not at the selected triggering level. In the CHANNEL-TWO mode the trigger signal is again derived from the vertical-deflection system, but before vertical switching has occurred and only from the channel-two signal (hence the name). Triggering sensitivity is 0.2 divisions from DC to 500 kHz in the COMP mode and 0.2 divisions from 2 Hz to 500 kHz in the CHANNEL TWO mode.

An external signal can also be used to trigger the scope. The external trigger signal must be time-related to the inputs for the display to be stable. The minimum usable level for the external trigger signal is 1 volt; the maximum level is 16 volts.

In some applications it is more useful to display one signal against another instead of against time. The scope has an X-Y function that allows you to do that. In it, the vertical (Y) signal is applied to channel 1, while the horizontal (X) signal is applied to channel 2. Note that in this mode the bandwidth is limited to 50 kHz.

Special features

There are two features that are surprising for a scope this size: storage and single sweep. The storage feature freezes the display. That's particularly handy in cases were you want to carefully analyze a waveform. It's also handy in cases where you need to take notes—the display stays on the screen even after the probes have been removed from the test points, allowing you to take those notes at your leisure.

Sometimes, the signal that you are interested in does not repeat regularly, or varies in amplitude, time, or shape. In those cases, using a conventional sweep can cause an unstable display. That's where the single-sweep function comes in. When that function is activated, the next trigger pulse initiates the sweep and a single trace will be displayed. At the end of that trace the sweep generator is locked out until the scope is reset. The single trace feature, when used with storage function, is especially handy for such things as looking for random or intermittent signals. When storing single sweeps, an automatic enhance feature allows the scope to display traces that exceed the device's normal writing speed. It is activated at sweep rates of 0.1-millisecond-per-division and faster.

Manuals

The unit we reviewed was supplied with two manuals. The smaller "operators manual" includes a rundown on the scope's inputs and controls, gives operating information, outlines some simple adjustments that can be made by the operator, and lists sample applications.

Far more impressive was the "service manual." It covers much of the information presented in the operator's manual but adds specifications and complete maintenance, calibration, and troubleshooting information. Also included are circuit descriptions, schematic and parts-placement diagrams, and a parts list.

We have one major safety-related complaint about the device. As with the other units in this series from Tektronix, due to its design, a possible shock hazard is present at the AC-power plug when the scope is battery-operated. Warning is given in the manual, with instructions to store the plug in an insulated compartment at the rear of the scope during battery operation. Still, accidents do happen and we feel that that measure is inadequate.

When you come right down to it, what sets this unit apart is its small size. If you've ever had to lug a full-sized scope around from place to place you know what we mean. Also the storage and single-sweep functions are sure to come in handy; once you've had a scope with those features, you'll wonder how you ever got along without them. The model *214* lists for $2410. **R-E**

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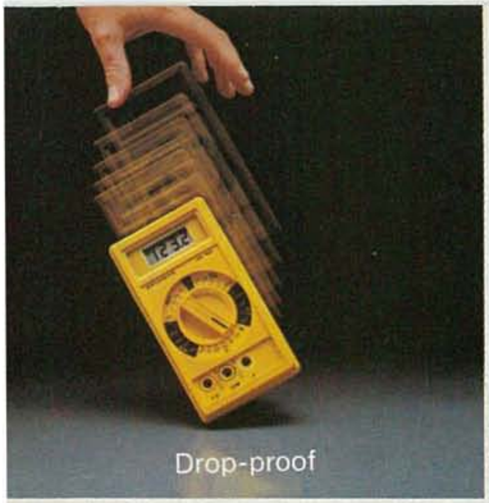

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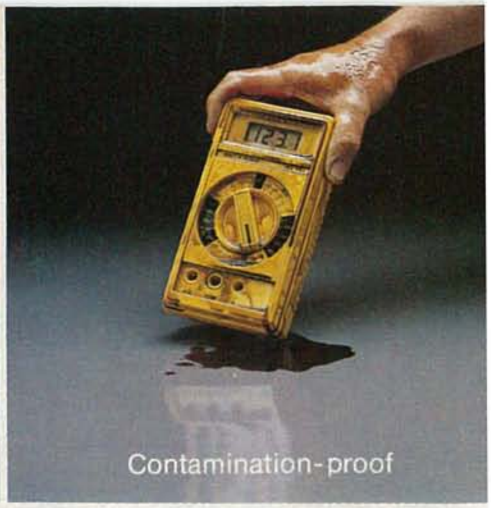
Overload-proof



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Contamination Proof

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All DC voltage inputs are protected up to 1500 Vdc or 1000 Vrms. Current ranges are protected to 2A/600V with resistance ranges protected to 600 Vdc. Transient protection extends up to 6KV for 10 microseconds.

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Feature for feature you can't find a more dependable meter with prices starting at just $169 (U.S. only).

To locate your nearest distributor, write Beckman Instruments, Inc., Instrumentation Products, 2500 Harbor Blvd., Fullerton, CA 92634 or call (714) 993-8803.

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BECKMAN

NEW IDEAS

Use your scope as a capacitance meter

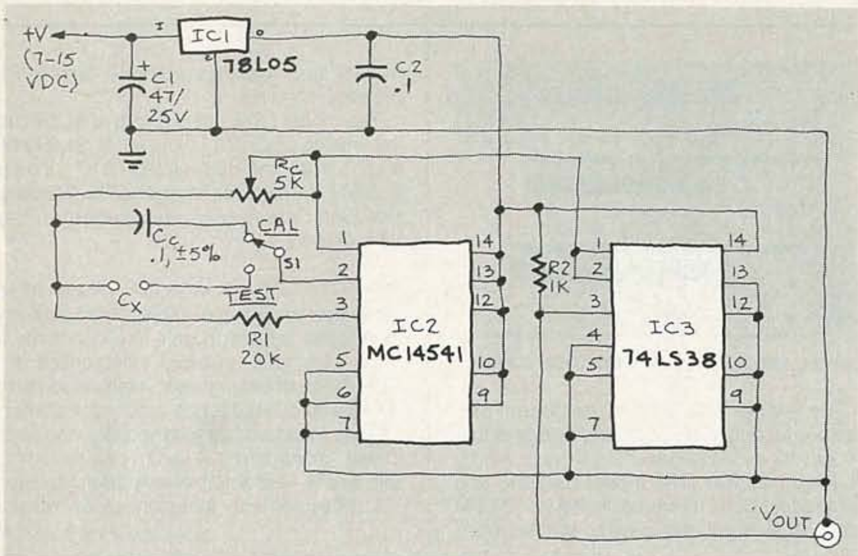

FIG. 1

THIS MONTH WE'LL TAKE A LOOK AT A handy little circuit that allows your oscilloscope to be used as a precision capacitance meter. Basically, the device is an R-C oscillator and a wave shaper. Figure 1 shows the schematic for that circuit. As you can see, it consists of three IC's along with some resistors and capacitors.

The circuit shown is powered by a 7- to 15-volt DC supply. (A 9-volt transistor battery works just fine.) The supply consists of IC1 (a 78L05 voltage regulator) and two filter capacitors. Next, look at the oscillator/shaper circuit; that circuit consists of IC2 (a MC14541 oscillator/timer) and IC3 (a 74LS38 quad NAND buffer) along with some resistors and capacitors. There are several IC's that might have been used but those were chosen because of their availability.

To calibrate the device, first connect your scope to V_{OUT}. Then put the CAL/TEST switch to the calibrate position and adjust the 5-kilohm potentiometer R_C until a 1-millisecond cycle is generated. That's it; easy, isn't it? The next step is to try it out using a known-valued capacitor.

To find the value of the capacitor, simply connect the component leads to the points labeled C_X in the schematic. With the scope still connected to V_{OUT}, set the scope's attenuation to (typically) 2 volts. Now, adjust the sweep of the scope until you see 3 cycles or so on the screen. At that point, measure the time between two identical points on the trace (one complete cycle) and multiply that value by 100. That calculated value is the capacitance value in microfarads. It should be pretty close to the specified value of the capacitor. If so, you can how find the value of an unknown capacitor.

The precision of the device, as well as the value of the smallest capacitor it can measure, is limited by the scope and the calibration capacitor C_C. Typically, the device can be calibrated to 2% or better without difficulty by using a capacitor good to 1% or better. Those capacitors are generally more expensive, but we're sure you'll find that they're worth it.—*Jeff C. Verive*

"First Ogg invented the wheel, then he discovered fire. Now he's trying to build a receiving dish for satellite TV."

NEW IDEAS

This column is devoted to new ideas, circuits, device applications, construction techniques, helpful hints, etc.

All published entries, upon publication, will earn $25. In addition, for U.S. residents only, Panavise will donate their *model 333*—The Rapid Assembly Circuit Board Holder, having a retail price of $39.95. It features an eight-position rotating adjustment, indexing at 45-degree increments, and six positive lock positions in the vertical plane, giving you a full ten-inch height adjustment for comfortable working.

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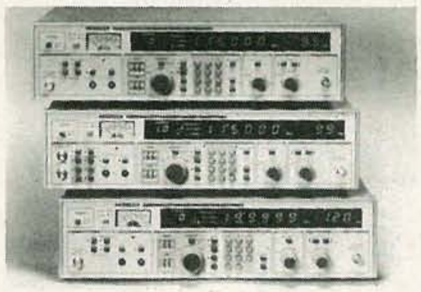
SIGNAL GENERATORS, model *LSG-215*, model *LSG-216*, and model *LSG-217* are programmable, and all feature convenient keyboard control of frequency and output level. Semi-automatic operation is available by preprogramming up to 100 different test conditions. A 2K memory stores frequency, output level, and modulation (0 to 100% AM, 0 to 100 kHz FM) data for each test condition.

The *LSG-217* offers an output frequency range of 0 to 70 MHz in two bands: 0.1 to 19.9999 MHz in 100-Hz steps and 20 to 70 MHz in 1-kHz steps. Output-level range is 0 to 120 dBμV in 1-dB steps.

The model *LSG-215* and model *LSG-216* offer frequency ranges of 0.1 to 30 MHz in 100-Hz steps and 75 to 115 MHz in 1-KHz steps. The model *LSG-216* also offers FM stereo multiplex with L, R, MAIN and SUB functions.



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The model *LSG-217* is designed particularly for use in the communications industry but is an ideal general-purpose signal generator as well. The model *LSG-215* and the model *LSG-216* are designed for AM/FM receiver design and production environments, and are also suitable for AM/FM broadcast testing.

The model *LSG-215* is priced at $1,685.00; the model *LSG-216* is priced at $1,900.00, and the model *LSG-217* costs $1,980.00.—**Leader Instruments Corporation,** 380 Oser Avenue, Hauppauge, LI, New York 11788.

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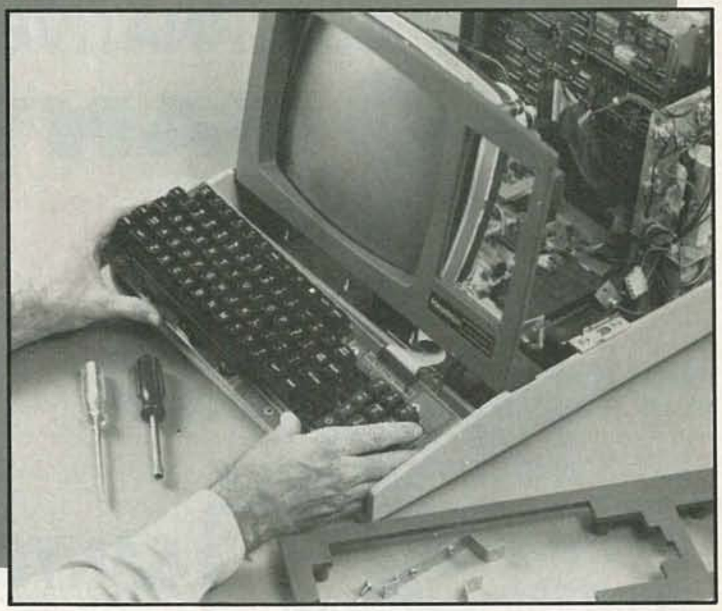

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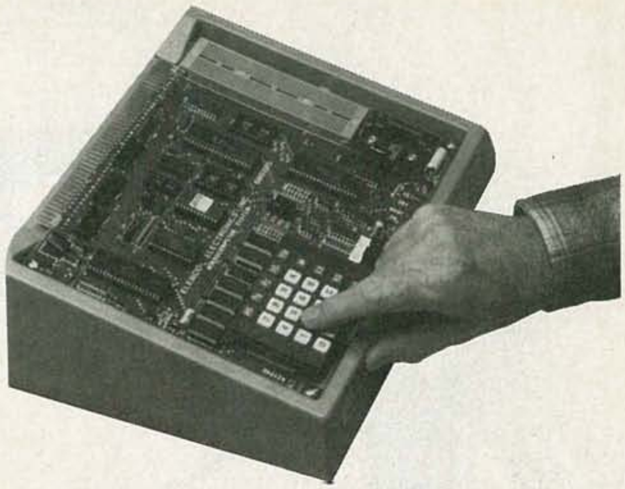

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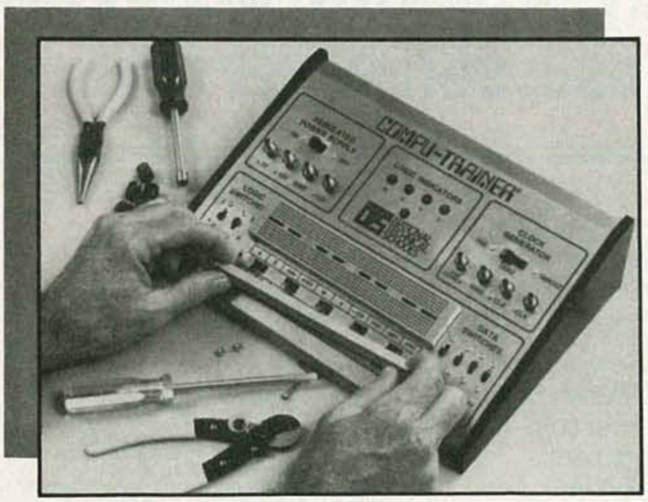

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NEW PRODUCTS

continued from page 32

mers, wire-round resistors, and even printed-circuit board traces, can be measured and evaluated, without designing a test setup or performing off-line computations.

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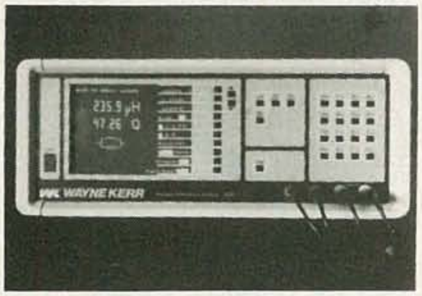

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tures (optional) allow the model *3245* to be networked as part of an automatic parts-handling station, remote-testing instrument, or part of an ATE installation. Optional RS-232 or IEEE-488 ports are available. In addition to those digital-output options, analog outputs may be generated (0-1-volt DC) proportional to measured values.

The model *3245* is priced at $7995.00.—**Wayne Kerr, Inc.,** 400 West Cummings Park, Woburn, MA 01801.

TRANSFER DEVICE, the *PORTAPAC,* is a portable data-retention and transfer device with storage capacity of up to 64K bytes of data. The *PORTAPAC* is line-transparent, using standard RS232C interface with RTS/CTS handshake and is selectable from

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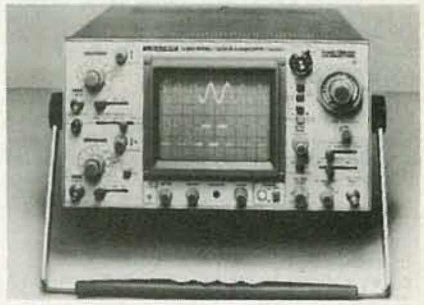
50–19,200 baud. Information can be transferred regardless of software protocols or disk format. Typical battery power retains memory for 15 months to 5 years, depending upon storage size. Power automatically switches to an internal battery source when the external source is disconnected. That switching causes neither loss nor alteration of data.

The *PORTAPAC* is particularly apt for transferring data between incompatible computer systems. It can also be used as a printer buffer, external storage for portable computers, or for backup storage. The *PORTAPAC* comes in three capacity versions: 16K, priced at $345.00; 32K, priced at $545.00 and the 64K version at $695.00 — **Cryptonics, Inc.,** 11711 Coley River Circle, Suite 7, Fountain Valley, CA 92708.

OSCILLOSCOPE, model *LBO-525L,* is a 50-MHz, two-channel oscilloscope that offers the flexibility and advanced features required for critical applications while being easy to operate.

It has a true calibrated delayed timebase with both run-after-A and trigger-after-A modes. There is 500 μV maximum sensitivity and 20 ns maximum sweep speed that permits analysis of low-level and high-frequency signals, while still offering a maximum input rating of 500 V (DC plus AC peak). There is



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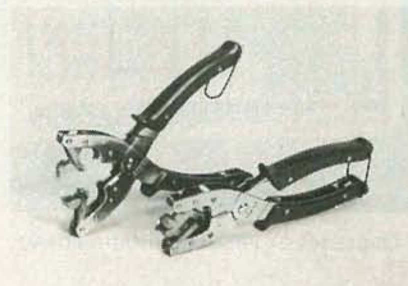
also an illuminated internal graticule for precise measurements and photography and 12 kV CRT accelerating potential for maximum trace intensity, even when observing transients at high sweep speeds. In addition, there is alternate triggering capability that allows the simultaneous display of two asynchronous signals.

The model *LBO-525L* is priced at $1195.00 —**Leader Instruments Corporation,** 380 Oser Avenue, Hauppauge, NY 11788.

PROTECTIVE COATING, *Konform,* is an aerosol-packaged, silicone/elastoplastic-based conformal coating for protecting rigid and flexible printed-circuit boards, thick film circuits, and electrical and electronics components and assemblies. It guards against moisture, fungus, thermal stress and mechanical abuse. *Konform* is formulated to withstand the heat of densely-packed computer circuitry, as well as the cold of aerospace communications systems in subzero temperatures. It meets the MIL-I-46058C Type SR and has been approved by Underwriters Laboratories. *Konform* is priced at $10.75 per 16-ounce container.—**Chemtronics,** 681 Old Willets Path, Hauppauge, NY 11788.

CIRCLE 107 ON FREE INFORMATION CARD

WIRE STRIPPER, the Rush model *2,* is designed for removing PVC-type insulation from the ends of stranded or solid wires from size 17 to 24 AWG.



CIRCLE 108 ON FREE INFORMATION CARD

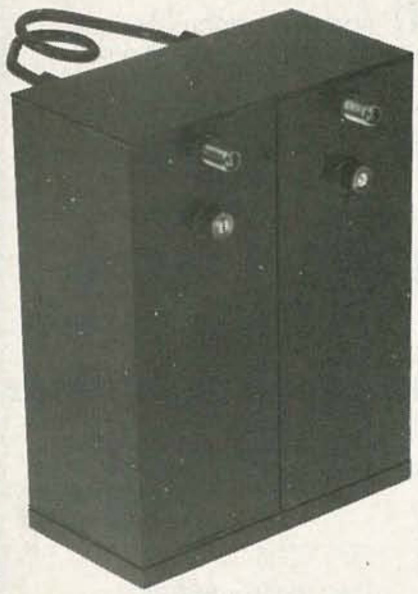
The automatic hand stripper is self-adjusting for different wire sizes, and cleanly cuts the insulation on both stranded and solid wires.

Stripping a wire is accomplished by placing the wire between two holding pads and closing the two handles. The insulation is cut automatically, and the unwanted insulation slug is removed from the end of the wire. The model *2* strippers are suitable both for production and occasional use and incorporate an integral wire cutter for cutting wires to length. The tool weighs 6 ounces and is 7 1/4 inches long.

The Rush model *2* is priced at $22.70—**The Eraser Company, Inc.,** PO Box 4961/Oliva Drive, Syracuse, NY 13221.

TVRO FILTER, model *3217U1* and model *3217U2* (shown) remove 4-GHz interference by trapping its downconversion at the receiver IF.

The model *3217U1* has a notch depth of 25 dB with a 3-dB bandwidth of ±1.5 MHz. Filters come with 50-ohm SMA connectors. It is priced at $165.00.



CIRCLE 109 ON FREE INFORMATION CARD

The model *3217U2* has a notch depth of 50 dB and a 3-dB bandwidth of ±1.5 MHz. It is priced at $340.00.—**Microwave Filter Co., Inc.,** 6743 Kinne Street, East Syracuse, NY 13057.

MULTIFUNCTION TESTER, model *105*, consists of two different type function generators, a pulse generator, a frequency counter, and an AC voltmeter. Each of those pieces is basically familiar test equipment and can be used in the normal manner. In addition, when

CIRCLE 110 ON FREE INFORMATION CARD

the various sections are properly connected to each other and to an X-Y plotter or scope, the system will generate a frequency-response plot. When connected to a scope, it will provide a response plot for breadboard work on amps and filters. When connected to a plotter, it provides hard-copy certification of equipment response.

The first function generator is called the timebase. Its primary task is to provide sweep voltage for the sweep generator and trigger voltage for the pulse generator. It generates a ramp with independently controlled leading and trailing sides. The timebase also produces sinewaves and squarewaves, has amplitude and DC-offset controls, and has an externally triggered FSK mode. There is a decade frequency-range switch which selects one of seven ranges from .001 Hz to 1kHz, and variable controls which multiply those ranges by a factor of 1 to 100. Output impedance is 600 ohms.

The second function generator is called the sweep generator. It can be swept internally with the timebase section, with an external signal, or manually with COARSE and FINE front-panel controls. There are log- and linear-sweep modes. Maximum linear-sweep range is 20 Hz to 20 kHz. Maximum log-sweep range is 10 Hz to 1 MHz. The unit can be set to sweep any portion of those ranges.

The pulse generator has a decade range switch and a variable control to produce pulse widths from 30 nanoseconds to 3 seconds. It can be triggered by the timebase or the sweep generator.

The frequency counter is seven-digits and updates every half second. It can be triggered by either the sweep generator or the voltmeter.

The AC voltmeter measures true RMS, has linear and log modes, and has fast and slow damping select. The meter will measure the signal at the timebase, sweep generator outputs, or an external output.

The model *105* is priced at $750.00 — **FSI,** PO Box 1423, Victorville, CA 92392.

PROTECTION UNIT, the *Protector 6000*, eliminates the damaging effects of transient voltage surges to expensive, sensitive electronics equipment. It uses silicon PN junction devices to provide fast response to surges,

CIRCLE 111 ON FREE INFORMATION CARD

before they can reach the equipment. It also provides full protection from electromagnetic and radio-frequency interference. The unit operates in both common and differential modes, and is outfitted with a circuit breaker to guard against current overloads higher than 15 amperes.

The *Protector 6000* is priced at $159.95.—**New-Tone Electronics, Inc.,** 44 Farrand Street, Bloomfield, NJ 07003. **R-E**

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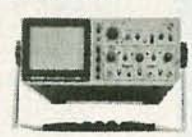

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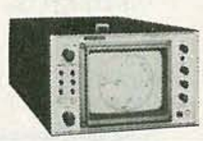

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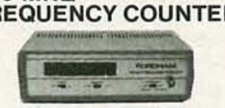

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BUILD THIS

VIDEO TEST GENERATOR

Build this low-cost, general-purpose video test generator and service TV receivers, video amplifiers, monitors, VCR's, and other video equipment.

GENE ROSETH

LOW-COST TEST EQUIPMENT FOR TELEVISION servicing has been available for many years. Today, it is possible to buy TV test generators—with dot-pattern, crosshatch-pattern, and even color-bar outputs—for less than $100. If you add in more features—such as a staircase-pattern output, RF *and* baseband-video outputs, and horizontal- and vertical-sync signals for oscilloscope triggering—the price can easily triple. And if you need an even more versatile instrument—and add in a multiburst-signal output and the means to interface the unit for gen-locking (we'll discuss that later)—then you can end up spending hundreds more.

The video test generator that we'll describe here will do all the things we've mentioned—and even more! Therefore, it can be used not only to service TV's and monitors, but also to test and align VCR's, video amplifiers, CATV systems—virtually all TV/video equipment. We will not only discuss how to build the generator, but also how to use it for testing video equipment.

A look at the output signals

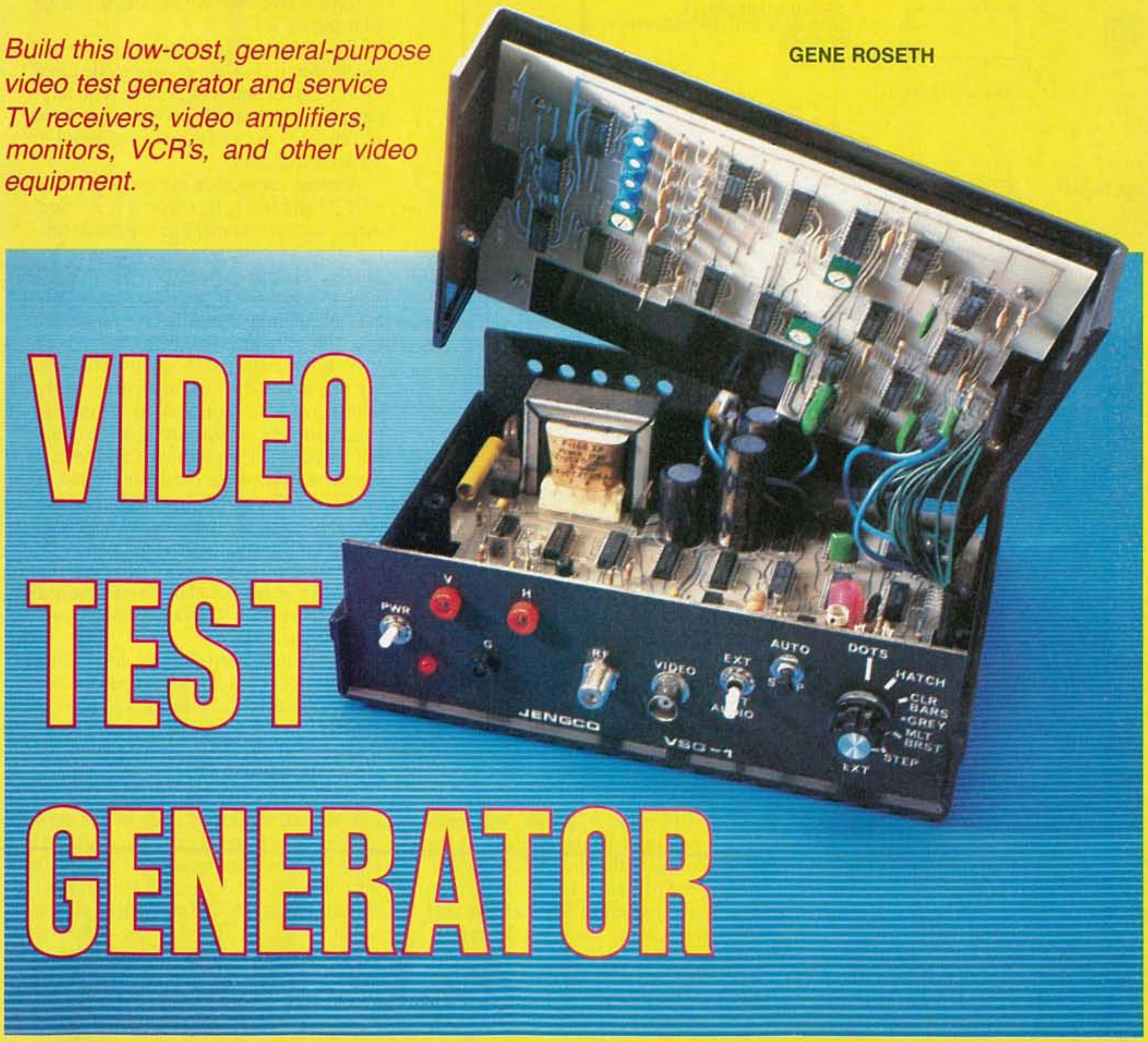
The test signals that the generator provides include: multiburst, up/down step, gray level, dots, hatch, and color bars. Figure 1 shows those various test signals, as well as what they look like on a monitor or TV screen. Some typical uses for each pattern are also listed, but we'll discuss how to use the test signals in more detail later.

Along with the test signals, sync-generator reference signals (LS-TTL compatible) are also available at a rear-panel card edge. They include: composite sync, blanking, colorburst gate, horizontal drive, and vertical drive. Front-panel vertical-rate and horizontal-rate outputs are provided for convenient oscilloscope synchronization.

Also at the card edge are provisions for external digital inputs (three for each primary color, three for synchronizing the generator from a external source, and one external-audio input). Although it is not easy, it is possible, by interfacing the generator with a computer, to generate any real-time pattern or display desired.

The basic generator

A block diagram of the video test gen-



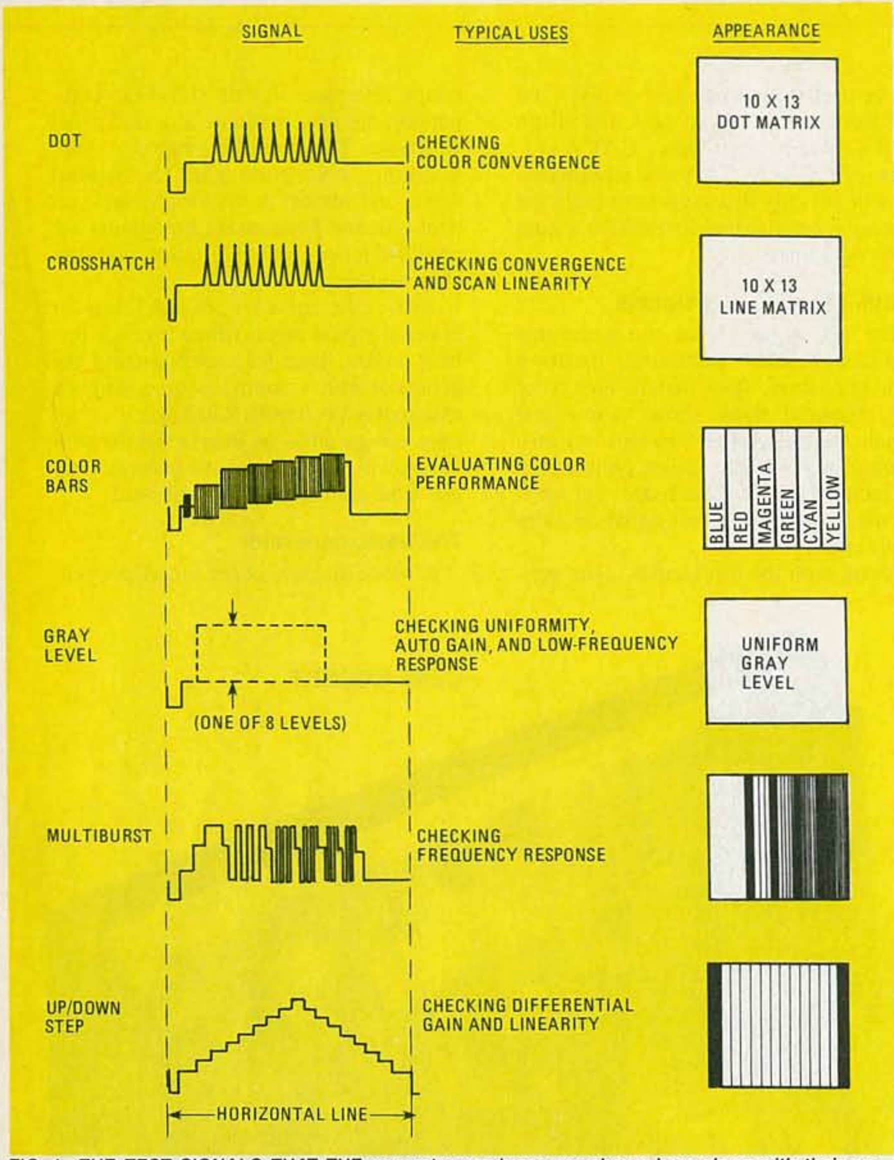


FIG. 1—THE TEST SIGNALS THAT THE generator produces are shown here along with their appearances on a TV screen, and some common test applications.

erator is shown in Fig. 2. We'll start with the 14.31818-MHz (we'll call it 14 MHz) oscillator, whose output is divided by 7 to provide the proper clock for the sync generator. The oscillator's output is also divided by 4 to generate the 3.579545-MHz color subcarrier. The divider, and thus the color subcarrier (at what we'll hereafter call 3.58 MHz) is synchronized with the sync generator by the field detector to maintain NTSC compatibility. It is then waveshaped and shifted in phase by 90° to act as a quadrature reference for the RF modulator section.

The four signal-generator blocks (multiburst, step/gray, color bar, and dot/hatch) receive timing information from the horizontal clock and the line counter. The signals that they produce are fed to a multiplexer that is controlled by switch S1. The multiplexer routes the selected test signal (or the external digital video signal) to a D/A converter and sync mixer.

The standard composite-video signal output from the sync mixer is buffered and is then sent to the video-output jack. It is also sent to an RF modulator (TV channel 3) and then to the RF-output jack. An audio signal is also modulated on the RF. That signal can be either a 1500 Hz internally generated sinewave, or any externally provided audio signal. Switch S3 selects between the internal and external signal.

The power supply for the generator provides +12 volts, −12 volts, and separate +5-volt rails for the digital and the analog portions of the circuit. Having separate +5-volt supplies minimizes crosstalk and prevents the various analog signals from being distorted by digital switching spikes.

A look at the circuit

A schematic of the video test generator is shown in Fig. 3. Since we started our look at the block diagram with the oscillator, we'll do the same here. Transistor Q4 and its associated components make up the crystal-controlled 14.31818-MHz oscillator that is the master clock for the test-generator system. The frequency of the oscillator can be fine-tuned by trimmer capacitor C22. The oscillator output is buffered by one of the AND gates in IC41 and is then fed to a countdown circuit made up of IC34 (an up/down synchronous counter) and IC35 (a dual J-K flip-flop).

Those IC's divide the oscillator's output by 7 to provide the 2.04545 MHz that the sync generator (IC36) needs. They are also used to divide the oscillator's frequency by 4 to provide 3.58 MHz for the color subcarrier. That 3.58-MHz signal is fed to op-amp IC40, which (along with its associated components) triangulates the signal. The output of the op-amp is fed to IC19. The nonlinearity of that IC is used to form a sinewave whose shape can be adjusted by R52.

The sinewave is then sent to the RF modulator, IC3. The network made up of C6, C7, R12, and R14 provide a quadrature phase relationship between pins 1 and 18 (the CHROMA-LEAD and -LAG pins) of the RF modulator.

Another countdown circuit is made up of IC23 and IC24. Its purpose is to "segment" each horizontal line to provide timing signals for the signal generators. The four-bit binary counter, IC38, serves a similar function. It provides timing signals by counting the individual horizontal scan lines produced by IC36.

A shift register, IC25, controls the timing of each of the five frequencies of the multiburst generator and its white flag (the beginning, white portion of the multiburst pattern). The multiburst frequencies originate in separate oscillators made up of IC28, IC29, and IC30 and their associated R-C networks. One half of both IC22 and IC26, and parts of IC21 and IC27, control the phasing and switching of the multiburst generator. The multiburst output is buffered by IC37 and is then sent to the multiplexer.

The up/down-step and gray-level generator consists of IC20 (an up/down counter) and parts of IC21, IC22, and IC19. A one-Hz oscillator is formed by R28, R29, C13, and IC19; which, along with S2, allows the user to select one of eight gray levels by momentarily pushing S2. You can also step through each of the eight gray levels at a one-Hz rate by holding S2 closed. A provision (jumper JU1) is made for changing the source of the up/down control signal to IC20 (pin 5) from pin 9 to pin 8 of IC22. That has the following effect: Instead of the TV screen displaying the maximum white level at center screen and black at the extreme edges, the opposite occurs. (That is, black is displayed in the middle of the screen, stepping to

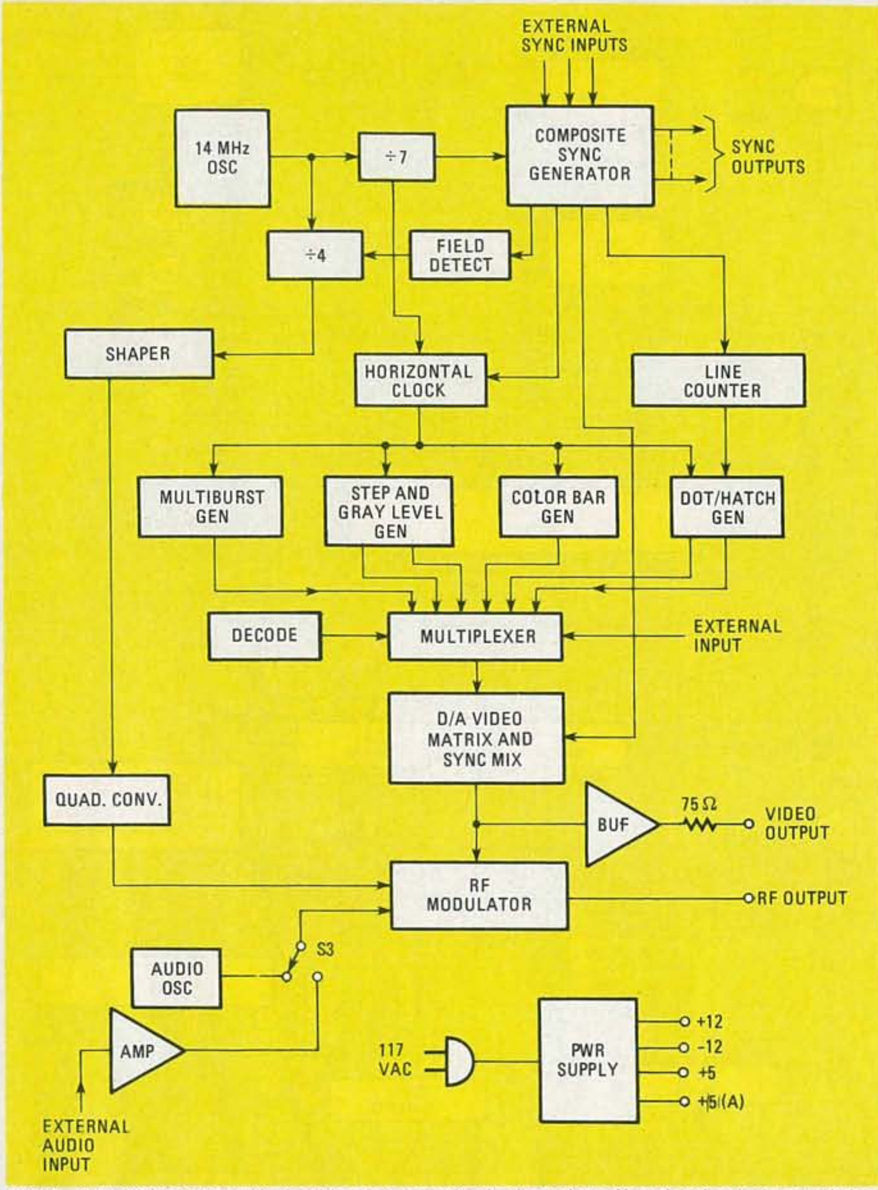


FIG. 2—A BLOCK DIAGRAM of the video test generator is shown here. Note that the power supply has two +5-volt outputs. That helps to keep digital switching spikes from distorting analog waveforms.

white at both edges.)

The dot- and hatch- pattern generator is made up of IC17 and part of IC5. Those IC's combine the outputs of the line counter and the horizontal clock at the proper times so that the hatch and dot patterns are produced. Those outputs are then sent to the multiplexer.

The color-bar generation is performed by a counter, IC16. It simply provides different binary states (which correspond to three primary and the three complimentary colors) to a multiplexer, which routes them to the color inputs of IC4, a TV video matrix D/A converter.

The multiplexer that we've mentioned is made up of IC7–IC15. It selects one of the signals from the signal generators (or the externally generated digital video signal at the edge connector) and then routes that signal to IC4.

The multiplexer is controlled by the function-select switch (S1) through the decoding network (D5–D14 and R20–R25). The operation is straightforward, except in the multiburst mode. In that mode, the decoding matrix changes its output state (and therefore the multiplexer input address) during the short time between each separate multiburst frequency. That causes the multiplexer to momentarily route a gray level "4" to the D/A video matrix which gives a more pleasing appearance to the multiburst display. That is, the displayed pattern will be black and gray instead of black and white. That function is performed by IC22, IC26, D4, and part of IC5.

Taking a closer look at IC4, we see that it encodes luminance and color-difference signals from 3-bit RGB inputs. It also mixes the various sync signals to form a standard, sync-negative, composite-video signal. The composite-video output signal goes to Q3 for output buffering and also to IC3 where it is RF modulated.

Transistor Q2 also receives composite video from pin 13 of IC3, but with the chrominance information included. The two signals are selected by part of IC2, depending on the function selected by S1. The reason that there are two separate paths for the video is because of bandwidth limitations of IC3. Either way, the video signal passes through emitter-follower Q1 and then is buffered for output by IC1, an LH0002 current amplifier. That IC can drive long lengths of coax without difficulty.

An audio oscillator (IC42 and associated components) produces about a 1500-Hz sinewave. That signal goes to S3, which is used to select between the internal audio source or an external signal from the edge connector. The selected signal is applied to Q5 whose collector-base capacitance acts as a varactor diode to modulate the audio subcarrier at IC3. Coil L2 can be used to adjust the frequency of the subcarrier, which is nominally 4.5 MHz. The RF carrier's frequency is adjusted at L1.

Building the generator

You must use printed-circuit boards for this project because the placement of many of the components is critical and will affect the generator's operation. Foil patterns are shown (half-size) for the two required double-sided boards in Figs. 4, 5, 6, and 7. Due to space restrictions, Figs. 6 and 7 are not shown in this issue. They will appear when the story continues in a future issue. If you are not equipped to etch boards, pre-etched, drilled, and silk-screened boards are available from the supplier indicated in the Parts List.

Installing the parts on the board is pretty much straightforward, but there are a few points that we'll mention in the following paragraphs. First, make sure that you follow proper soldering practices. In other words, avoid cold solder joints—make sure that the connection is properly heated *before* you apply solder. (Of course, when soldering transistors and other heat-sensitive components, try not to use too much heat. If possible, use a soldering heat sink.) Don't use so much solder that you form solder bridges between PC-board traces. Finally, it is a good practice to use sockets for all IC's.

Now we can discuss the parts-placement diagrams. There are three, even though you might have expected two. Figure 8 shows the on-board component placement for what we'll call board A and the inter-board jumpers to board B. Figure 9 shows the off-board components for Board A and also 37 on-board jumpers. That brings us to board B, whose parts-placement diagram (both on- and off-board components) is shown in Fig. 10. (Note that Figs. 8, 9, and 10 will appear in a future issue.)

Assembly consists mainly of inserting

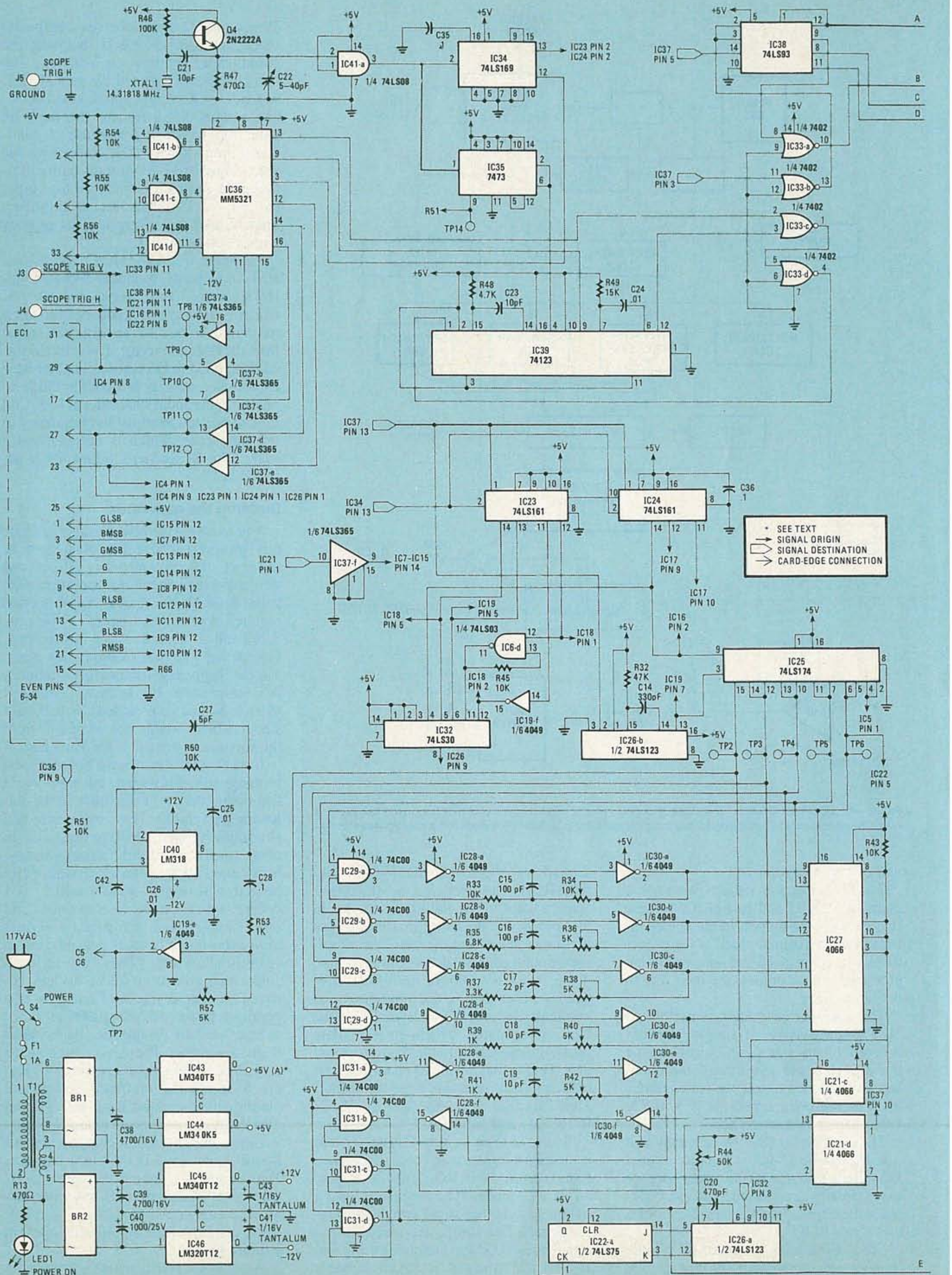
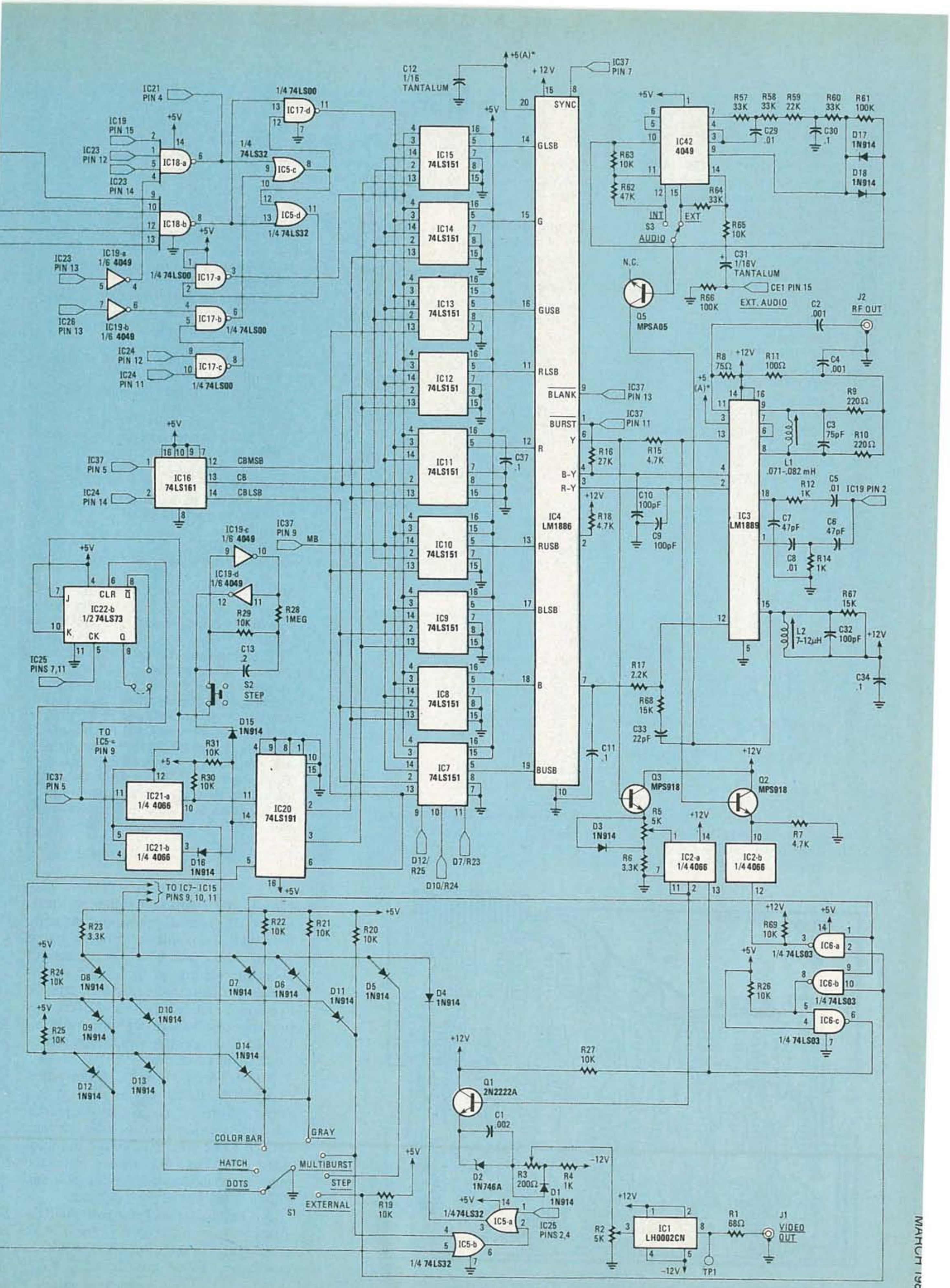


FIG. 3—VIDEO TEST GENERATOR SCHEMATIC. Note that some voltage sources are labeled +5V, while others are labeled +5(A). That is becaus



as mentioned previously, there are two separate +5- volt supplies.

PARTS LIST

All resistors ¼-watt, 5%, unless noted
R1—68 ohms
R2,R5,R36,R38,R40,R42,R52—5000 ohms, trimmer potentiometer
R3—200 ohms, trimmer potentiometer
R4,R12,R14,R39,R41,R53—1000 ohms
R6,R23,R37—3300 ohms
R7,R15,R18,R48—4700 ohms
R8—75 ohms
R9,R10—220 ohms
R11—100 ohms
R13,R47—470 ohms
R16—27,000 ohms
R17—2200 ohms
R19, R20–R22, R24–R27, R29–R31, R33,R43,R45,R50,R51,R54–R56, R63 R65,R69—10,000 ohms
R28—1 megohm
R32,R62—47,000 ohms
R34—10,000 ohms, trimmer potentiometer
R35—68,000 ohms
R44—50,000 ohms, trimmer potentiometer
R46,R61,R66—100,000 ohms
R49,R67,R68—15,000 ohms
R57,R58,R60,R64—33,000 ohms
R59—22,000 ohms

Capacitors
C1—0.002 µF, ceramic disc
C2,C4—0.001 µF, ceramic disc
C3—75 pF, mica
C5,C8,C24–C26,C29—0.1 µF, ceramic disc
C6,C7—47 pF, ceramic disc
C9,C10,C15,C16,C32—100 pF, ceramic disc
C11,C28,C30,C34–C37,C42—0.1 µF, ceramic disc
C12,C31,C41,C43—1 µF, 16 volts, tantalum
C13—0.2 µF, ceramic disc
C14—330 pF, ceramic disc
C17,C33—22 pF, ceramic disc
C18,C19,C21—10 pF, ceramic disc
C20—470 pF, ceramic disc
C22—5–40 pF, trimmer capacitor
C23—10 pF, ceramic disc
C27—5 pF, ceramic disc
C38,C39—4700 µF, 16 volts, electrolytic
C40—1000 µF, 16 volts, electrolytic

Semiconductors
IC1—LH0002CN current amplifier (National)
IC2,IC21,IC27—4066 quad bilateral switch
IC3—LM1889 TV video modulator
IC4—LM1886 TV video matrix D/A converter
IC5—74LS32 quad OR gates
IC6—74LS03 quad NAND gates
IC7–IC15—74LS151 one-of-eight selector/multiplexer
IC16,IC23,IC24—74LS161 synchronous 4-bit counter
IC17—74LS00 quad NAND gates
IC18—74LS20 dual 4-input NAND gate
IC19,IC28,IC30,IC42—4049 hex inverting buffer
IC20—74LS191 synchronous up/down counter
IC22—74LS73 dual J-K flip-flop
IC25—74LS174 hex D-type flip-flop
IC26,IC39—74LS123 dual retriggerable monostable multivibrator
IC29,IC31—74C00 quad NAND gates
IC32—74LS30 8-input NAND gates
IC33—7402 quad NOR gate
IC34—74LS169 4-bit synchronous up/down counter
IC35—7473 dual J-K flip-flop
IC36—MM5321 TV camera sync generator (National)
IC37—74LS365 hex bus driver
IC38—74LS93 4-bit binary counter
IC40—LM318 op-amp
IC41—74LS08 quad AND gate
IC43—LM340T5 5-volt regulator, T0-220 case
IC44—LM340K5 5-volt regulator, TO-3 case
IC45—LM340T12 12-volt regulator, TO-220 case
IC46—LM320T12 12-volt negative regulator, TO-220 case
Q1,Q4—2N2222A
Q2,Q3—MPS918
Q5—MPSAO5
D1,D3–D18—1N914 or 4148
D2—1N746A
S1—7-position rotary switch (Allied 7471001 or similar)
S2—pushbutton switch, normally closed
S3—SPDT toggle switch
S4—SPST toggle switch
LED1—standard red
T1—Transformer (Triad F-166XP or similar), primary: 117 volts; secondary: 24 volts, center-tapped, .125 amps; 9 volts, center-tapped .5A
BR1,BR2—bridge rectifier, 1.5 amps
L1—0.071–0.082 mH adjustable coil (J.W. Miller 48A778MPC or similar)
L2—7–12 µH adjustable coil (J.W. Miller 23A105RPC or similar)
XTAL1—14.31818 MHz crystal
F1—fuse, 1 amp, pigtail leads
J1—BNC jack
J2—type N jack
J3–J5—standard tip jacks

Miscellaneous—Heat sinks, cabinet (Pactec CM86-225), power cord, strain relief, T0-3 mounting kit, IC sockets, etc.

The following are available from Jengco, 3232 San Mateo, Suite 75, Albuquerque, NM, 87110: Complete kit including PC boards, all components, cabinet (no IC sockets), $295; Etched, drilled, and silkscreened PC boards (boards A and B), $49.50; Complete test generator, assembled and tested, $395. Please add 5% for postage and handling, New Mexico residents add 4.25% sales tax, allow 6–8 weeks for delivery.

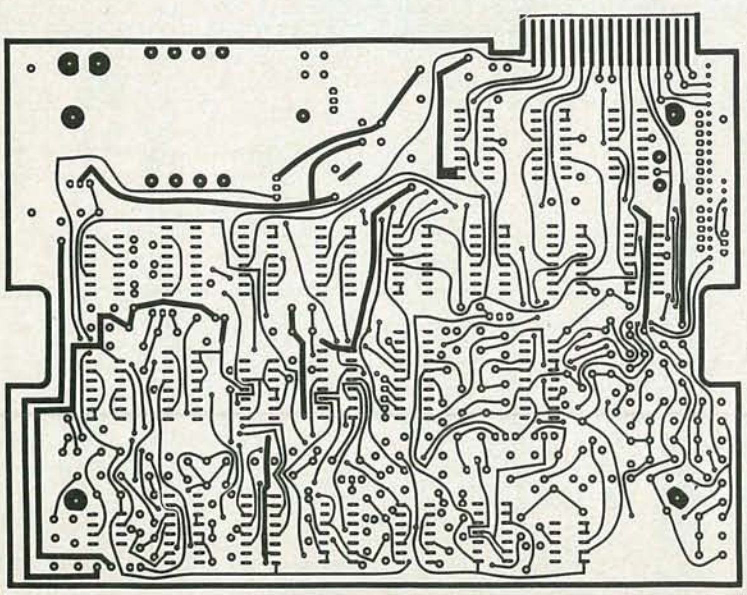


FIG. 4—THE COMPONENT SIDE of board A is shown here at half its actual size.

parts in the board and soldering them. Follow the three diagrams and the parts list, and and solder the parts where shown. Make sure that you are careful about the polarity of the diodes, transformer T1, polarized capacitors, and the two bridge rectifiers (BR1 and BR2). It is probably best to start with the resistors. Definitely do *not* start with the jumpers—we'll get to those shortly.

A few notes are in order: All resistors, except R15, should be installed so that they stand on one end. The POWER indicator, LED1, should have its leads left long enough to be inserted through the front panel hole. For safety's sake, insert the pigtail fuse into a short length of shrink tubing before soldering it in place.

It is best to use sockets for all the IC's. And don't forget that some of the IC's are static-sensitive and should be handled accordingly. Those include IC2, IC19,

continued on page 98

"UNITED TWO-FORTY-TWO HEAVY, HEADing one four zero, number two for the ILS runway fourteen left," the controller's voice crackled in the headset. The 747 made a slow right turn and continued its descent toward what looked like a sea of white—the top of the overcast. As the aircraft entered the clouds, the flight attendant went through her standard "Seat back, tray tables in the upright and locked position" speech. Minutes later, the ground loomed dim and gray through the rain-streaked windows and, with a gentle bump, another 300 passengers arrived safely at Chicago's O'Hare International Airport. It was just one of an average two-million-plus instrument landings routinely made every year in the United States.

But how can a pilot put a giant airliner exactly on the center of the runway when he cannot even see the airport except during the last seconds of the flight? The answer is his ILS or *I*nstrument-*L*anding *S*ystem—part of a complex world-wide electronic navigation-and-landing system that makes airplanes the safest and most dependable way to travel.

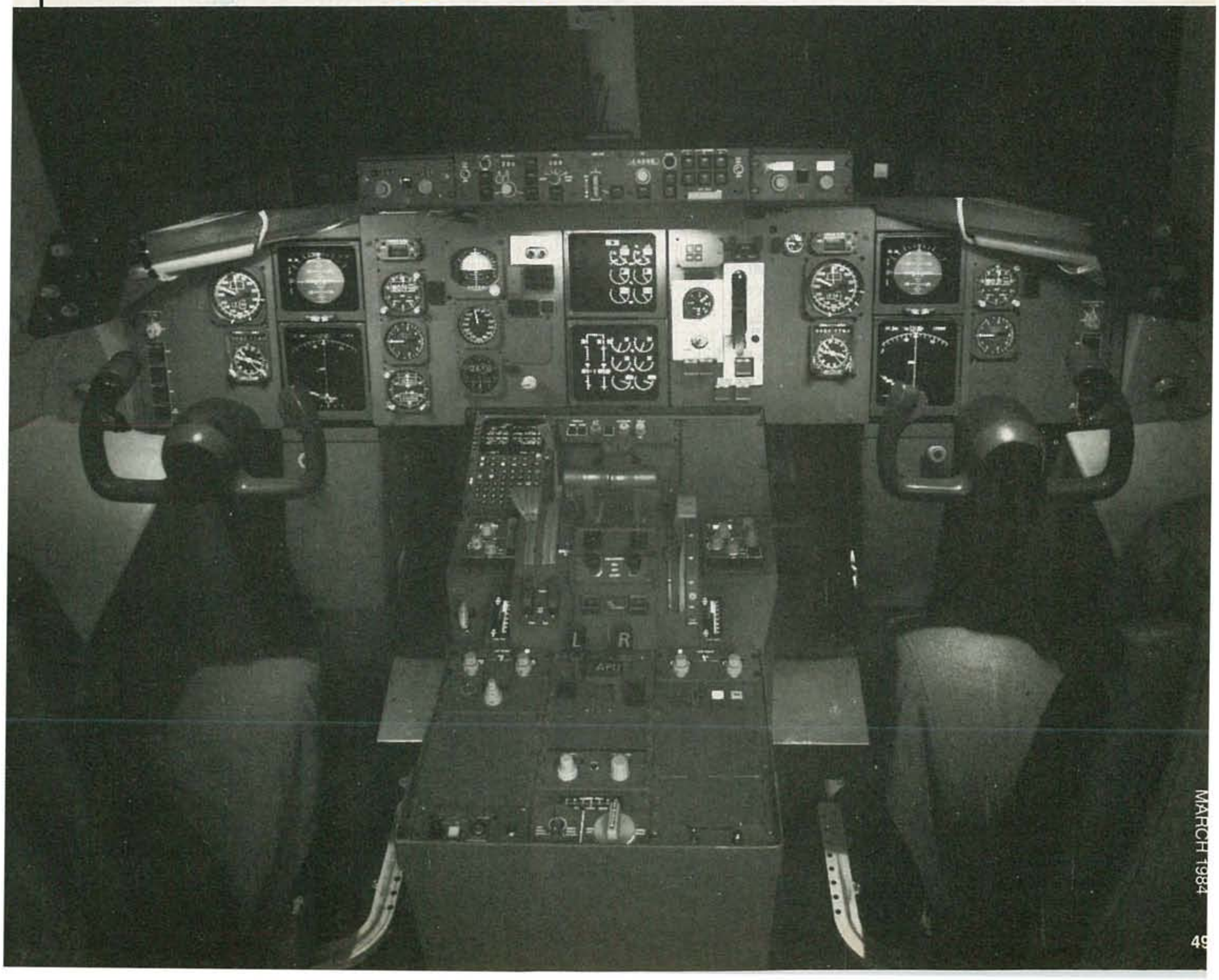
The early years

Toward the end of World War I, while aviation was still in its infancy, there was no governmental control over civilian pilots or the aviation industry. Automobiles were the up-and-coming thing, and aviators were pretty much left to their own resources. The Army Air Corps had a few airfields, but civilian aircraft landed anywhere there was an open and flat area

Instrument Landing Systems

Have you ever wondered how a pilot can safely land an airplane when weather conditions are so bad that he can't even see the runway? If so, read on as we describe instrument landing systems.

BILL SEWELL



large enough to get down safely (and sometimes even where there wasn't).

If a pilot needed to make a night landing, he might arrange for a friend to build a fire in a field where he planned to land. He would then circle the field when he arrived and the friend on the ground would frantically pile straw and wood on the fire so that it would blaze up and light the field. Because of the use of that technique, many a pilot came down with parts of his airplane on fire!

Civil aviation got its start in May, 1918, when the first bag of air mail left the infield of Belmont Race Track on Long Island (the airplane was a Curtiss Jenny) and landed three hours and forty minutes later on the polo grounds of Washington, D.C. The pilot who was to carry the North-bound mail to New York shook hands with President Wilson and then took off from the polo grounds and turned Northeast. He landed in Delaware to ask directions and broke his propeller in the process. His bag of air mail went to New York on the train!

After that shaky start, however, air mail did settle down to regular service. In order to keep the mail flying, even in bad weather, large beacon lights were installed at airports and along the routes. Their purpose, of course, was to help pilots find their way in reduced visibility. But the pilots often described the beacons, saying, "When you need em, you can't see 'em, and when you can see 'em, you don't need 'em." That fact, coupled with pressure from Congressman Fiorello LaGuardia, led to the adoption of the Air Commerce Act in May, 1926, and the development of civil aviation came into full bloom.

One of the first goals of the Commerce Department's new Civil Aviation Authority was to develop a system that would allow planes to take off, fly, and land without any reference to the ground. General Jimmy Doolittle was chosen to head that task. On September 24, 1929, during a secret demonstration flight, Doolittle took off, flew a prescribed course, and landed while sitting under a canvas hood that completely covered his cockpit. He had with him a compass, an altimeter, a stop watch, and a spotter pilot (who never touched the controls) in the front cockpit.

That same year, two-way radio came into its own and enabled the pilot to talk to spotters on the ground who could assist in landing. Also during that time, Elmer Sperry and the Sperry Gyroscope Company were busily developing flight instruments. In May, 1932, Albert F. Hegenberger made the first solo flight from takeoff to landing while completely in the blind. Shortly after that, the Sperry Company developed the auto-pilot and radio direction-finder. But there was still clearly a need to be able to bring an airplane to a safe and precise landing after a long flight.

From 1928 to 1938, several system approaches were tried, but none really gave satisfactory performance. In 1938, the Bendix Corporation and the United Airlines Company demonstrated a localizer system which would bring the aircraft in on the runway heading using two highly directional antenna arrays radiating different signals down either side of the runway. Shortly thereafter, the Federal Telecommunications Laboratories installed four identical instrument-landing systems at Indianapolis, Indiana. The development of those systems under contract from the Civil Aviation Agency led to a precision instrument-landing system before the end of World War II. That system was adopted as a world standard by the International Civil Aviation Organization (ICAO) in 1949. The basic technology developed at Indianapolis has remained virtually unchanged to this day.

The basic system

The basic instrument-landing system consists of four (or five) transmitting stations, as Fig. 1 shows. The *localizer* transmits a signal down the runway to provide lateral guidance and line the aircraft up on the runway. The *glide slope* transmits a signal which is inclined with respect to the ground at an angle around 3°. It ensures that the aircraft will make a smooth descent to the end of the runway while safely clearing all obstacles on the ground under the approach path. The other transmitters are the *fan markers*. The *outer marker* transmits a narrow beam straight up through the approach path to mark the point where the pilot must begin his final descent. That point is about three to five miles from touchdown. The *middle marker* also transmits a narrow vertical beam which marks the point where the aircraft should be below the clouds. That point is typically one-half to three-quarter mile from touchdown. If the clouds are so low that the pilot cannot see the runway within a few seconds after passing the middle marker, he is required to immediately execute a "missed approach." That means he must climb to a prescribed altitude and fly to a prearranged point so that the air-traffic controller can get him set up to try again. A few airports around the country use a high-precision ILS. Specially trained flight crews are allowed to continue their approach and land even though the cloud cover is down to within a few feet of the runway and the forward visibility is virtually zero. At those airports, there is a third fan marker, the *inner marker*.

The localizer

The localizer transmitting-antenna array is located just off the stop end of the runway. A typical array consists of eight folded-dipole elements or horizontally polarized loops that radiate a highly directional signal down the runway and into the space beyond. The two center antennas radiate an RF carrier (f_c) on one of 40 assigned channels between 108.1 and 111.9 MHz. That carrier is modulated 20% with 90-Hz and 150-Hz audio tones; the sidebands ($f_c \pm 90$ and $f_c \pm 150$) are also radiated. (A three-letter Morse-code identifier is also put on the carrier using a 1020-Hz tone as a cross check to tell the pilot which station he has selected. The absence of the identifier upon proper selection of the station tells the pilot that the station is off the air.)

The other 6 antennas radiate only the 90-Hz and 150-Hz sidebands—the carrier is suppressed. The signals transmitted from one side of the center are 180° out of phase with those transmitted from the other side, and both sides are 90° out-of-phase with the center antenna. Let's see why that is important.

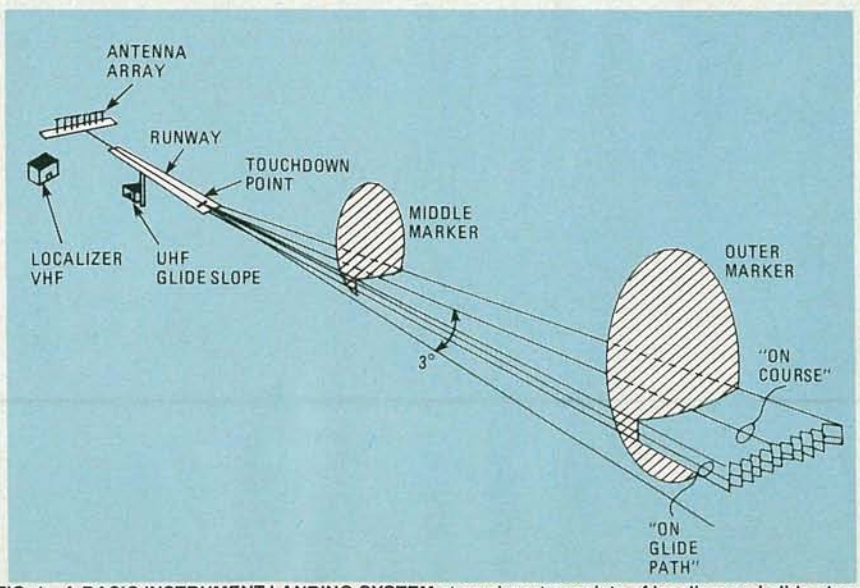


FIG. 1—A BASIC INSTRUMENT-LANDING SYSTEM at an airport consists of localizer and glide-slope transmitters, and two or three fan markers.

If a single omnidirectional antenna radiates a signal, the strength of the signal at a given distance is (ideally) constant—regardless of the direction you choose with respect to the antenna. However, if *two* antennas that radiate the same signal are spaced some distance apart (say ½ wavelength), then the signals arrive at a receiver exactly in-phase, exactly out of phase, or somewhere in between—depending on the position of the receiver. That principle is used in ILS so that the relative strengths of the radiated 150-Hz and 90-Hz sideband signals depend on the position of the aircraft with respect to to the transmitting antennas. Let's see how it's done.

We mentioned that the signal in the left side is 180° out of phase relative to the signal in the right side. Those signals combine with the carrier-plus-sideband signal in such a way that, on one side of the array, the 90-Hz sideband-only signal signal adds to the 90-Hz sideband of the carrier, while the 150-Hz sideband-only signal subtracts from the 150-Hz sideband of the carrier. On the other side of the array, the opposite is true. Figure 2 shows the resulting simplified radiation pattern—two narrow lobes, one effectively modulated with 90 Hz and the other with 150 Hz.

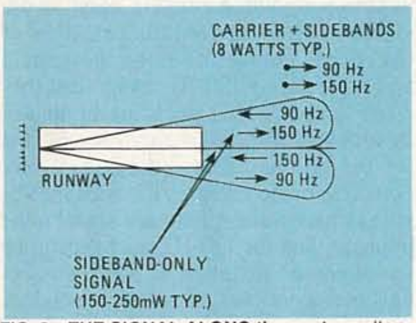


FIG. 2—THE SIGNAL ALONG the center or "on-course" line: the 90- and 150-Hz signals are equal.

At this point, we can make some simplifications that will make the rest of the explanation easier to understand. The array of eight antennas can be thought of as three antennas. First, the center two antennas can be thought of as a single antenna, A_0, radiating carrier-plus-sideband signals. The other antennas can be thought of single antennas to the left and right of the center antenna. They radiate sideband-only signals.

The 90-Hz sideband energy in what we'll call antenna A_1 will lag the 90-Hz energy from A_0 by 90°, while the 90-Hz sideband energy from what we'll call A_2 will lead that from A_0 by 90° (thus there is a 180° phase difference between A_1 and A_2). The 150-Hz sideband signals from A_1 will lag those from A_0 by 90°, while the 150-Hz signals from A_2 will lead those from A_0 by 90°.

Because the sideband-only signals radiating from our two antennas are 180° out of phase, the signal along the center line separating the antennas consists of equal 90-Hz and 150-Hz components. That's because the sideband-only signals cancel completely at that point—leaving behind the 90-Hz and 150-Hz signals that were radiated with the carrier; the amplitudes of those signals are set equal to each other in the transmitter.

Now that we have gone to all this trouble of putting an electronic line down the runway, how does the aircraft follow the line?

On board the aircraft, the signal is received and detected. The recovered audio is sent to a 90-Hz filter and a 150-Hz filter as is shown in Fig. 3. The filtered audio is then rectified, and a DC current that is proportional to the amplitude of the audio signal energizes a galvanometer-type meter movement. As the aircraft flies along the center line of equal audio, the needle will be centered, indicating that the aircraft is "on course."

Current will flow through resistor R_M whenever either a 90- or 150-Hz signal is present. The current flow is used to tell the pilot that the system is operational by energizing a solenoid. When no current flows, the solenoid is de-energized, and a warning flag appears in the instrument.

Now let's say the aircraft drifts to the right of the center-line course as in Fig. 4. Remember that the 90-Hz sidebands from A_1 lag those from A_0, while the 90-Hz signals from A_2 will lead those from A_0. As the wave travels to the airplane, the phase of the signal from A_1 along d_1 is advanced with respect to the signals from A_0. The opposite is true of the signals from A_2. The resultant of the 90-Hz sidebands is 180° out of phase with the signals from A_0, and therefore produce a weakened 90-Hz signal.

On the other hand, the sidebands of the 150-Hz signal from antenna A_2 lag those from antenna A_0, while the 150-Hz sidebands from A_1 lead those in A_0. The phase of the 150-Hz sideband signal from A_1 (travelling along d_1) is advanced with respect to that from A_0, while the opposite is true of the signals from A_2. The resultant is in phase with the signal from A_0, and therefore adds to it to produce a

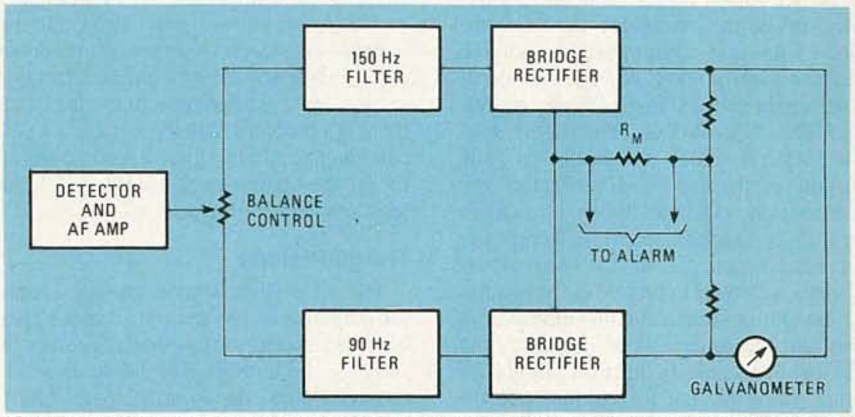


FIG. 3—THE LOCALIZER INDICATOR is usually combined with the glide-slope indicator to form a cross pointer.

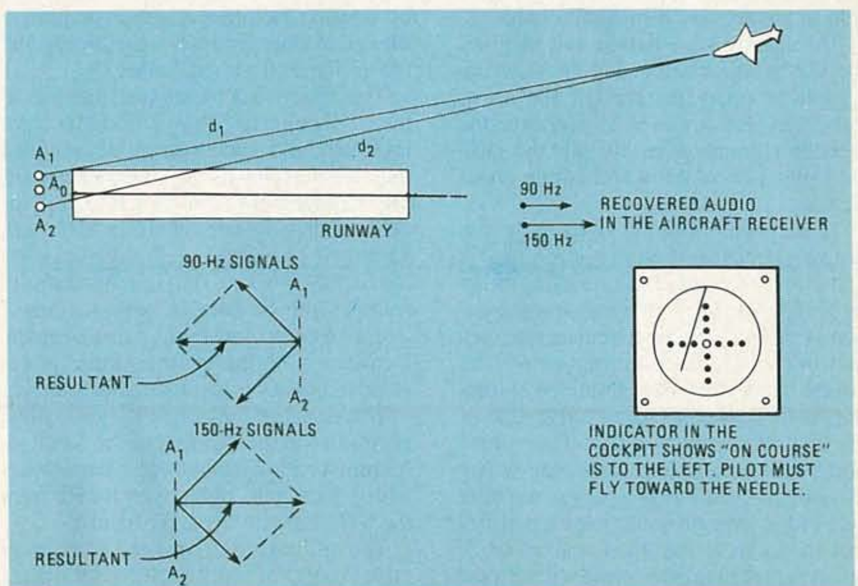


FIG. 4—WHEN A PLANE is flying off-center, the sideband-only signals add to or subtract from the 90- and 150-Hz sidebands in the carrier-plus-sideband signals to tell the pilot which direction to move.

150-Hz signal that is much stronger than the 90-Hz signal.

The resulting unbalance causes the meter-movement needle to swing to the left side of the indicator, telling the pilot that he must fly to the left to get back on course. The same principle applies on the opposite side of the centerline with the 90-Hz sidebands becoming larger than the 150-Hz sidebands and deflecting the needle in the opposite direction.

Generating the localizer signal

Figure 5 shows that the localizer transmitting station consists of a transmitter, power supply, oscillator/keyer, modulator, control unit, monitor, and antenna distribution unit. The transmitter section generates the RF carrier using a crystal-controlled exciter operating at one-half the assigned frequency. That signal then passes through a frequency doubler and five stages of amplification. The high voltage in the final stage of the power amplifier is modulated with a 1020-Hz Morse-code identifier tone from the oscillator/keyer to put the station identifier on the carrier.

The RF carrier is then sent to the modulator. Inside the modulator, the RF is divided into two components by an RF coupler. One of those components is divided again and sent to the 90-Hz and 150-Hz sideband generators where pure double-sideband signals are produced. The outputs of the sideband generators are sent to to the sideband hybrid unit where they are combined to form the composite sideband signal. There are two outputs from the sideband hybrid unit. One output is sent straight to the antenna distribution unit and the other output is sent to the carrier hybrid unit. In that unit, the carrier signal from the first RF coupler is combined with the sidebands to give the carrier + sideband signal. That signal is then sent to the antenna distribution unit.

The antenna distribution unit provides the 180° phase difference in the sideband signals at opposite sides of the array. Power dividers are used to distribute the antenna currents to ensure that the radiated signal is balanced and highly directional.

To be certain that the signal is within proper safety specifications, the signal is constantly monitored. That's done either by pick-up probes in the transmitting antennas or by receiving antennas mounted in front of the transmitting array. The course centerline is maintained within one-tenth of one degree to either side of the runway's center stripe. The course width (the area in approach zone where the aircraft needle is not pegged to either side of the indicator) may not exceed 700 feet in width at the outer marker or 3° either side of the center stripe with respect to the center of the antenna array, whichever is smaller. If either of these limits are

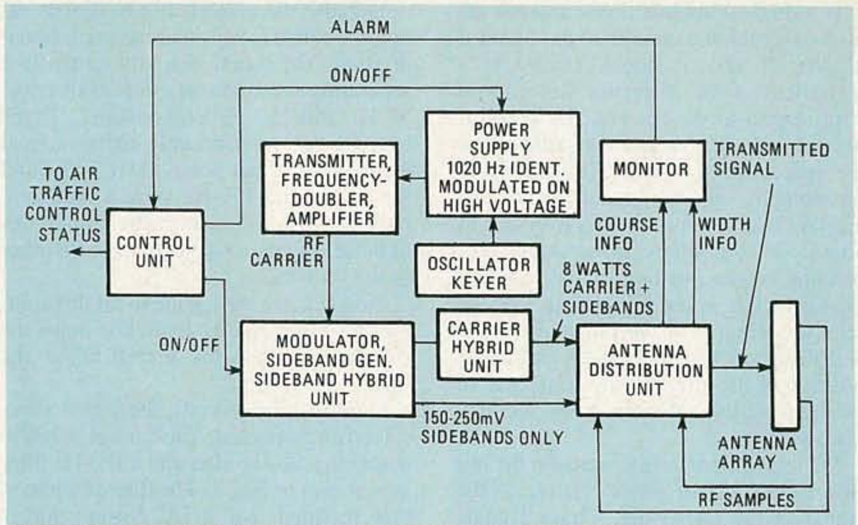


FIG. 5—LOCALIZER BLOCK DIAGRAM. The localizer is constantly monitored to make sure that it is within safety specifications.

exceeded, an alarm is generated in the monitor circuitry. Also, if the radiated power (typically 8 watts) is reduced more than 50%, or if the Morse-code identifier is missing, or the modulation level changes more than 17%, an alarm is generated. Those alarm signals are sent to the control unit which shuts the station down and immediately alerts the air-traffic controller and maintenance personnel that there is a problem with the station. As you can imagine, there is then a mad scramble to get the station back on the air in the least amount of time possible.

The glide slope

The glide-slope station provides vertical guidance to the aircraft to make sure that the descent to the runway is smooth and that the aircraft will safely clear all obstacles under the approach path. Many airports that were once some distance out of town now find themselves surrounded by houses, factories or office buildings. The glide slope protects the building and the airplanes from each other.

The glide-slope transmitter operates in the UHF range of 329.3–335.0 MHz. All localizers and glide slopes are assigned their frequencies using a frequency-pairing arrangement. For example, all localizers that operate on 108.5 MHz will have their associated glide slopes operating on 329.9 MHz. That relieves the pilot from having to tune in both stations—aircraft receivers are built so that when the localizer is dialed in, the proper glide-slope frequency is automatically selected.

The signal generation of the glide slope is almost identical to that of the localizer (except for a frequency-tripler stage that is added in the transmitter to get the RF from the VHF band to the UHF band.)

The glide-slope antenna is an array consisting of two dipole antennas mounted on a 40-foot mast. The lower antenna radiates the carrier (f_c) with its side-bands ($f_c \pm 90$ and $f_c \pm 150$). The upper antenna radiates only the sidebands. Those two dipoles use reflectors to make the signal forward directional.

Unlike the localizer, the 150-Hz sidebands in both signals are radiated in phase. But the 90-Hz sidebands in the carrier (lower) antenna are radiated 180° out of phase with the 90-Hz signal in the sideband-only (upper) antenna. Part of that signal propagates along the ground and has a strong 150-Hz component (because both 150-Hz signals are in phase). In addition, part of the signal is reflected off the ground. That reflection is very complex, but in essence, it causes the 90-Hz sidebands in the reflected signal to be in phase, and the 150-Hz sidebands to be out of phase. The angle at which the signal bounces off the ground is at a slightly higher angle than the direct signal. As shown in Fig. 6, that effectively puts 90-Hz modulation above the "on-path" line and 150-Hz below. Each of those signals

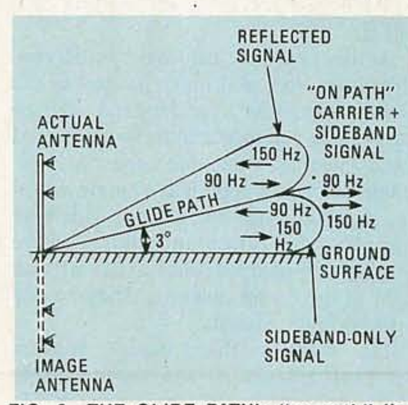


FIG. 6—THE GLIDE PATH's "on-path" line makes an angle of 3° with the ground surface.

retains the same "small amount" of the other just as in the localizer. In other words, a strong 90-Hz signal and weak 150-Hz signal above the on-path line, and the opposite below.

The reflected signal makes the entire radiation pattern seem to originate from a point at the base of the mast, midway between the actual antenna and its mirror image. If that "image" antenna is taken into account, then the array really looks like a localizer turned on edge.

But in the localizer array, the on-course signal was perpendicular to the axis of the antenna—that would put the glide path along the ground. But the glide-slope antenna heights are adjusted so that the distance between the actual and image antenna is not ½ wavelength. Because of that, the on-path signal is skewed about 3° above the horizon. The antenna mast is precisely located so that an aircraft flying down the path will cross the end of the runway between forty-five and fifty-five feet about the ground.

As you might expect, the ground contour in front of the antenna is assumed to be flat and level when the design calculations are made. But in reality, the actual ground is seldom perfect. At most metropolitan airports the ground is reasonably flat and smooth enough to form a straight and smooth path well within the FAA's strict safety limits. Smaller airports and those in mountainous or unusual terrain, however, often have rough ground next to the runway or they have little or no room in front of the touchdown zone to form the signal. These airports have always been denied the luxury of an all-weather landing system and are forced to close when the weather turns sour.

An antenna system called the *end-fire array* has just passed its final tests. It was expected to begin to appear at those smaller airports by early 1984. That array does not use the ground to form the path signal in space. It radiates its signal, instead, from a slotted coaxial cable into space. It gets its name from the fact that all the path information is radiated from the end of the axis of the array (hence, "end-fire") instead of broadside to the array as in the other two types discussed so far. That array promises to bring all-weather operation to many more airports around the world.

As stated earlier, the generation of the glide-slope signal is the same as the localizer except for a frequency-tripler stage in the transmitter exciter. Another difference is that no identification tone is transmitted from the glide slope.

A monitoring system is also used for glide-slope systems. The signal is monitored by a pick-up antenna in front of the mast; the station will automatically shut itself down if the glide-slope angle changes more than 0.2° or the modulation decreases by more than 26% or the radiated power changes more than 45%. Again, when a station shuts itself down there is a mad scramble to find out why and get it back on the air. Incidentally, such shutdowns occur only two or three times a year at the average station. But since the stations are generally on 24 hours a day, the shutdowns often occur during clear weather. There has never been an aircraft accident in the United States which was attributable to an ILS shutdown.

The fan markers

Two marker-beacon transmitting stations are part of the standard ILS. And as we mentioned previously, a third, inner fan marker is added in the high-precision systems.

The outer marker is installed about three to five miles from touchdown. Its exact location and the height of the on-path signal above the ground at that point are depicted on a chart which the pilot has in the cockpit for that particular runway. That gives the pilot an opportunity to crosscheck his instruments against known conditions as he starts his final approach.

The middle marker is located about 3500 feet from the end of the runway and, as stated earlier, is the point at which the pilot must either begin a visual approach—that is, he must be able to see the runway—or execute a missed approach.

With a high-precision system, an inner marker is installed 1000 feet from the end of the runway; that lets the pilot know he is about to cross the end of the runway and he should be completely set up for touchdown.

Each marker station is nearly identical in the way it generates its signal. Each has an exciter that generates the 75-MHz RF carrier that all marker stations operate on. An audio tone is modulated onto the carrier to identify the marker as outer, middle, or inner. The outer marker is identified by a continuous series of Morse-code dashes using a 400-Hz audio tone at a rate of two dashes per second. The middle marker transmits alternate dots and dashes using a 1300-Hz tone. The inner marker is identified by a continuous series of Morse-code dots (six-per-second) using a 3000-Hz tone.

After leaving the exciter, the modulated 75-MHz signal goes through three stages of amplification and is sent out to the antenna. The antenna is highly directional and the beam width along the runway centerline is about 1000 feet when the aircraft is 1500 feet above the antenna.

A small pick-up antenna is mounted with the main antenna and monitors the radiated signal. If the identification stops or if the power is reduced by 50%, the station shuts itself down.

The future

The future of instrument navigation and landing systems may take one of two radically different approaches. One approach is to continue with a vast network of land-based systems. That is the course that the current FAA administration is pursuing in its recently released National Airspace System Plan which outlines the direction that the air-traffic control and airway-facilities systems will take through the year 2000. The other approach is a satellite-based system which is now well under development by a private firm.

The replacement of some ILS's will begin in early 1985. The new system is called MLS or *M*icrowave *L*anding *S*ystem. That system works in the 5-GHz band and transmits course and glide-path data to the aircraft by sweeping a narrow fan-shaped beam back-and-forth and another beam up-and-down. The airborne receiver measures the time between the left-to-right scan (or the "up" scan) and the right-to-left (or the "down" scan). That time difference will give the aircraft's position relative to the start of the scan. An on-board computer then translates the information to position relative to the runway centerline or the glide path. Synchronization of the receiver to the scan start is done by data words transmitted to the aircraft on the same scanning beam using differential phase shift keying (DPSK). Station identification and other data is transmitted in the same way. The data and position data may be displayed on a single CRT in the cockpit.

MLS has started to pick up some opposition among some aircraft-user groups who are lobbying in Congress in favor of a satellite-based system which may turn out to be cheaper for the taxpayer, since the system would not be government-owned as most ILS's are, and would be paid for exclusively by its users.

That system would use four satellites parked in a stationary orbit over the continental United States. A user would transmit a signal which would be picked up by at least three of the four satellites. The satellites then communicate with each other and compare signal-arrival times to calculate the transmitter's position in three axes. The features that make the system more desirable are the fact that it operates using four satellites as opposed to thousands of ground-based systems; and also, the ground-based systems are dedicated to aircraft only and to the small areas the individual systems serve, whereas the satellite system could be used by anyone with the proper transceiver, whether an airplane, ship, commercial truck, private auto, or even a backpacker. According to estimates by the company developing the system, it could be in place by 1987; however, it would probably be a few years after that before the final system would be fully operational.

No matter what systems are ultimately put in place, the air traveler can take comfort in knowing that when he boards the aircraft, he is about to participate in the most extensive and safest transportation system available to man. **R-E**

BUILD THIS

Audio-Frequency Generator

Here's an audio-frequency generator with a digital frequency-readout that is easy to build, align, and use, yet is precise enough for servicing today's sophisticated audio equipment.

RICHARD SCHROEDER

TO SAY THAT BOTH HOME AND PROFESSIONAL sound installations have become extremely sophisticated would be an understatement. For example, a ⅓-octave band equalizer as well as lowpass and highpass filters are integral parts of virtually all professional sound systems. In fact, these days equalizers, tone controls, and lowpass and highpass filters are considered to be necessary even in home or auto systems.

Today's consumer demands more in the way of performance, which means more precision is required when servicing audio devices and circuits. Because of that, old-fashioned frequency generators often prove to be inadequate. Among other things, they suffer from inaccurate frequency dials, require range switching, and often their output level changes as the frequency is varied. What we need, then, is an audio-frequency generator that has an accurate output-frequency indicator, a "flat" output level as the frequency is varied, and one that is free of any range switching, thereby allowing the operator to "sweep" the entire audio range with just a "twist of the wrist."

Well, look no further, because the audio-frequency generator described in this article has all the above-mentioned desirable qualities and a few more. Let's look at some of its features and specifications.

It has a frequency range of 10 Hz to 50 kHz. That range is continuous, which eliminates the need for range switching. For increased precision, two controls are used to set the frequency. The COARSE FREQUENCY control is used to set the approximate frequency while the FINE FREQUENCY control is used to zero it in precisely.

The amplitude of the generator's sinewave output is adjustable from 0- to 6-volts RMS into a high-impedance load or 0- to 3-volts RMS into a 600-ohm load. The device's output impedance is 600 ohms. The sinewave has a distortion figure of less than 1% (THD), and its output level doesn't vary more than a few tenths of a dB as the frequency is changed over the entire range. The unit also boasts a simultaneous squarewave output with a low source impedance and a fixed 5-volt level for TTL or CMOS logic work.

One unique feature is a built-in frequency counter that continually monitors the output frequency. The device can also be wired so that the counter can be used to measure external signals. That frequency counter not only allows you to make precise frequency settings, but also eliminates the need for usual large, cumbersome dial with its myriad of marks and numbers. Generators using that type of frequency "readout" have always been difficult for the hobbyist to build and calibrate.

The frequency counter itself features autoranging and a large, four-digit LED display. For frequencies up to 9,999 Hz, the display reads out in Hz with 1-Hz resolution. For higher frequencies, the counter automatically switches to the kHz mode, which features 10-Hz resolution. You can tell which mode the generator is in the by the absence or presence of the decimal point. In the kHz mode, a decimal point appears after the first two significant digits.

All of the components except the power

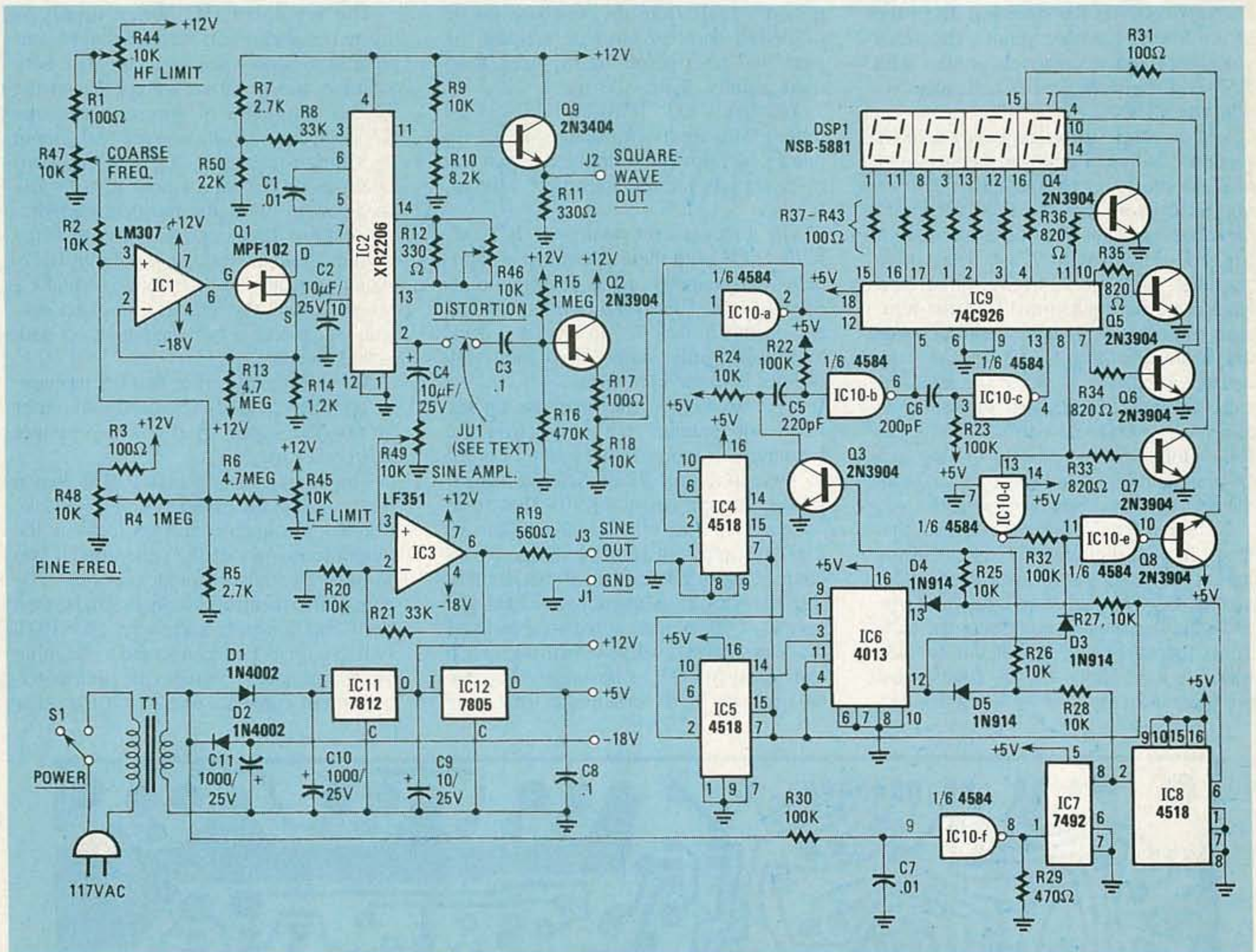


FIG. 1—SCHEMATIC DIAGRAM of the audio-frequency generator. If you want to use the built-in frequency counter to measure external signals, jumper JU1 should be replaced with a SPDT switch (see text).

transformer, potentiometers, display, and output connectors mount on a single PC board. The completed project can be housed in a small, metal cabinet.

In short, this is an audio-frequency generator that provides high-quality performance at a low cost, along with some unique features.

How the circuit works

A schematic diagram of the unit is shown in Fig. 1. Let's start with the audio-frequency-generator section. Positive voltage is applied to the COARSE FREQUENCY potentiometer, R47, through trimmer potentiometer R44 (labeled H.F. LIMIT) and resistor R1. In a similar manner, positive voltage is applied to the FINE FREQUENCY potentiometer R48, through resistor R3. Depending on the settings of those potentiometers, some voltage will be fed to the non-inverting input of op-amp IC1 through resistors R2 and R4. Note that a very small voltage will reach that same input through R6 in conjunction with trimmer potentiometer R45 (labeled L.F. LIMIT). That arrangement sets the low-frequency limit of the generator when the COARSE and FINE FREQUENCY potentiometers are set to their low-frequency positions, which, of course, is when both wipers are all the way toward ground. Trimmer potentiometer R44, in setting the maximum voltage that is applied to R47, in turn sets the generator's high-frequency limit when R47 is set to maximum.

Op-amp IC1, along with transistor Q1 and its associated components make up a voltage-to-constant-current converter, the current of which controls the output frequency of function-generator IC2. The sinewave output signal from IC2 (pin 2) feeds the SINE AMPLITUDE potentiometer, R49, through capacitor C4. Depending on the setting of the potentiometer, some voltage will be fed to the non-inverting input of op-amp IC3. That op-amp amplifies the signal, which is then fed to the SINE output binding post through resistor R19.

Note that the sinewave signal from IC2 also feeds the base of transistor Q2 through a jumper wire and capacitor C3. That transistor is configured as an emitter follower and acts as a buffer between the audio-frequency generator section and the frequency-counter section.

The squarewave output signal from

function generator IC2 (pin 11) feeds the base of transistor Q9. That transistor is configured as an emitter follower and serves as a level shifter, buffer, and impedance matcher to provide a squarewave level of 5 volts from a low-impedance source at the SQUARE output binding post.

Trimmer-potentiometer R46 (labeled DISTORTION) sets the sinewave distortion to its lowest possible point. The other capacitors and resistors associated with IC2 set its frequency range and sinewave-amplitude levels.

Let's now turn to the frequency-counter section. Sinewave signals from the output of emitter-follower Q2 (actually the junction of resistors R17 and R18) are fed to the input (pin 1) of one of the six Schmitt triggers contained in IC10. That stage "squares up" the sinewave signal and feeds it to the input (pin 12) of the four-digit counter IC9. That IC counts or totals the squarewave "events," and because the counter is reset at 1- or 1/10-second intervals, it causes the readout to display in either Hz or kHz. Resistors R37 through R43, along with transistors Q4 through Q7 and their associated resistors, make up the segment and digit-drive system.

Note that the "squared up" signal that feeds the four-digit counter also feeds the input (pin 2) of dual decade-counter IC4, and that IC4's output feeds the input (pin 2) of another dual decade-counter, IC5. Those four counters connected in cascade make up a divide-by-10,000 counter that produces an output only when the frequency to be counted is equal to or greater than 10 kHz. That serves as the detector that determines which mode the auto-range system will settle on. The output of that counter (pin 14, IC5) feeds the input (pin 3) of flip-flop IC6. That device, and its associated components, serves to determine whether 1-second- or .1-second-period signals from the timebase (to be discussed shortly) ultimately reach the latch and reset points on the main four-digit counter, IC9.

Transistor Q3, IC10-b, IC10-c, and their associated components make up pulse generators that supply the latch and reset signals for the four-digit counter, IC9.

The circuit composed of IC10-d, IC10-e, Q8, and their associated components make up the gated decimal-point-drive system. That system works with signals from flip-flop IC6 to display a decimal point only when the frequency counter is in the kHz mode.

Next we turn to the timebase for the frequency counter. AC voltage from the secondary of power transformer T1 is fed to the input (pin 9) of Schmitt trigger IC10-f through resistor R30. That stage "squares up" the 60-Hz signal and feeds it to the input (pin 1) of the divide-by-six counter, IC7. The output of that counter (pin 8), with its frequency of 10 Hz and period of .1 second, is fed to a resistor/diode system that works with flip-flop IC6 and transistor Q3 to ultimately become the timebase for the kHz mode. That same 10-Hz signal is also fed to the input (pin 2) of divide-by-ten counter IC8. The output of that counter (pin 6), with its frequency of 1 Hz and period of 1 second, is also fed to the resistor/diode system to ultimately become the timebase for the Hz mode. That latter signal is also fed to the reset points on IC4, IC5, and IC6.

The regulated DC power supply is made up of two half-wave rectifiers configured in such a way as to produce both positive and negative voltages from the 12-volt secondary of power transformer T1. The positive voltage is fed to the input of voltage-regulator IC11, which produces at its output a stable 12-volts DC that powers the audio-frequency-generator section. That same 12-volts DC is fed to the input of voltage-regulator IC12, which produces at its output 5-volts DC, which powers the frequency-counter section. AC power is switched on or off with power switch S1.

We mentioned earlier that the frequency counter could also be used to monitor an external signal. That is where jumper JU1 comes in.

That jumper should be wired as shown on the schematic diagram if you want the frequency counter to always measure the output frequency of the generator. If you would prefer that the frequency counter be able to also measure external signals, then omit the jumper, and wire an SPDT switch with its pole connected to the input of the frequency counter (the jumper terminal that connects to C3). Of the other

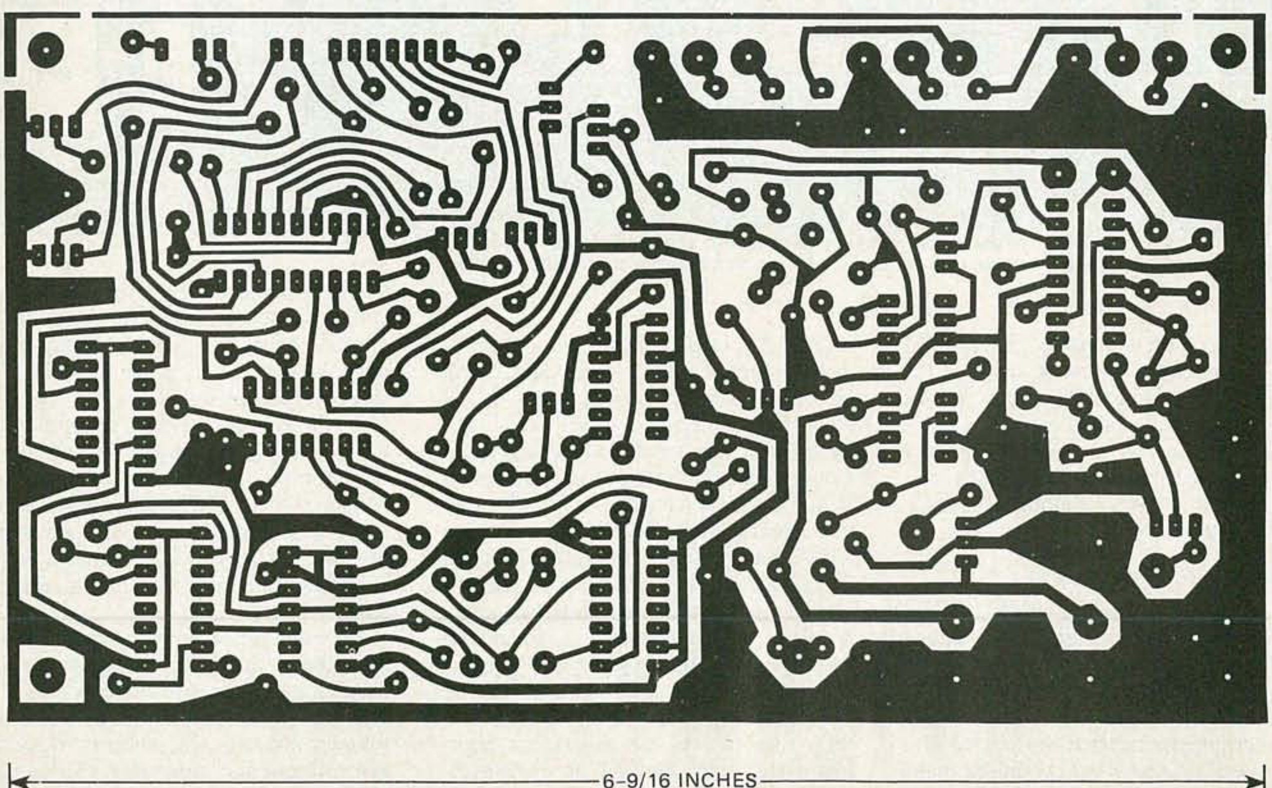


FIG. 2—ALTHOUGH POINT-TO-POINT wiring could be used, it is recommended that the project be built using the PC board above. That board is shown full-sized.

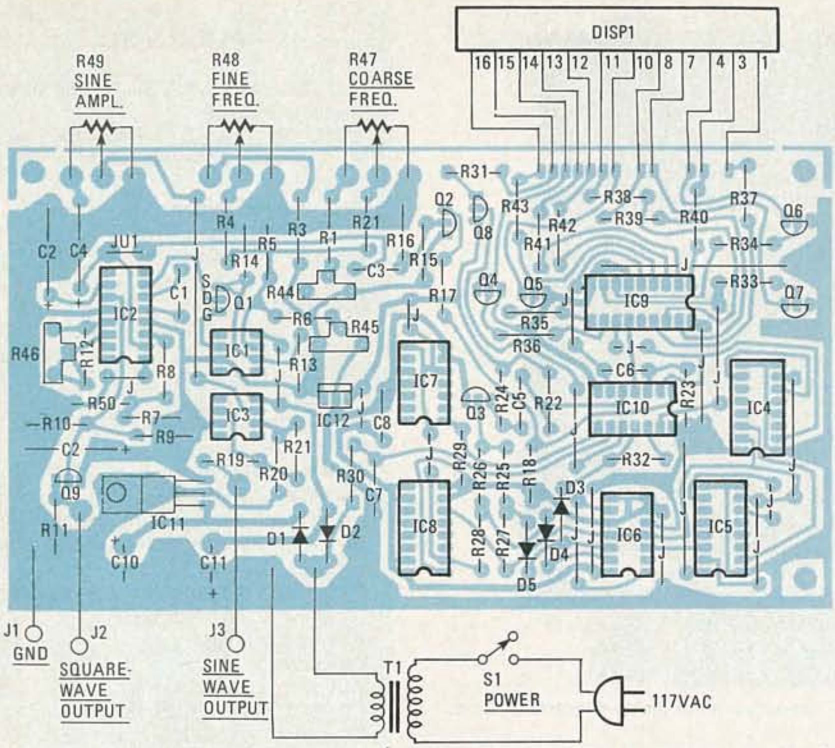


FIG. 3—THE PARTS-PLACEMENT diagram for the PC board shown in Fig. 2 is shown here. Note that even if you are using perforated construction board and point-to-point wiring it is recommended that you follow the layout shown.

two switch contacts, connect one to the jumper terminal that connects to pin 2 of IC2; the other switch contact becomes the "external" input terminal.

Construction

Several methods of construction are possible. You may choose to mount the components on perforated construction-board (with .1 inch hole spacing) and use point-to-point wiring. A much better idea is to use a PC board. A foil pattern for an appropriate board is shown in Fig. 2; a parts-placement diagram for the board is shown in Fig. 3. If you decide to use perforated construction-board and point-to-point wiring, it is recommended that you lay out the components much as they are in the PC. board layout to avoid ground loops, noise, and other undesirable characteristics.

If you plan to use a PC board, and will be drilling it yourself, you will find that a No. 60 drill bit works well for all holes except those for the trimmer potentiometers and external wires. For those, a No. 55 bit is needed; and, of course, the holes for mounting the three terminal voltage regulators and the PC-board mounting holes will require a larger bit, say ⅛ inch.

After the PC board has been drilled, it should be throughly burnished with steel wool or very fine sandpaper to remove the photochemicals and tarnish. That will definitely contribute to better solder connections. All soldering should be done with a high-quality rosin-core solder and a pencil-type iron. The newer type metal-clad tips are highly recommended.

Use special care to properly install polarized components such as diodes, transistors, IC's, and electrolytic capacitors, because those are very unforgiving when put in backwards. If you follow the parts-placement layout shown in Fig. 3 you should have no problems.

Although IC sockets are not required, their use is recommended. If nothing else, it will make servicing and troubleshooting the instrument easier later on.

Note several things in regard to mounting the three-terminal voltage regulators. The 12-volt regulator, IC11, is mounted with a 6/32 × 1½-inch brass bolt and a ¼-inch hex nut, with the excess bolt length extending upward. The bolt provides a small but adequate heat sink for the voltage regulator. The 5-volt regulator, IC12, mounts in a vertical position and it, too, has a brass bolt mounted to it for heat-sinking purposes. The excess bolt length should extend toward the rear of the PC board. Be sure to install the regulator with its bare-metal side facing the panel-mounted potentiometers (see Fig. 4).

The three panel-mounted potentiometers connect to the PC board by means of short wires that hold their solder lugs about ⅛ to ¼ inch above the surface of the PC board. That is done to allow the potentiometers some flexibility, so that when they are finally tightened against the front panel they will align properly without breaking. It would be best to attach those wires first to the solder lugs and then solder them to the board. Make sure that each wire passes through the lug hole with the wire being wrapped several times around the lug and soldered. Be sure that when finally soldering the wires to the PC board that you not only make allowance for the required clearance, but that you keep that clearance uniform for all three potentiometers so as to have them reasonably in line horizontally.

In a similar manner, the four-digit display is supported mechanically by its twelve signal wires. The attaching of the wires is best done by soldering a two- to three-inch length of bare No. 22 solid wire to each of the twelve appropriate connectors on the display board. Note that there are 16 total connectors on the display, but that four of them are not used. As an aid to getting the wires soldered to the proper points, tape or clamp the display to your work table with the viewing surface facing downward and the solder connectors closest to you. The connector on the left front corner can be considered as connector 16 and the one on the right as connector 1.

Solder wires then to the following connectors: 16, 15, 14, 13, 12, 11, 10, 8, 7, 4, 3, and 1. Be very gentle in soldering and handling the display because the foils are very thin and breakable. When all the wires have been attached, bend them downward (toward you) with the right-angle bends made close to the connectors. The display with its attached wires can now be installed on the PC board. Insert the display wires into the appropriate PC-board holes and be sure to hold the display level with its horizontal center line about an inch above the PC-board surface before soldering the signal wires into place. After soldering, cut off any excess wire.

When choosing your cabinet be sure that it is large enough to accommodate the board and the off-board components comfortably. Also, using a vented cabinet is a good idea.

At some point, you will need to drill the various holes and a rectangular opening in the cabinet for the potentiometers, display bezel, PC-board mounting bolts, transformer, etc. Plan ahead and carefully measure everything so that it will all fit well. Although most cabinets have a thin coat of paint when purchased, the drilling process usually puts some nicks and scratches in it. Most find that re-painting at least the front panel and then applying press-on lettering gives the instrument a professional appearance.

The PC board is supported about 1¼ inches above the bottom of the cabinet with four 6/32 × 1½-inch bolts. Each bolt has three 6/32 × ¼-inch hex nuts attached; one holds the bolt to the cabinet and the other two sandwich the PC board at the proper height.

When all the PC-board components have been soldered in place, it's a good idea to thoroughly check the parts place-

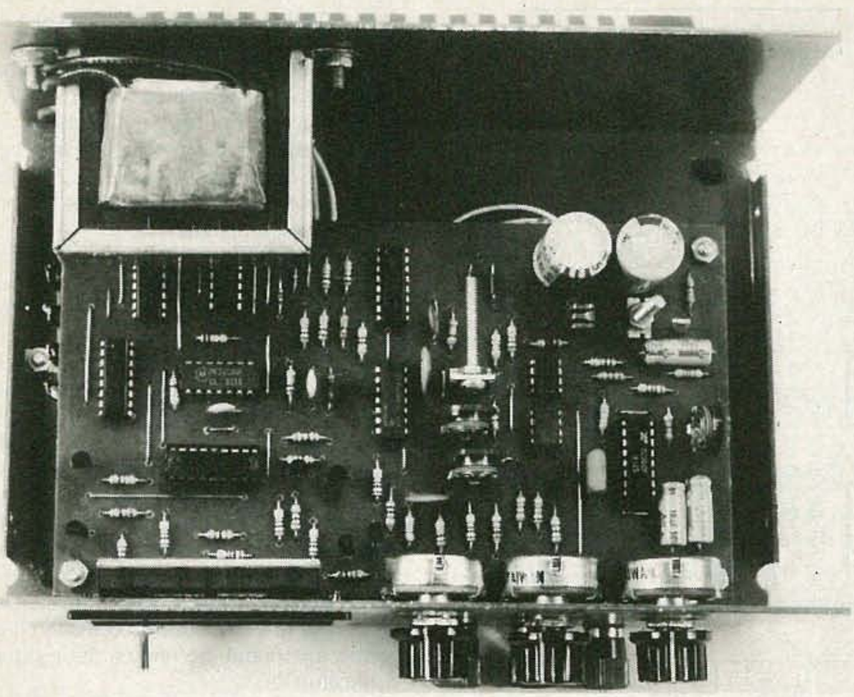


FIG. 4—THE COMPLETED BOARD is shown here mounted inside the case. Note the orientation of IC12.

ment, and the solder connections to be sure all is correct. When that has been done, it's time to "fire up" the device to test and calibrate it. Although that can be done with the PC board and transformer mounted in the cabinet, it is usually best to at least do the initial testing and calibration with the "electronics" out on the bench.

Testing and calibration

All you will need in the way of calibration equipment is an oscilloscope to check the squarewave and sinewave outputs. The frequency-limit adjustments, of course, can be made using the built-in frequency counter.

Before applying power, set all the trimmer and front-panel potentiometers to their approximate mechanical midrange. Connect the oscilloscope to the sinewave output and apply power. The oscilloscope should display a sinewave, although it may be distorted, and the frequency counter should display the frequency of the waveform. Confirm that the frequency changes as the COARSE FREQUENCY and FINE FREQUENCY controls are rotated. Set the frequency at approximately 1 kHz and adjust the DISTORTION trimmer potentiometer (R46) for a sinewave that looks normal on the oscilloscope. If you're a purist you'll need a distortion meter or spectrum analyzer for that adjustment, but for most of us, the eyeball method works well enough. Next, check the squarewave using the oscilloscope. It should look the way the name implies and have a peak-to-peak value of around five volts.

The next step is to adjust the L.F. LIMIT and H.F. LIMIT potentiometers. Rotate the COARSE FREQUENCY and FINE FREQUENCY controls to their lowest-frequency positions (fully counter-clockwise) and adjust the L.F. LIMIT potentiometer (R45) for a frequency of 10 Hz. Then, rotate the COARSE FREQUENCY control to its highest-frequency position (fully clockwise) and adjust the H.F. LIMIT potentiometer for a frequency of 50 kHz. Check the FINE FREQUENCY control by rotating it to its extremes while observing the frequency change. It should have a total range of around 500–700 Hz, regardless of where the COARSE FREQUENCY control is set. That completes the testing and calibration procedure.

If you experience some problems, here are some troubleshooting hints that may be helpful:

As experience has shown, most problems in home-built instruments are caused by poor solder connections, solder bridges between two adjacent foils, or components installed backwards. It would be wise then to first check for those troublemakers.

If you still can't track down the problem, the use of a multimeter is required. With it, check the three major DC power-supply points at various points on the PC board with respect to the ground foil. The output side of the 12-volt regulator (IC11) should of course measure +12 volts ± .5 volt, and the output of the 5-volt regulator (IC12) should of course measure 5 volts ± .25 volts. The negative voltage bus (the negative side of C11) should measure around −17volts.

It should be noted that the voltage regulators normally operate quite hot to the touch and the same holds true for the main four-digit counter IC. So, if the voltages are normal, don't let that be a source of concern.

If a problem exists in the frequency-counter section, some key points to check would be the 60-Hz, 10-Hz, and 1-Hz points on the time-base system and also the squarewave signal that constitutes the frequency to be counted. That latter point can be found at the input of the main four-digit counter IC9, at pin 12. **R-E**

PARTS LIST

All resistors ¼ watt, 5% unless otherwise specified

R1, R3, R17, R31, R37–R43—100 ohms
R2, R9, R18, R20, R24–R28—10,000 ohms
R4, R15—1 megohm
R5, R7—2700 ohms
R6, R13—4.7 megohms
R8, R21—33,000 ohms
R10—8200 ohms
R11, R12—330 ohms
R14—1200 ohms
R16—470,000 ohms
R19—560 ohms
R22, R23, R30, R32—100,000 ohms
R29—470 ohms
R33–R36—820 ohms
R44–R46—10,000 ohms, trimmer potentiometer, upright mount, thumbwheel
R47—10,000 ohms, potentiometer, panel mount, audio taper
R48, R49—10,000 ohms, potentiometer, panel mount, linear taper
R50—2200 ohms

Capacitors

C1—.01 µF, 100 volts, mylar or polyester
C2, C4, C9—10 µF, 25 volts, electrolytic
C3, C8—.1 µF, 50 volts, ceramic disc
C5, C6—220 pF, 50 volts, ceramic disc
C7—.01 µF, 50 volts, ceramic disc
C10, C11—1000 µF, 25 volts, electrolytic

Semiconductors

IC1—LM307 op-amp
IC2—XR2206 function generator (Exar)
IC3—LF351 op-amp
IC4, IC5, IC8—4518 dual decade counter
IC6—4013 D flip-flop
IC7—7492 divide-by-six counter
IC9—74C926 4-digit counter/driver
IC10—4584 hex Schmitt trigger
IC11—7812 voltage regulator
IC12—7805 voltage regulator
DSP1—NSB-5881 4-digit LED display
Q1—MPF-102 FET
Q2–Q9—2N3904 NPN or equivalent
D1, D2—1N4002
D3–D5—1N914
T1—117-volt primary, 12- or 12.6-volt secondary, .5 to 1 amp
S1—SPST, miniature toggle.
J1–J3—binding posts

Miscellaneous: PC board, cabinet, display bezel with red filter, knobs, line cord, 5/32 nuts and bolts, etc.

An etched and drilled printed-circuit board is available from: E²VSI, PO Box 72100, Roselle, IL 60172 for $21.00 (check or money order) postpaid. Shipping by UPS or best way 3-5 days after receipt of order.

BUILD THIS

Telephone Add-On

NO MORE WRONG NUMBERS!

Receive only the calls you want to receive with this inexpensive and easy-to-build telephone accessory.

GARY McCLELLAN

IT'S 3 O'CLOCK IN THE MORNING AND YOU are jarred out of a sound sleep by the telephone ringing. You get up to answer it, but by the time you pick up the phone the caller has hung up. Naturally, you can't go back to sleep and so you start the day in a bad mood.

Or perhaps you are enjoying a nice dinner with friends. The phone rings and you answer it. A salesperson who can't pronounce your name wants to sell you aluminum siding for your new house.

Do those annoying little scenarios sound familiar? All of us at one time or another have received unwanted telephone calls, often at inconvenient times. But there is an electronic solution to that problem and once you build it you won't have to tolerate unwanted calls.

The project we'll be describing has a variety of special features. First, it works with either pushbutton or rotary-dial-type phones. Installation is easy, too—it simply plugs into an AC outlet and a modular phone jack. All phones connected to that line are protected from unwanted calls. And finally, the project operates unattended. The only controls are the POWER and RESET switches. The POWER switch is included for those times when you want to receive all calls. The RESET switch is included to silence an internal ringer, which would otherwise sound for 10 seconds.

The project is easy to build and inexpensive, too. The parts cost about $60, although careful shopping can reduce that figure greatly. The construction is simplified in that all parts are contained on two small PC boards. A third PC board serves as a front panel, providing a professional appearance for the project. In all, 12 IC's are used, plus a small handful of discrete parts.

Aligning the project is simple, and requires just three easy-to-make adjustments. The only thing you need to make those adjustments is a friend with a pushbutton phone. A frequency counter would also be useful, but is not necessary.

And finally, a few words about the FCC. Special attention was paid to Part 15 requirements during the design of the project. Optoisolators were used to prevent noise or interference from being coupled to the phone line, and the use analog circuitry minimizes the chances of interference being generated. In the places where digital circuitry is used, the maximum frequency is limited to under 1500 Hz. All that helps assure the user of interference-free operation.

One last point. Due to the fact that the project must be connected directly to the phone line, we recommend that construction should be undertaken only by experienced individuals. In other words, do not make this your first construction project. Also, do not make parts substitutions unless you are certain of what you are doing.

Theory of operation

Basically, the circuit works on the principal that if the phone doesn't ring you don't answer it. In other words, when an undesirable caller dials your number, the phone doesn't ring. But if a friend, relative, or someone else who you don't mind hearing from calls, the device sounds a beeping tone, telling you to answer the phone.

So how does the circuit know the difference between friend or other? It is really quite simple. As soon as a telephone connection is made, the circuit captures the line preventing your phone from ringing. It then waits 10 seconds for the party at the other end to dial (or press) an extra "code" number. If the device receives the code number it beeps for 10 seconds alerting you to pick up your phone. Otherwise, if no code number, or if the wrong code number is received, the device disconnects the phone line, terminating the call. If you give the code number only to those who you want to be able to reach you at any time, then they will be the only one's you will hear from when the device is active.

Figure 1 shows a block diagram of the project. Note that two PC boards are used in the device; a main board and a decoder board. We will discuss both boards briefly and then go into detail on the main board. The decoder board will be discussed in the next part of this article.

The main board is the workhorse of the project. It contains the circuitry that detects the ring signal and listens to the line. Plus, there is the beeper circuitry, power-on-reset circuitry, and a power supply.

In operation, the ringing signal is detected by IC1. The output from the optoisolator drives a ring-detector circuit, IC2. When three things happen, the ring detector produces an output. First, the ring-signal amplitude must exceed 0.5 volt. Second, the ring frequency must be within 15 and 50 Hz. And third, the signal must last for at least 0.5 second. The purpose of those conditions is to prevent the project from being falsely triggered by telephone line checking equipment, line noise, or outgoing calls being made. If those conditions aren't met, the ring detector IC resets itself and no output is generated.

The ring detector's output triggers a 10-second one-shot, IC3-a. That device closes relay RY1 for 10 seconds. When the relay closes, optoisolator IC5 is connected across the phone line. That completes a DC path, which in effect "answers the phone." The output from IC5 contains any audio or dial pulse information and is sent to the decoder board.

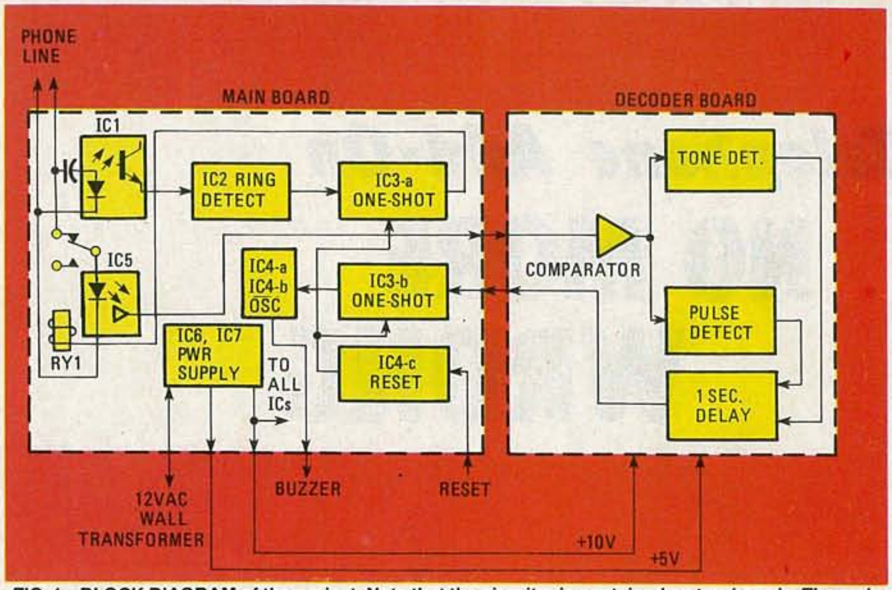


FIG. 1—BLOCK DIAGRAM of the project. Note that the circuitry is contained on two boards. The main board is the topic of this article; the decoder board will be discussed in full in the next installment.

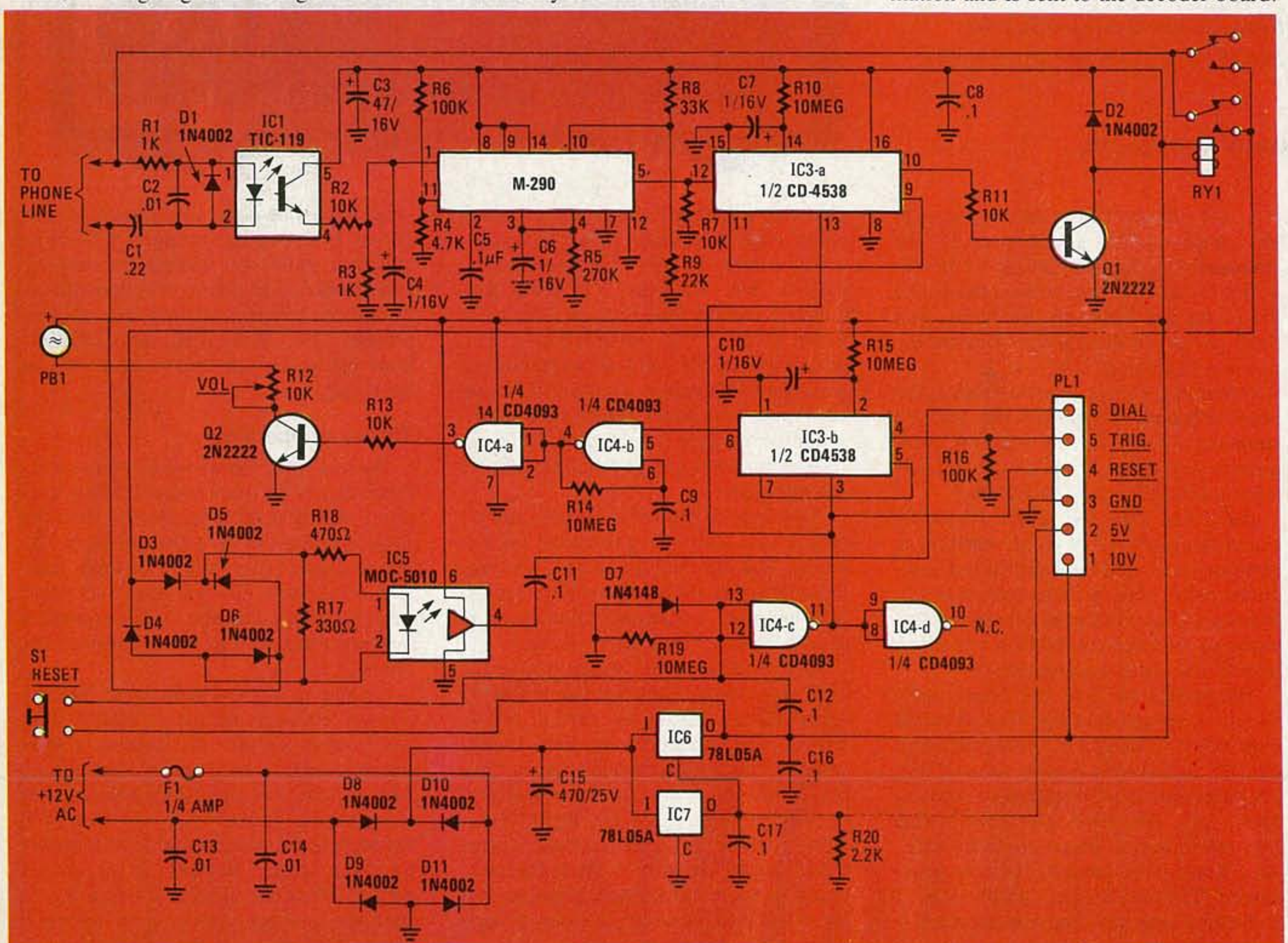


FIG. 2—SCHEMATIC DIAGRAM of the main board. The use of optoisolators prevent any chance of noise or interference being coupled to the phone line.

After IC3-a times out, the relay opens and the project is ready for another caller.

If the decoder board detects a valid code, one-shot IC3-b is triggered. That simply enables a 2-Hz oscillator, IC4-a and IC4-b, which causes a piezoelectric beeper, PB1, to sound. The result is a steady beeping tone that lasts for 10 seconds.

The remainder of the circuitry consists of a power-on reset circuit and a power supply. The purpose of the power-on reset circuit is to reset both one-shots (IC3-a and IC3-b). Otherwise, upon power-on, the project would answer the phone and beep for 10 seconds. Schmitt trigger IC4-c handles that function. A pushbutton RESET switch, S1, is included to silence the beeper if it is still sounding when you pick up the phone. The power supply provides 10 volts from IC6 for all circuitry. A 5-volt output (IC7) is also provided exclusively for the tone decoders on the decoder board. Both of those IC's are standard three-terminal voltage regulators.

The decoder board simply detects the incoming code signal. Two decoder circuits are used to detect the tones from pushbutton phones or dial pulses from rotary dial phones. A one-second delay circuit is connected to the decoder outputs to prevent speech or people playing with the phone from false triggering the project.

Let's turn next to Figure 2, the schematic diagram, for a more detailed discussion of the main board circuitry.

The incoming phone line is AC coupled to optoisolator IC1. As a result, IC1 is triggered only on the high-voltage ringing pulses, which are typically 90 volts AC at 20 Hz. The output from IC1 is attenuated, filtered by C4, and drives IC2, the ring-detector circuit.

The ring detector replaces a handful of IC's and contains three basic sections. The first section is a signal processor that amplifies and shapes the incoming signals. Also provided is a Schmitt trigger circuit that prevents dial-phone contact bounce from false triggering the circuit. Resistors R4 and R6 set the input hysteresis to 0.45 volt. The second section determines the period of the incoming signals and detects signals in the 15- to 50-Hz range. Resistors R8 and R9 center the frequency range. And finally, the third section is a one-second timer. Capacitor C6 and R5 set the time period. The output of the ring detector is at pin 5 and it is fed to one-shot IC3-a.

One-shot IC3-a determines how long a caller has to dial in the code number. Capacitor C7 and resistor R10 set the time period. With the values shown, that time interval will be 10-seconds. The output from IC3-a drives transistor Q1, which controls relay RY1.

When RY1 closes, it connects a bridge rectifier made up of D3–D6 across the phone line. That circuitry completes a DC path that "answers the phone." Resistors R17 and R18 reduce the line current to values acceptable to optoisolator IC5. Thus, that circuitry draws 20 mA from the line, simulating a phone that has been answered.

Optoisolator IC5 has been designed by Motorola especially for this type of application and it contains a built-in amplifier. The output from IC5 is AC coupled to SO1, which is the interconnection to the decoder board.

Moving on, the beeper is activated by a positive-going pulse from pin 5 of PL1. That pulse triggers another 10-second one-shot, IC3-b. Capacitor C10 and resistor R15 set the one-shot's time period. The output from IC3-b controls a 2-Hz oscillator, IC4-b. The output from IC4-b is inverted by IC4-a and drives transistor Q2. That transistor simply switches power to a piezoelectric buzzer, PB1. Potentiometer R12 serves as a volume control.

The power-on reset circuitry consists of IC4-c. When the power is turned on, capacitor C12 charges through resistor R19. That action resets the one-shots. After about a second, C12 is charged and reset is removed. Note that a reset may be manually performed using switch S1. Diode D7 is included to prevent C12 from discharging through the IC when the power is removed. Also note that a reset is supplied to SO1. However, with the decoder board used in this project that reset signal is unused.

The remaining circuitry on the main board is the power supply. AC voltage from a plug-in transformer passes through a fuse, F1, and is rectified by D8–D11. The DC output from that circuit is filtered by C15 and regulated by two three-terminal regulators, IC6 and IC7. The 10-volt output of IC6 powers all analog and digital circuitry except for the tone decoders; the 5-volt output of IC7 takes care of them.

That completes our discussion of the theory. Now, let's move on and assemble the main board.

Assembly

The first step is, of course, to obtain the parts; here are a few suggestions regarding that. The parts used are common and may be obtained from many of the advertisers in this magazine. Regarding the capacitors—we specify both the value and the type of each unit. One problem area might be the tantalum types. If desired, low leakage electrolytics may be substituted to save money. However, do not use standard electrolytics—the high leakage and wide capacitance tolerance of those will cause problems.

About the fuse clips for F1: Industry standard PC type fuse clips are specified. Most larger electronic stores carry them or substitutes. If you can't get them, simply use a pigtail fuse for F1.

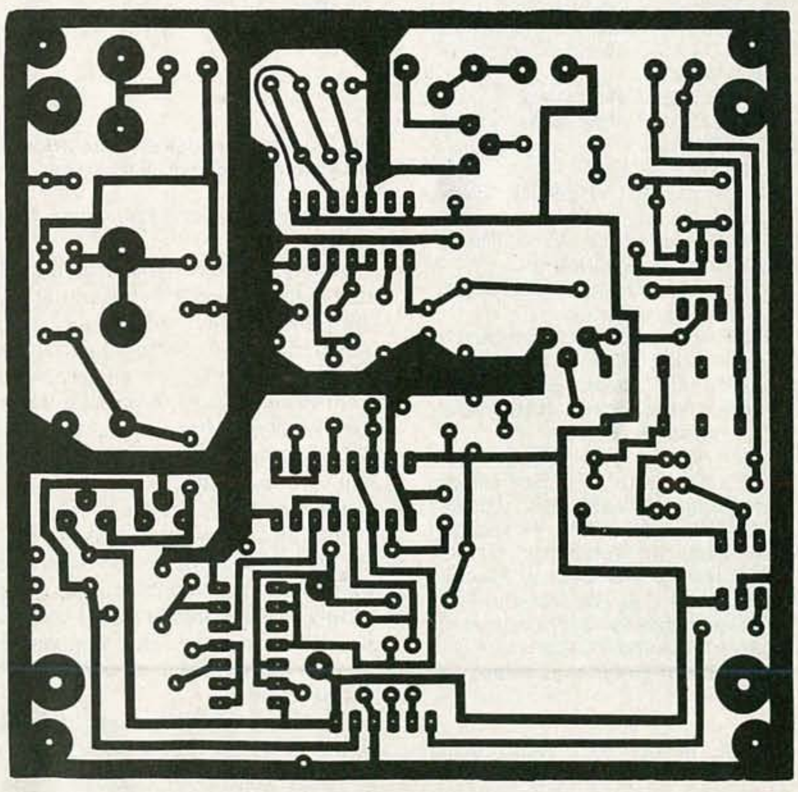


FIG. 3—PRINTED-CIRCUIT BOARDS should be used for this project. The foil pattern for the main PC-board is shown here full size.

PARTS LIST—MAIN BOARD

All resistors ¼-watt, 5% unless otherwise noted
R1, R3—1000 ohms
R2, R7, R11, R13—10,000 ohms
R4—4700 ohms
R5—270,000 ohms
R6, R16—100,000 ohms
R8—33,000 ohms
R9—22,000 ohms
R10, R14, R15, R19—10 megohms
R12—10,000 ohms, potentiometer, linear taper, PC-board mount (Radio Shack 271-218)
R17—330 ohms
R18—470 ohms
R20—2200 ohms
Capacitors
C1–0.22 μF, 250 volts, metal film
C2, C13, C14—0.01 μF, 50 volts, ceramic disc
C3—47 μF, 16 volts, radial leads, electrolytic
C4, C6, C7, C10—1 μF, 16 volts, radial leads, tantalum
C5, C9, C11, C12—0.1 μF, 50 volts, polyester
C8, C16, C17—0.1 μF, 16 volts, ceramic disc
C15—470 μF, 25 volts, radial leads, electrolytic
Semiconductors
IC1—TIL-119 optoisolator (Texas Instruments)
IC2—M290 ring-detector subsystem (Mendakota—see below)
IC3—CD4538 CMOS one-shot (RCA)
IC4—CD4093BE CMOS Schmitt trigger NAND gates
IC5—MOC-5010 optoisolator (Motorola)
IC6, IC7—78L05ACP 5-volt, 100-mA regulator (Motorola)
Q1, Q2—2N2222 NPN transistor
D1–D6, D8–D11—1N4002 diodes
D7—1N4148 diode
F1—0.25 amp, 3AG fuse
PL1—6 pin male PC-header (GC Electronics 41-046 or similar)
RY1—DPDT relay, 12-volt DC coil (Radio Shack 273-213 or equivalent)
PB1—Piezoelectric buzzer (Radio Shack 273-060 or equivalent)
S1—SPST momentary pushbutton switch (Radio Shack 275-618 or equivalent)
Miscellaneous: PC board, solder, wire, 2 PC-mount fuse clips (Littlefuse 122087), IC sockets, etc.
The following is available from Mendakota Products, Ltd., PO Box 20HC, 1920 W. Commonwealth Ave., Fullerton, CA 92633: A set of three PC boards and the M290 ring detector IC (order part No. NWR). The cost is $26.00 postpaid in the U.S. and Canada. The M290 is available for $12. California residents please add 6% sales tax. Sorry, no C.O.D's or credit-card orders.

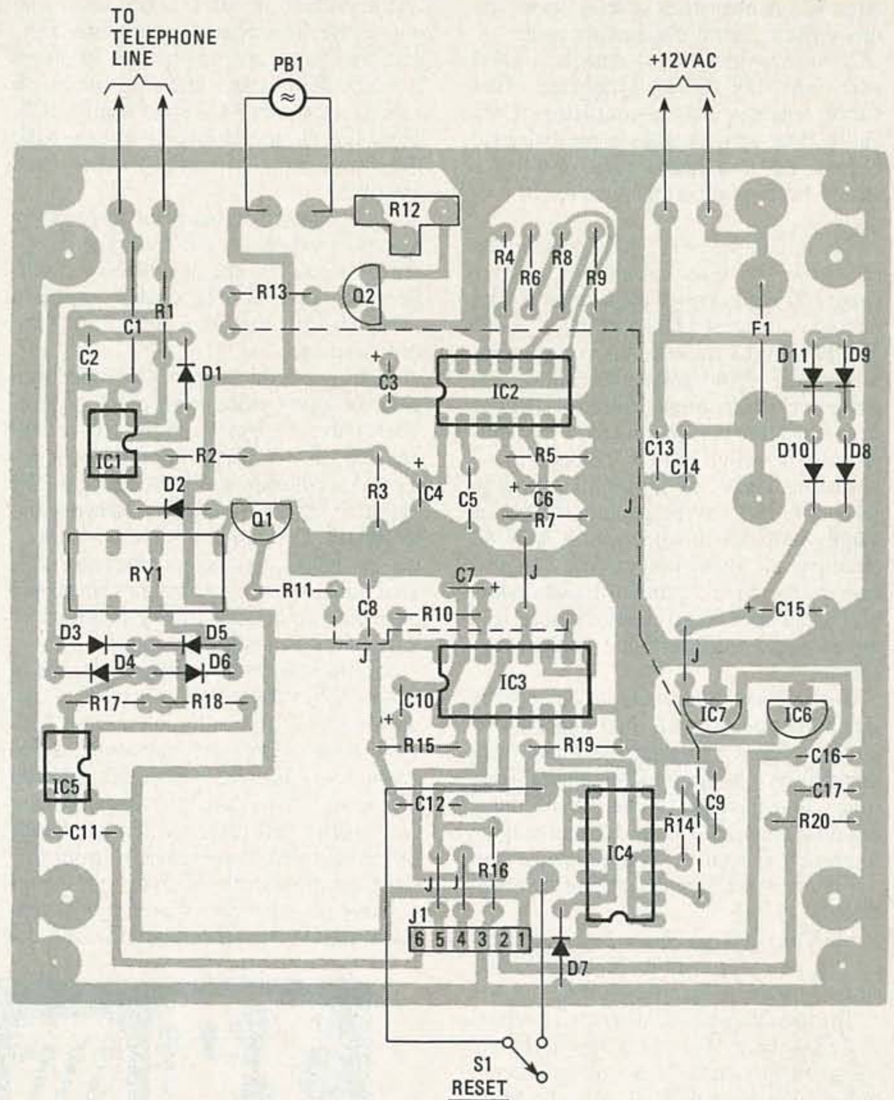


FIG. 4—PARTS-PLACEMENT DIAGRAM for the main board. Note that two insulated jumpers are installed on the foil side of the board.

About the header, PL1: Many better stocked electronics stores sell GC Electronics products, so try your local stores. Otherwise contact GC Electronics (400 South Wyman St., Rockford, IL 61101) directly for your local dealer. If all else fails, any miniature 6-pin connector may be substituted.

About the IC's: Note that the M290 ring-detector circuit is custom made for this project and is available only from the supplier given in the Parts List. The other IC's are standard types, and are available from many sources. Note that while we used 78L05A voltage regulators, standard 78L05 units may be used without problem. We used the 78L05A's simply because they were available.

And finally, you must make or buy the circuit boards. Due to the high gain of some parts in this project, plus the possibility of noise problems, PC-board construction is a must. That way you don't have to worry about ground loops and wiring errors.

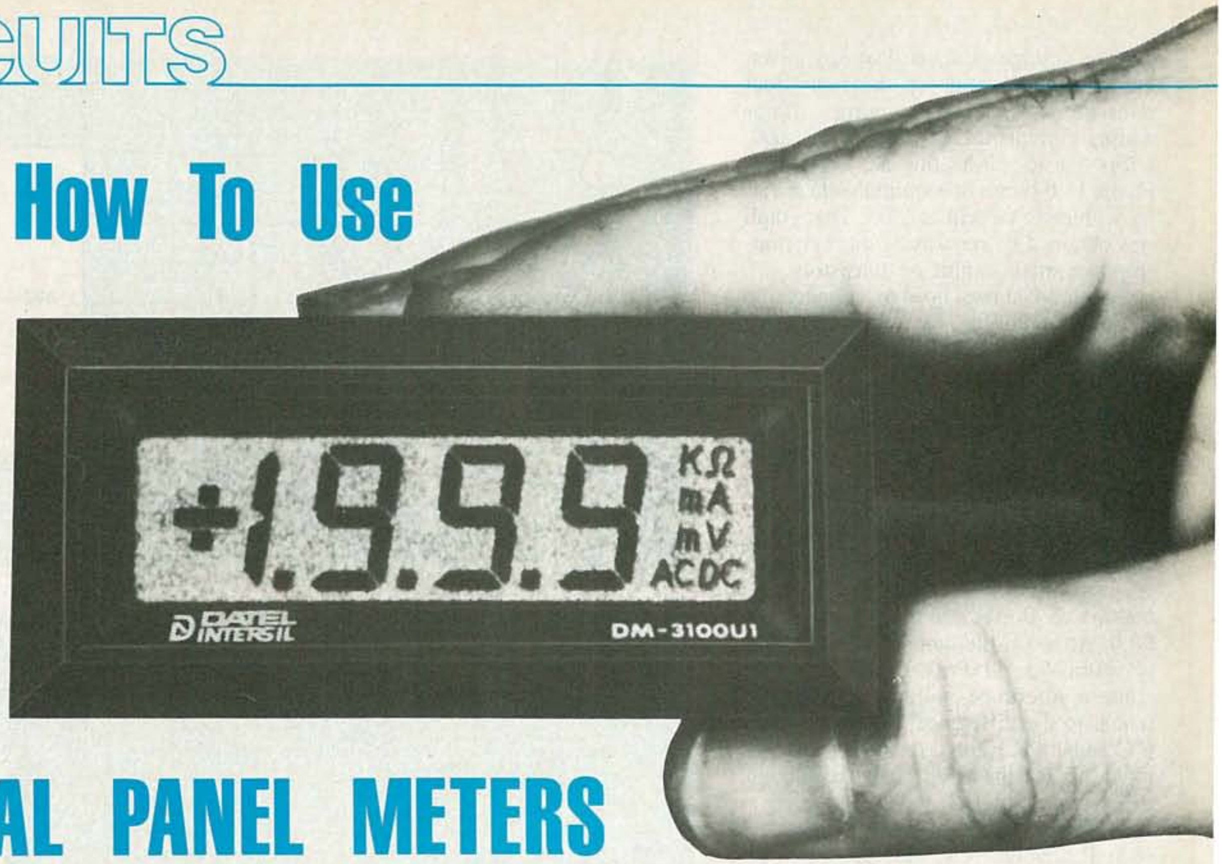
The foil pattern for the main board is shown in Fig. 3. The parts placement diagram for that board is shown in Fig. 4. Begin assembly by installing the IC sockets and PL1. Be sure to position them with the pin 1 notch as shown before soldering. Install a 14-pin socket at IC2, a 16-pin socket at IC3, and another 14-pin socket at IC4. Next, install the header at PL1. Note that it is installed so that the plastic tab is adjacent to resistor R16.

Install the fuse clips and fuse next. Place a fuse clip into the holes at F1. Push down firmly and solder. Likewise, install the other fuse clip in the same way. Snap a 0.25 amp, 3AG fuse in place when the clips are cool. Then install IC1 and IC5. Note that sockets are not used on the optoisolators. Install a TIL-119 at IC1, positioning it as shown. Likewise, install a MOC-5010 at IC5, positioning it as shown.

After that, install relay RY1. Note that the relay can be inserted into the board only one way. Install the relay and push against the board firmly and then solder.

We're almost done with the main board now, but unfortunately, we've run out of room for this month. When we continue this article, the first thing we'll attend to is finishing up that main board. Then we'll turn our attention to the smaller decoder board. R-E

How To Use



DIGITAL PANEL METERS

This month we look at how digital panel-meters can be used to measure temperature and frequency.

RAY MARSTON

Part 2

IN LAST MONTH'S ARticle we explained the basic characteristics and use of 3½-digit LCD digital panel meter modules, with particular emphasis on the Datel-Intersil (11 Cabot Boulevard, Mansfield MA 02048) DM-3100U1. We showed how these units can be used to measure voltage, current, and resistance. In this month's conclusion we'll see how those units can be used to measure other parameters such as temperature and frequency. Let's start off by looking at temperature-measuring techniques.

Digital thermometers

A digital panel-meter module can be made to act as a wide-range (−50°C to +150°C) digital thermometer by feeding the output of a linear-voltage-generating temperature sensor to its inputs. One suitable type of sensor is the ordinary bipolar silicon transistor; dedicated temperature sensor IC's are also available. In either case, the resulting digital thermometer is sensitive to changes of as little as 0.1°C. Its linear accuracy varies from 0.5°C to 1.5°C, depending on the sensor and circuitry used.

Because of the low mass of a transistor sensor, the device has a thermal response time some 10 to 100 times faster than that of a normal mercury thermometer. When used to measure a sharp change in the temperature of free air, a transistor-sensor circuit typically settles to within 0.1°C of the new temperature within one minute; a mercury thermometer takes some 20 minutes to attain the same accuracy.

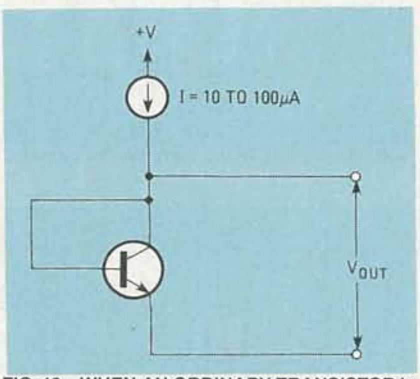


FIG. 12—WHEN AN ORDINARY TRANSISTOR is connected as shown and driven from a constant current source, the value of V_{OUT} will vary in direct proportion with the temperature.

When an ordinary NPN silicon transistor is connected as shown in Fig. 12 and is driven from a constant-current source, it generates an output voltage that varies in direct proportion to the temperature of the transistor. That voltage has a negative temperature coefficient of about −2-mV-per-°C, and typically varies from about 600 mV at 0°C to 400 mV at 100°C, as shown in the idealized graph of Fig. 13-a.

In practice, the "straight line" graph shown in Fig. 13-a is linear within 1 mV or so over the 0°C-to-100°C range, but the

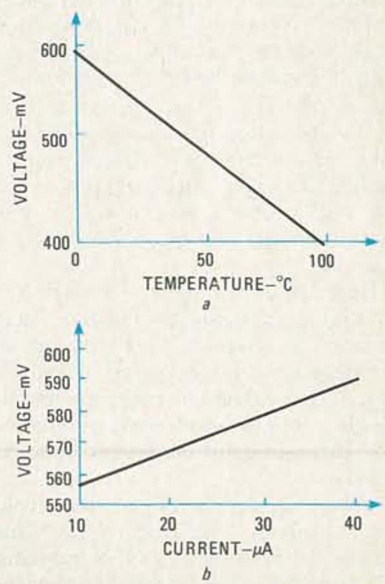


FIG. 13—HOW VOLTAGE VARIES with temperature is shown in *a*. The relationship between the output voltage and the drive current at 25°C is shown in *b*.

precise voltage generated at any given temperature depends on the individual transistor and its operating current. If operating currents are kept below 100 μA, errors due to self-heating are negligible. Figure 13-b shows how output voltage varies with drive current at 25°C. That graph was obtained by measuring that relationship in a small sample of transistors.

Figure 14 shows how to connect the sensor circuit of Fig. 12 to a digital panel-meter so that the meter gives a direct readout of temperature in °C. The output of the sensor is fed directly to the units ANALOG LOW input, pin A2, and a 600-mV offset voltage (equal to the sensor voltage at 0°C) is fed to the ANALOG HIGH input, pin B5. The module actually responds to the differential value of the inputs (that is, the voltage at pin B5 minus the voltage at pin A2), so that it sees an input of 600 mV − 600 mV = 0 mV, and gives a reading of 00.0. At 100°C the module sees an input of 600 mV − 400 mV = 200 mV, and since a reference voltage of 200 mV (equal to the difference voltage between 0°C and 100°C) is fed to the REFERENCE input, pin B1, the meter gives a reading of 100.0.

Figures 15 and 16 show two practical digital thermometers. The circuit shown in Fig. 15 is virtually the "standard" one found in many magazine articles and application sheets, and has a typical linear accuracy of 1.5°C over the 0°C to 100°C temperature range.

The circuit as shown requires a stable supply of approximately 2.8 volts to operate properly. A regulated 6.9 volts is available from the panel meter's internal LM329 via pin B2. That voltage can be divided by resistors R6 and R7 to provide an appropriate supply. When that is done, R1 drives the sensor with a current of about 22 μA at 0°C, rising to about 24 μA at 100°C. That current variation, combined with the basic linear error of the transistor, causes the 1.5°C linear error of the circuit. The CAL-0° voltage feeding A2 can be varied from zero to 875 mV using R4, and the CAL-100°C voltage feeding B1 can be varied from zero to 255 mV via R5. Those two controls are used to calibrate the meter; we will describe how shortly.

Figure 16 shows a precision version of the digital thermometer; it has a linear accuracy of about 0.5°C. In that circuit the transistor sensor is energized at about 20 μA via constant-current generator Q1, which is temperature compensated by Q2. That section of the circuit works as follows.

Voltage divider R3-R4 generates a voltage V_T (about 1 volt) across R3. That voltage is "followed" by NPN transistor Q2, causing $V_T + V_{BE2}$ (the base-emitter voltage of Q2) to appear on the base of Q1; let's call that voltage V_B. The voltage V_E appearing on the emitter of PNP transistor

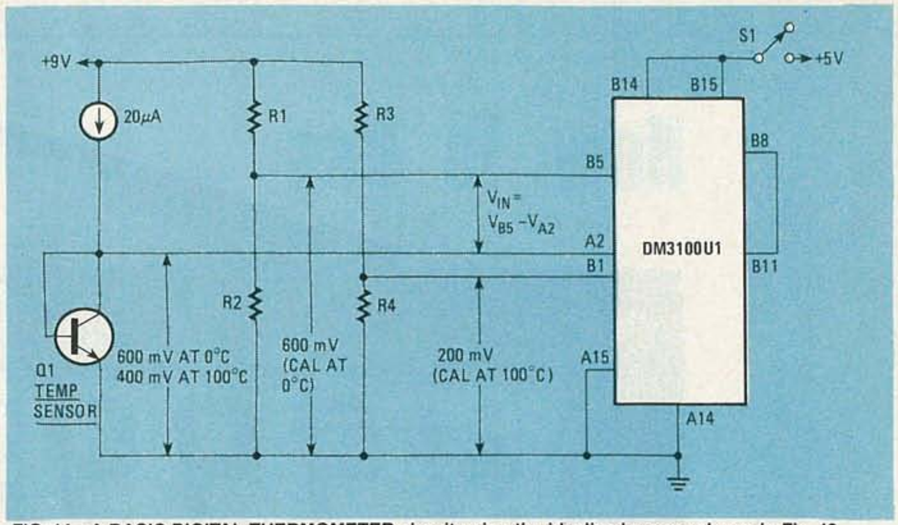


FIG. 14—A BASIC DIGITAL THERMOMETER circuit using the idealized sensor shown in Fig. 12.

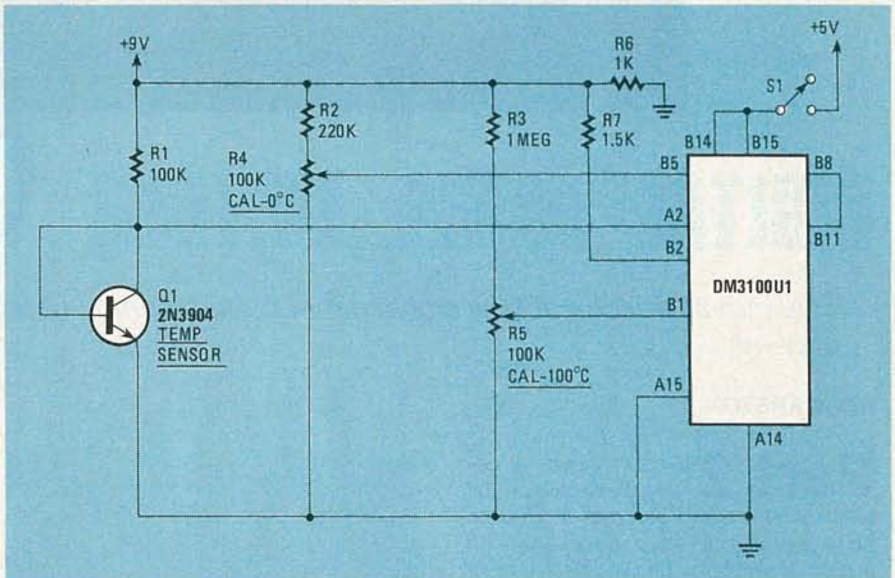


FIG. 15—A PRACTICAL thermometer circuit. The linear accuracy of this design is about 1.5°C.

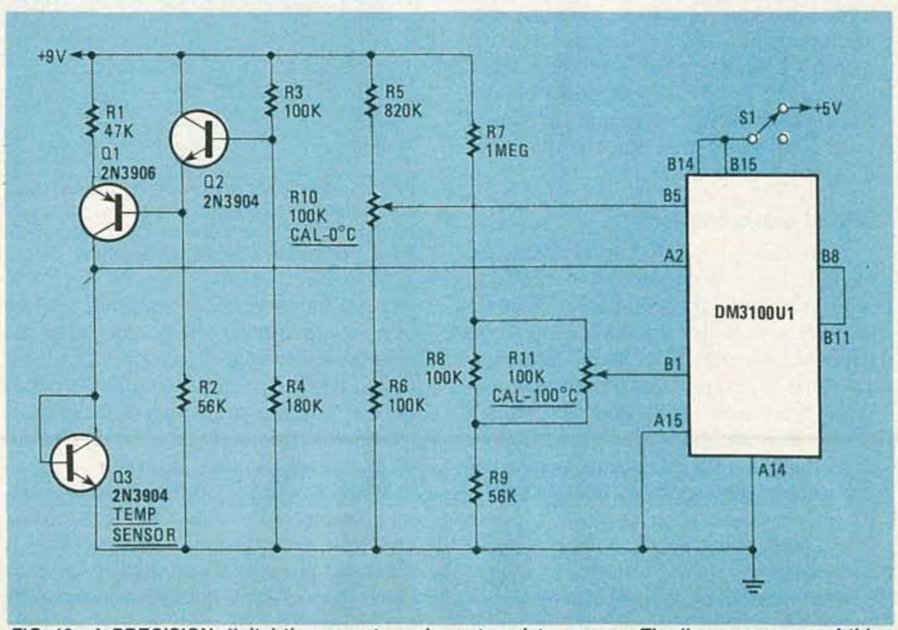


FIG. 16—A PRECISION digital thermometer using a transistor sensor. The linear accuracy of this circuit is 0.5°C.

Q1 is equal to $V_B - V_{BE1}$ (the base-emitter voltage of Q1), and it is that voltage and the value of R1 that determine the magnitude of the constant-current output of Q1. Note, however, that V_E is in fact equal to $V_T + V_{BE2} - V_{BE1}$, and that, since Q1 and Q2 operate at virtually identical temperatures and at similar current levels, the V_{BE1} and V_{BE2} values cancel out at all temperatures and V_E thus equals V_T. Thus, the output current of Q1 is independent of the ambient temperature.

Another point to note about the precision circuit shown in Fig. 16 is that the output of the CAL–0°C control, R10, is adjustable over the range of 460 to 710 mV, and that the CAL–100°C control, R11, is adjustable over the range of 140 to 260 mV. Those controls allow very precise adjustment of each calibration point.

Calibration procedure

The procedure for calibrating the circuits shown in Figs. 15 and 16 is as follows. First, solder the base and collector leads of the sensor transistor together, solder the sensor to a pair of flexible leads, and connect the leads to the meter circuit. Coat all visible transistor leads and solder joints with insulating varnish; GC Electronics' (200 Wyman St., Rockford, IL 61101) Red GLPT is excellent for that. Next, set R10 and R11 at mid value, mix a quantity of crushed ice and cold water in a tumbler (to act as a "0°C" standard), and immerse the sensor in the tumbler. Now adjust R10 to give a reading of 00.0 on the meter. Next, remove the sensor from the tumbler and immerse it in gently boiling water (to act as a "100°C" standard) and adjust R11 to give a meter reading of 100.0. When that's done the basic calibration is complete.

Frequency Measurement

A digital panel-meter module can be made to read frequency by connecting the unknown frequency to the module's input via a frequency-to-voltage converter. A suitable converter can easily be made by using a 7555 monostable multivibrator; Fig. 17 shows the principles behind such a converter. The input signal is first fed to an input conditioner and trigger-pulse generator, which triggers a fixed-period 7555 monostable multivibrator on the arrival of each new input cycle. The output pulses of the 7555 are converted to mean DC values by integrator R2-C2, scaled by R3-R4, and then fed to the input of the digital panel-meter.

The mean DC value of the 7555 output pulses equals V_P (the peak amplitude of the pulses) multiplied by W/P, where W and P are the widths and periods of the pulses respectively. The values of V_P and W are, however, fixed. Only the pulse period is variable, and that period is inversely proportional to the input frequency, f, so the mean output voltage is equal to $V_P \times W \times f$ and is thus directly proportional to f. Therefore, when a digital panel-meter module is suitably scaled via resistors R3-R4 it gives a direct reading of the input frequency.

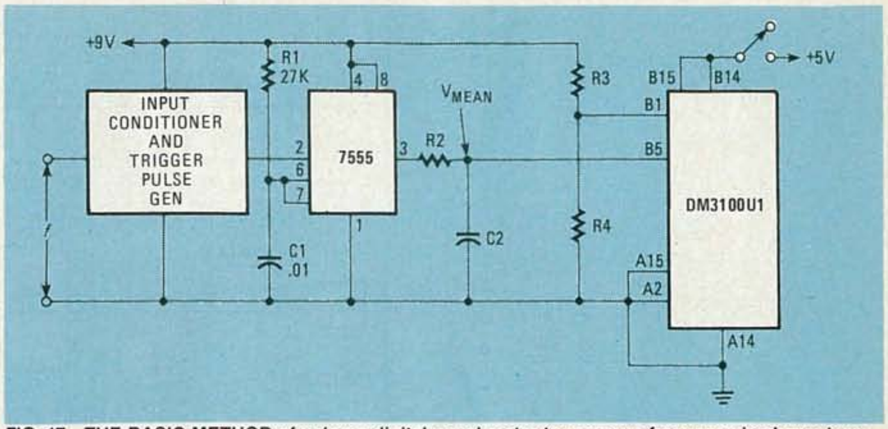


FIG. 17—THE BASIC METHOD of using a digital panel meter to measure frequency is shown here.

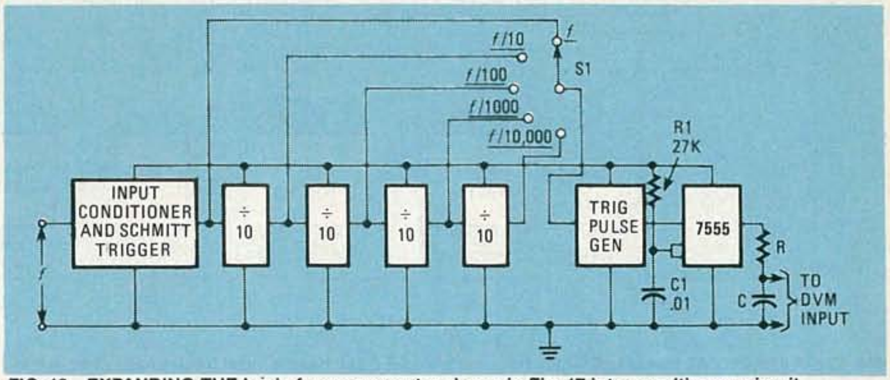


FIG. 18—EXPANDING THE basic frequency meter shown in Fig. 17 into a multirange circuit.

In practice, the lowest convenient full-scale frequency range of a digital-panel-meter-based 3½-digit frequency meter is 1.999 kHz. The 7555 pulse has a period of 500 μs at full scale. For maximum accuracy, the pulse width must be as large as possible but must not be greater than ⅔ P. A pulse width value of about 300 μs is thus called for, and that can be obtained from the 7555 by making R1 equal to 27 kilohms and C1 equal to .01 μF.

Figure 18 shows how the basic circuit shown in Fig. 17 can be modified to act as a multi-range frequency meter. In that case the input signal is fed to an input conditioner and Schmitt trigger, and the Schmitt output is used to ripple-clock four decade dividers. The 7555 300-μs monostable multivibrator is provided with a trigger generator that can be fed from the output of the Schmitt or from any of the dividers. Thus, when the 7555 is triggered directly from the Schmitt, the meter reads 1.999 kHz full scale, and when fed from the output of the last divider stage, the meter reads 19.99 MHz full scale.

Practical frequency meters

Figure 19 shows a practical digital-panel-meter-based digital frequency meter circuit that reads up to 19.99 MHz full-scale in five decade ranges. When calibrated, the meter has a reading accuracy of ±1 digit. The circuit accepts input signals in the range 200 mV to 5-volts RMS, and operates as follows.

Input signals are fed, via C1-R1, directly to the input of IC1-a, ¼ of a very fast 74HC132 CMOS Schmitt trigger, which is biased at half the 4.5-volt supply via R2-R3. The Schmitt output is used to ripple-clock four decade-divider stages. Ordinary CMOS dividers typically operate at maximum speeds of only 800 kHz or so when powered from 4.5-volt supplies, so, to give the required fast operating speeds, the very latest "HC" types of silicon-gate CMOS counters are used for the first two counters (IC2 and IC3).

The output of IC1-a and the four divider stages are fed to range-selector switch, S1-a, and from there to a 4-μs trigger-pulse generator, made up of C4, R4, IC1-b, and IC1-c, which triggers the 7555 monostable multivibrator via Q1. The output of the 7555 is fed to the ANALOG HIGH input of the unit, pin B5, via R8-R9, and a calibration "reference" voltage is fed to REFERENCE HIGH input, pin B1, via R12. The circuit is calibrated by feeding in a signal of known frequency, switching to the appropriate range, and trimming R12 for the appropriate reading.

Once R12 has been initially calibrated, that calibration is influenced only by variations in the width of the pulses output by the 7555. Since such variations can be

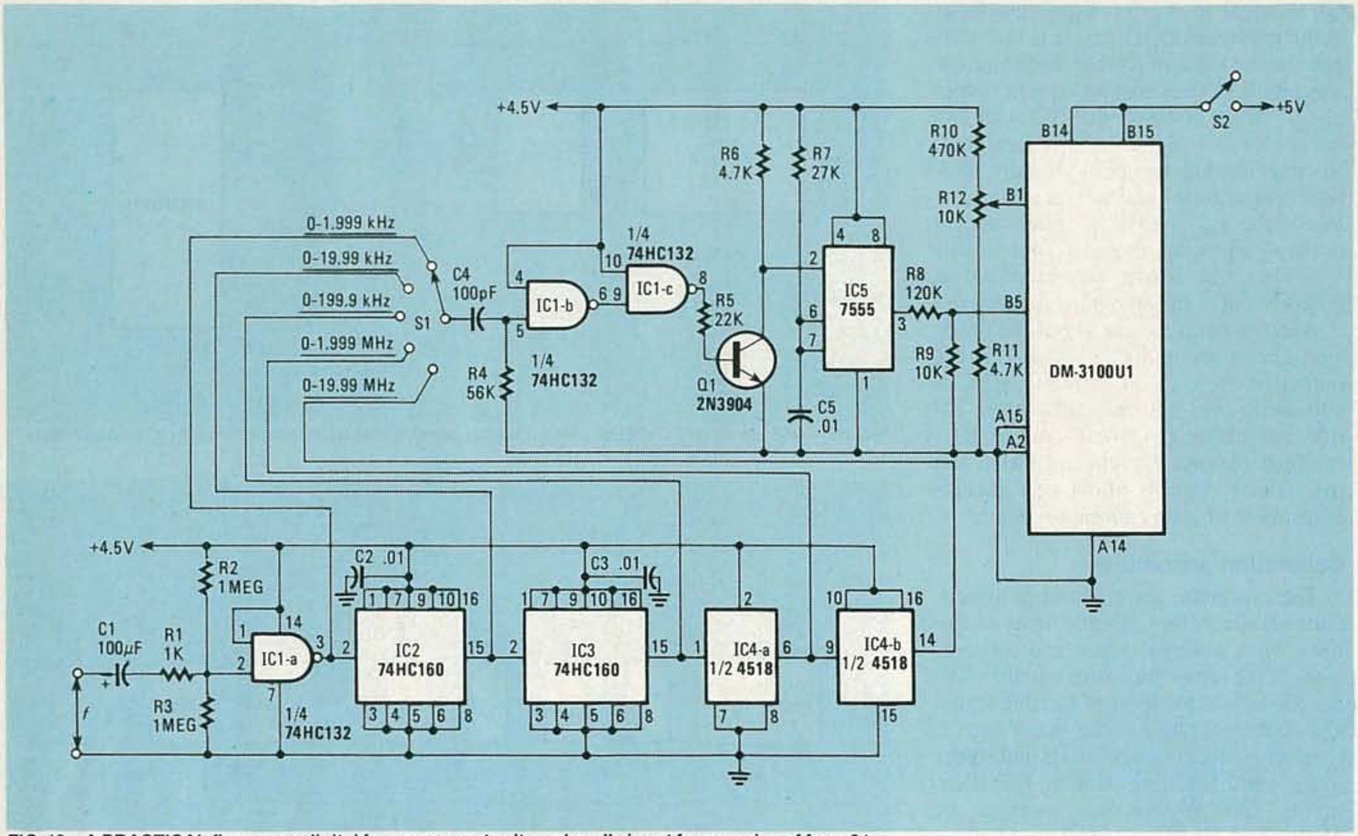


FIG. 19—A PRACTICAL five-range digital frequency-meter. It can handle input frequencies of from 0 to 19.99 MHz.

TABLE 1—SUPPLIERS

In addition to the manufacturer mentioned in the article, digital panel meters are available from a wide variety of sources. Some of those sources are listed below.

Ametek
2 Station Square
Paoli, PA 19301

Analog Devices
PO Box 280
Norwood, MA 02062

Analogic Corporation
Audubon Rd.
Wakefield, MA 01880

API Instruments
1601 Trapelo Rd.
Waltham, MA 02254

Ballantine Labs
90 Fanny Rd.
Boonton, NJ 07005

Data Precision Corporation
Electronics Ave.
Danvers, MA 01923

Fluke Manufacturing Company
Box C9090
Everett, WA 98206

Non-Linear Systems
533 Stevens Ave.
Solana Beach, CA 92075

Sigma Instruments
170 Pearl St.
Braintree, MA 02184

Simpson Electric Company
853 Dundee Ave.
Elgin, IL 60120

Weston Instruments
614 Frelinghuysen Ave.
Newark, NJ 07114

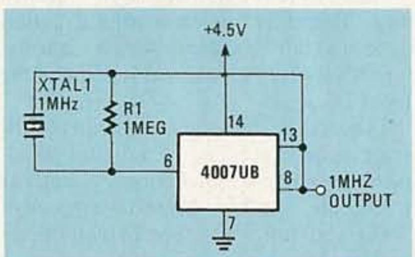


FIG. 20—THIS 1-MHz crystal calibrator can be easily added to the circuit shown in Fig. 17.

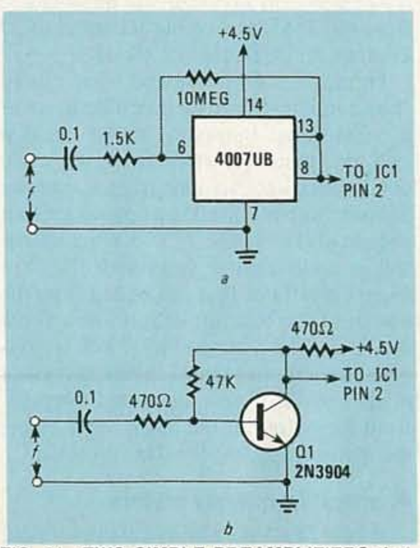


FIG. 21—TWO SIMPLE PREAMPLIFIERS that can be used with the digital frequency-meter are shown here.

caused if the values of R7 and C5 change due to changes in temperature, care should be taken so that the units chosen are thermally stable.

The circuit shown in Fig. 19 can be modified in a variety of ways to satisfy individual requirements. Figure 20 shows a 1-MHz crystal calibrator designed around one section of a 4007UB CMOS IC. That circuit can easily be added to the frequency meter and consumes a mere 300 μA when active. Figure 21 shows two simple pre-amplifiers that can be used to improve the basic sensitivity of the meter. The circuit shown in Fig 21-a, which uses one section of a 4007UB, has an input impedance of about 1 megohm and improves the sensitivity of the frequency meter by about 20 dB (to 20-mV RMS) at audio frequencies, but is useful to only a few hundred kHz. The simple design shown in Fig. 21-b also gives a gain of about 20 dB at low frequencies, but has a low input impedance (about 2.2 kilohms) and is useful to several MHz.

We've only touched upon a few possible applications for a digital panel-meter. There are, of course, many more as those devices can be used to indicate the value of any parameter that can be converted into a predictable (linear or log) voltage, current, or resistance. Linear transducers are available for measuring values of pH, light intensity, radiation, and many other factors. Cyclic parameters such as RPM and heart rate can be measured by adapting the frequency-meter circuit. R-E

How to Design Power Supplies

MANNIE HOROWITZ

All about unregulated and regulated power supplies, IC regulators, and overvoltage-protection circuits.

IN THIS, THE FINAL INSTALLMENT IN OUR series, we will turn our attention to power supplies for analog circuits. All circuits require some source of power to operate and the most convenient source of such power is an AC wall outlet. Unfortunately, many electronic circuits cannot make use of AC directly. Instead, some way to convert the AC to DC is required.

Let's look once again at the junction diode. You will recall that in our previous discussions of that device we saw that it only conducts when its anode is positive with respect to its cathode. That property is important when we are dealing with AC. If the diode were connected in a series circuit along with an AC supply and a load, its presence would mean that current could only flow through the load during the half of the AC cycle when the anode was positive with respect to the cathode. During the other half cycle the diode would not conduct and no current could flow.

Such an arrangement is referred to as a half-wave rectifier because only half the waveform (i.e. alternate half-cycles) is allowed to pass freely. The other half of the waveform is cut off.

The presence of those half-cycles of current causes pulsating DC to be generated across the load. The amount of voltage variation in that pulsating DC can be reduced by wiring a "filter" capacitor across the load. The amount of ripple in the output is then determined by the values of the capacitor and the load.

Full-wave rectifiers

When dealing with electronic circuits such as amplifiers, the power source should be as stable (i.e. free of ripple) as possible. The ideal power source then is a battery, as all DC voltages that are derived from an AC supply have some ripple. Using a battery is not always possible or practical, but fortunately most circuits can tolerate the presence of ripple if it is sufficiently attenutated.

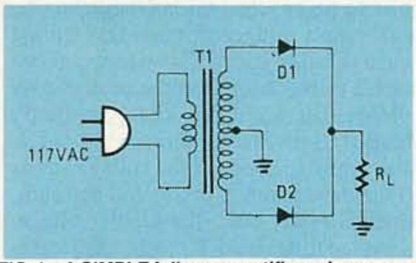


FIG. 1—A SIMPLE full-wave rectifier using a center-taped transformer.

One way to minimize ripple is to use a full-wave rectifier. Such a circuit is shown in Fig. 1-a. Note that the circuit consists of a center tapped transformer, with the tap grounded, and two diodes. Let's see how this circuit works. We'll start by looking at what happens during the positive half-cycle. During that half-cycle the polarity of the applied voltage is such that the upper terminal of the transformer's secondary is positive with respect to the center tap and the lower terminal. Also, during that half-cycle the polarity across D1 is such that the anode of the diode is positive with respect to its cathode and the device conducts. Thus, current flows from the upper transformer terminal, through D1 and R_L, and back to the center tap through the ground. Note that the voltage during this half-cycle varies in phase from 0° to 180° and that the current varies from zero, to some peak value, and then back to zero. Because of that varying current, the voltage developed across R_L varies identically with the input waveform. Finally, during the positive half-cycle the cathode of D2 is more positive than its anode, so the diode does not conduct and no current flows through it.

The polarity of the voltage across the transformer is reversed during the negative half-cycle. Now, the bottom terminal of the transformer is positive with respect to ground and with respect to the top terminal. Diode D1 ceases to conduct because its cathode is more positive than its anode. But as for D2, its anode is now positive with respect to its cathode and the device conducts. Thus, current flows from the lower terminal of the transformer, through D2 and R_L, and back to ground and the center tap, and a positive half-cycle of voltage is developed across R_L. Note that here, once again, the voltage across R_L varies identically with the input waveform, but the polarity of the voltage across the resistor is reversed—it is positive.

That sequence repeats during the succeeding positive and negative half-cycles. Note that current always flows through R_L in the same direction so that only a positive voltage with respect to ground is across the load. That is true regardless of the instantaneous polarities of the AC voltage applied to the circuit.

The advantage of the full-wave rectifier over the half-wave rectifier lies in the fact that in the half-wave circuit no voltage is developed across the load during negative half-cycles. Because of that, the ripple in the output of the half-wave rectifier is higher.

For ripple to be minimized in either type of circuit, some type of filtering must be used. To do so, a large capacitor is usually placed across R_L. That capacitor is charged to the peak voltage, V_P, during the first half-cycle. Between peaks, it discharges slowly through R_L. But it does not have enough time to discharge substantially before the next half-cycle appears and recharges it.

Without the capacitor, the ripple voltage across R_L varies from $+V_P$ to 0 volts. But with the capacitor present, it varies from $+V_P$ to whatever its voltage dropped to before the next half-cycle appeared to recharge it. From that, you should be able to see why the ripple is easier to filter in a full-wave rectifer. The reason is that the filter capacitor is recharged once during each half-cycle in a full-wave circuit, while in the half-wave arrangement it is recharged only once during each full cycle. Because of this longer recharge cycle, the voltage across the capacitor drops to a lower level. The ripple voltage, the voltage variation from $+V_P$ to that discharge voltage level, is therefore larger for the half-wave than the full-wave circuit.

In both circuits, the amount of ripple at the output is related to the values of the filter capacitor and the load resistor. For a full-wave circuit, ripple will be kept within reasonable limits if the product of the values of the load resistor and the filter capacitor is about 0.1. To keep the ripple to the same levels in a half-wave circuit, that product must be about 0.15. In other words, since we must assume the load to be fixed, the value of the capacitor must be more than 50% higher than for the full-wave circuit.

We want to mention one more thing about ripple before we move on. If the voltage across the filter capacitor varies during the cycle, the mean DC voltage output will be somewhat less than its possible maximum. Thus, for maximum DC output, the ripple must be very low.

Full-wave bridge

The circuit shown in Fig. 2 shows another type of full-wave rectifier, the full-wave bridge. Notice that it does not normally require the use of transformer, although one can be used if the input voltage needs to be stepped up or down.

Let's see how that circuit works. During positive half-cycles, current flows through D1, R_L, and D4. During the negative half-cycle current flows through D2, R_L and D3. Note that the current always flows in the same direction regardless of the polarity of the input voltage and that the end of R_L marked + is always positive with respect to the end marked −. As before, a capacitor is usually wired across the load resistor to filter out the ripple.

Voltage doubler

When a transformer is used in a rectifier

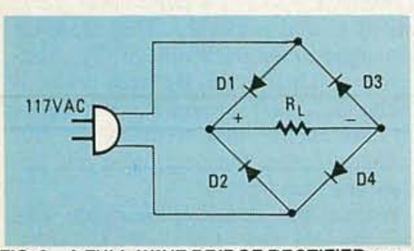


FIG. 2—A FULL-WAVE BRIDGE RECTIFIER uses four diodes but eliminates the need for a transformer.

circuit, the output, or DC voltage across the load, is determined by the peak voltage across the secondary of the transformer (or across one-half the secondary of a center-tapped transformer if a full-wave rectifier is being used). Should one of the previously described rectifiers be used without a transformer between it and the voltage source, the DC voltage at its output seems to be limited to the peak voltage of the AC source. But a voltage-doubler circuit can be used to increase the level of the rectified DC. Two circuits involving doublers are shown in Fig. 3.

In the circuit shown in Fig. 3-a, C1 is charged to the peak level of the supply voltage through D1 during the positive half-cycle. On the negative half-cycle, C2 is charged through D2 to the same peak level. Since the series combination of the two capacitors is across the load, the voltages across them add; and that sum is applied to the load, R_L.

In the circuit shown in Fig. 3-b, during positive half-cycles, C1 is charged to the peak supply voltage through D1. During negative half-cycles D2 conducts, allowing C2 to be charged to the peak supply voltage. In addition, the previously charged C1 discharges through D2 to C2. The supply voltage and the voltage across C1 are then summed in C2; and that sum, which is nearly twice the supply voltage, is applied to the load, R_L, when the waveform goes positive and D2 is once again cut off.

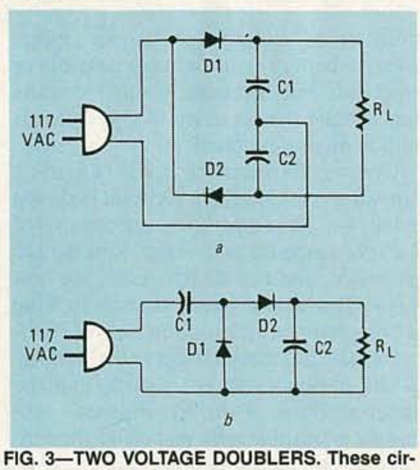


FIG. 3—TWO VOLTAGE DOUBLERS. These circuits are used between the AC source and the rectifier circuit to nearly double the level of the DC output.

Combinations of these circuits can be used to form triplers, quadruplers, and so on. A tripler is shown in Fig. 4-a. In it, the portion of the circuit involving D1, D2, C1, and C2 is identical to the circuit shown in Fig. 3-b, while the D3-C3 portion behaves just as the D2-C2 circuit of Fig. 3-a. The sum of the voltages across C2 and C3 are applied across R_L.

As for the quadrupler circuit, shown in Fig. 4-b, two circuits similar to the one shown in Fig. 3-b, are used. After the two double voltages are developed across C2

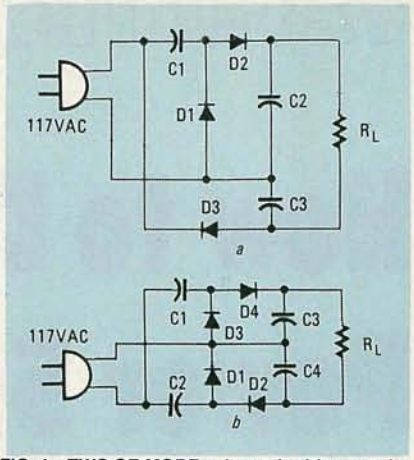


FIG. 4—TWO OR MORE voltage doublers can be combined to form voltage triplers, such as the one shown in *a*, or a voltage quadrupler, such as the one shown in *b*.

and C4 they are applied across R_L.

Specifying the diode and transformer

When the rectifying diode is not conducting, twice the peak supply or transformer secondary voltage may be across the device. This is true for all full-wave, half-wave and, voltage-multiplier circuits with the exception of the full-wave bridge. So when designing a power supply circuit, be certain that the diodes have a sufficient voltage rating.

The average current flowing through the diode is equal to the voltage across the load resistor divided by its resistance. The diode once again must be capable of accommodating that amount of current.

Power dissipation capabilities of the diode are limited. Information as to just what these limits are is supplied by the manufacturer and can be found on data sheets. The power the diode must be able to dissipate is equal to the average current it passes in the forward direction multiplied by 1 volt. At times, it may be necessary to mount the diode on a heat sink so that its operating temperature will not exceed its specified limit.

When a circuit involving a diode is first turned on, the filter capacitor being charged by the DC behaves as a short circuit. Because of that, a large initial current surges through the diode.. That surge current is equal to the supply-voltage peaks divided by all resistance in the circuit other than the resistances wired across the shorting capacitor. If the surge current is more than the diodes being used can accommodate, the device will be damaged. The best way to avoid damage is to use diodes that can safely handle that initial current surge. Alternately, you çan connect a small resistor in series with each diode to limit current surges to safe levels.

As for the transformer, it, too, can overheat if it conducts excessive quantities of current. To check if a transformer is operating within reasonable temperature limits, first measure the cold resistance of one winding while noting the ambient temperature in °C. Refer to that as R_C, the cold resistance. Then apply power to the transformer while its output is loaded as it would be normally. Be sure that all environmental factors (ambient temperature, etc.) are what they would be under normal operating conditions and run the transformer for eight hours. After that time, remove the power from the circuit. Immediately after removing the power, check the hot resistance, R_H, of the winding. Be sure that nothing is connected across this winding. The temperature rise of the transformer, in °C is:

$$\Delta T = 254\left(\frac{R_H - R_C}{R_C}\right)$$

Add the value you get for ΔT to R_C. If the total exceeds 90°C you should start to be concerned. If it exceeds 105°C, then the transformer is overheating and a different transformer should be used in the circuit.

Regulated power supplies

Throughout the discussion, it was assumed that the line voltage is fixed at 117-volts AC and that the load does not change in resistance but remains a constant R_L. If anyone assumes that to be a realistic condition, then he is living in a dream world. Line voltage fluctuates from minute to minute. Over time it can vary ±10% or more. During periods of extremely heavy usage, power companies have been known to greatly reduce voltage levels.

As for the load, it is seldom a fixed resistor. If the supply is feeding an audio, RF, or electronic-switching circuit, the load impedance varies, sometimes from instant-to-instant, with the signal or switch current fed to it.

A fixed, stable voltage is frequently required when powering an electronic circuit. That constant voltage is not present when there are either supply-voltage or load variations. As we discussed earlier in this series, a fixed voltage developed across a Zener diode can be used to stabilize the voltage across a load if the Zener is placed across that component or circuit. That is fine where low currents are involved. But when large quantities of current must flow through the load, the Zener diode can seldom be used economically as the sole regulating device for the circuit. Series, parallel, and feedback circuits using Zener diodes along with one or more transistors have been developed as practical regulators.

Series regulators

In the series-regulator circuit, DC current flows from the unregulated portion of the DC power supply through a transistor to the load. If the circuits are like the ones shown in Fig. 5, the voltage across the load is regulated. In both of those circuits, current flows through R1 and Zener diode

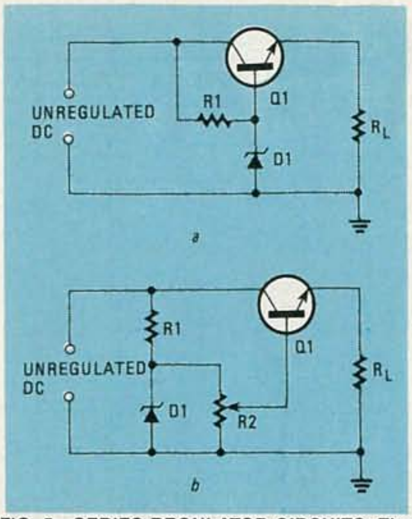


FIG. 5—SERIES REGULATOR CIRCUITS. The one in *a* provides a fixed voltage while the output from the one in *b* can be varied using R2.

D1 which causes a fixed voltage to be developed across D1. In Fig. 5-a, current flowing through R1 also flows through the base-emitter junction of Q1. A fixed voltage, about 0.6 or 0.7 volt, is developed across this junction, turning on Q1. The voltage between the emitter of Q1 and ground, or across R_L, is about 0.7 volt plus the voltage across D1. That fixed voltage is across R_L regardless of supply-voltage or load variations.

In that circuit, little current flows through the Zener diode. What does flow is limited to safe values by R1. The current that is supplied to R_L flows through Q1. If the required load current is high, Q1 should be rated adequately and mounted on a heat sink. Circuit components must be chosen so that the transistor is not in saturation at any time.

The regulated output-voltage can be varied by simply placing a potentiometer across the Zener diode and connecting its wiper, rather than the cathode of D1, to the base of Q1. That is shown in Fig. 5-b. Now, the voltage across R_L is the sum of the voltages between the wiper of the potentiometer and ground, which is the voltage between the base and emitter of the transistor. Resistor R1 must be selected so that the proper current is available at the base of Q1 to keep it turned on and out of saturation at all times.

Several improvements can be made in the circuit shown in Fig. 5-a. Those are shown in Fig. 6.

In order to achieve good regulation, the Zener diode should see a high impedance. In Fig. 5-a it sees an impedance equal to R_L multiplied by the beta of Q1. To increase the impedance, a Darlington circuit can be used rather than an individual pass transistor. Such a Darlington pair is shown in Fig. 6 as Q1 and Q2. The impedance seen by D1 in that circuit is essentially the product of the betas of the two transistors multiplied by R_L.

To further improve regulation, a constant current should be applied to D1 and to the base-emitter circuits of the series transistors. The circuit around Q3 establishes that constant current. Current flows through D3, D4, and R1 due to the voltage from the unregulated DC supply. The voltage across the two forward-biased diodes, D3 and D4, is relatively fixed at 1.4 volts (0.7 volt across each diode). That voltage is between the upper end of R2 and the base of Q3. Because the base-emitter junction of Q3 is turned on at 0.7 volt, the balance of the 1.4 volt, or 0.7 volt, is across R2. The fixed emitter current, in milliamps, is 0.7/R2. The collector current is just about equal to the emitter current of Q3 and the collector and emitter currents do not fluctuate to any degree. The collector current is applied to the Zener diode and base of Q2. Resistor R2 is selected to set the current at the desired level.

In the event that a short is placed accidentally across R_L, excess current will flow through Q1, which is likely to destroy the device. The circuit around Q4 performs the function of protecting Q1 in the event of a short.

Transistor Q4 is turned off when the current flow through the circuit is at its normal level. It remains off until the current flowing through R4, which is also the current through the load, is sufficient to develop about 1.4 volts across the resistor. Notice in Fig. 6 that Q4's collector is

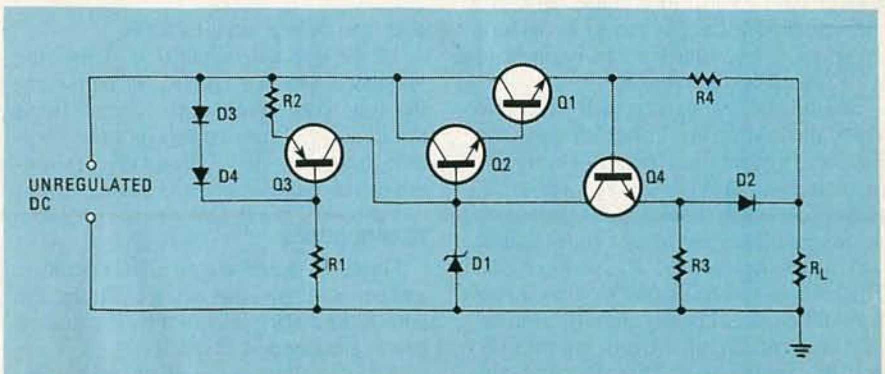


FIG. 6—THE BASIC SERIES regulator circuit can be improved by using a Darlington pair in place of Q1 and adding a constant-current source.

connected to the junction of Q2, Q3, and D1. When Q4 is on, it draws the bulk of the current from Q3 so that insufficient current remains to fully turn on the base-emitter junctions of Q1 and Q2. That also reduces Q1's collector current. Thus, less power is dissipated by Q1, preventing it from being destroyed due to the presence of an excessively heavy load.

Parallel regulators

There are two types of parallel regulator circuits—one supplying a voltage that is only slightly lower than the breakdown voltage of the Zener diode used in the circuit, and one supplying a voltage that is considerably higher than that of the diode. Both are shown in Fig. 7.

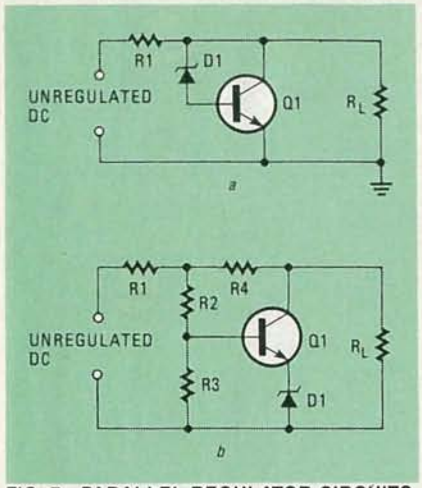


FIG. 7—PARALLEL REGULATOR CIRCUITS. The output from *a* is 0.7 volt above the Zener breakdown voltage; the output from *b* is considerably higher.

In Fig. 7-a, current flows through R1, D1, and the base-emitter junction of Q1. Fixed voltages are developed across D1 and the base-emitter junction of Q1. The sum of those two voltages is the regulated voltage applied across R_L.

In Fig. 7-b, current flows through R1, R2, the base-emitter junction of transistor Q1, and Zener diode D1. A fixed voltage is developed between the emitter and collector of Q1. The circuit's regulated output, V_R, which is across R_L, is equal to the sum of the Zener voltage, V_Z, and the voltage developed across Q1. It can be shown that that voltage is equal to:

$$V_2\left(\frac{R_2+R_3}{R_3}\right).$$

Resistor R4 is critical in and must be selected by trial and error. That resistor should be selected for the minimum variation of voltage across R_L as the unregulated input voltage is varied from its minimum to its maximum.

Performance can be improved by using Darlington pairs rather than individual transistors and by replacing R1 with a constant-current source.

Feedback regulators

A commonly used series regulator-circuit using feedback is shown in Fig. 8.

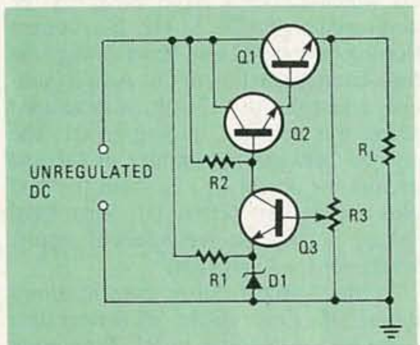


FIG. 8—THIS REGULATOR circuit uses feedback.

Current from R2 flows into both the collector of Q3 and the base of Q2. Because of D1, the emitter of Q3 is at a fixed voltage with respect to ground. Note that the regulated voltage is across R_L as well as across R3 so that R3 can be used to adjust the voltage across R_L.

Should voltage V_R across R_L increase above the desired level, the voltage at the base of Q3 rises. That transistor conducts more heavily than when V_R was at its proper level. The base of Q3 is then more positive with respect to its emitter than it was when the level of V_R was correct. That causes the transistor to draw more current than it did before from R2, reducing the amount of current previously available for the base of Q2. Because current through Q2, and consequently the current through Q1, are reduced, less current than before remains for R_L.

In the opposite condition, when the voltage across R3 and R_L is below the desired fixed level, less current flows through Q3. More current is now available to flow through Q2 and Q1, rebuilding the output voltage to its desired level.

IC regulators

Figure 9 shows a typical IC regulator and some of its surrounding circuitry; the part of the circuit enclosed by the dashed box is usually part of the IC.

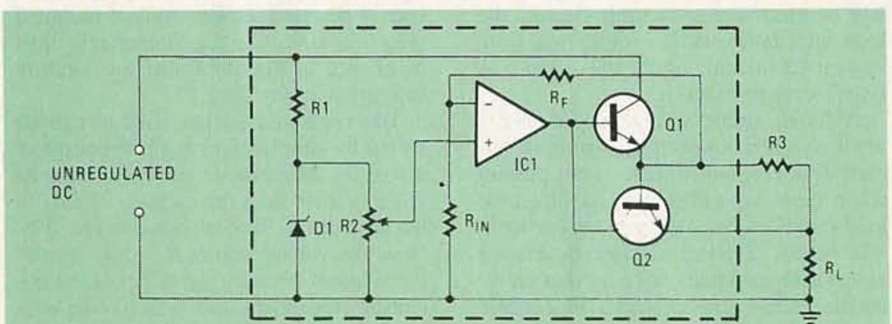


FIG. 9—REGULATOR CIRCUITS are commonly found in IC form. The circuitry within the dashed box is usually contained in the IC.

A fixed voltage is developed across D1. A portion of that voltage, as set by R2, is applied as a reference voltage to the non-inverting input of the op-amp. The output from the op-amp is passed on to Q1. The voltage at the emitter of Q1, which is close to the voltage at the output of the op-amp, is fed back through R_F to the inverting input terminal of the op amp. That inverting input is connected to ground through R_{IN}. The voltage at the inverting input, and at the emitter of Q1, is equal to the voltage at the non-inverting input multiplied by $1 + (R_F/R_{IN})$. The output voltage is therefore fixed by the voltage across D1, the setting of R2, and the ratio of resistors R_F and R_{IN} at the inverting input.

In Fig. 8 we've added a circuit to protect against damage in the event there is a demand for excessive current from the regulator. Excess current flow can not only damage a transistor, but can destroy an op-amp, and consequently an IC. Transistor Q2 is in the IC to protect it from being damaged. When excess current flows, sufficient voltage is developed across R3 to turn on Q2. When turned on, the base-collector circuit of Q2 is across the base-emitter circuit of Q1, preventing it from conducting excess current.

Crowbar circuits

A crowbar circuit is used to prevent damage to a regulated power supply in the event a high voltage is applied across the load. In the arrangement shown in Fig. 10, the inverting input of the op-amp is fixed at the breakdown voltage of D1. Resistors R2 and R3 are selected so that with normal voltage across R_L, the voltage at the non-inverting input of the op-amp is less than the voltage at the inverting input and the output from the op-amp is negative. The gate of SCR1 is then also negative with respect to its cathode so that the SCR remains off.

When a high voltage is applied across R_L, the voltage across D1 and at the inverting input of the op-amp, remain fixed. But the voltage at the non-inverting input increases. Divider resistors R2 and R3 should be selected so that the voltage at the non-inverting input exceeds that at the inverting input when a high voltage from an external source is applied across R_L. When such a high voltage is across R_L the

continued on page 101

Compatibility

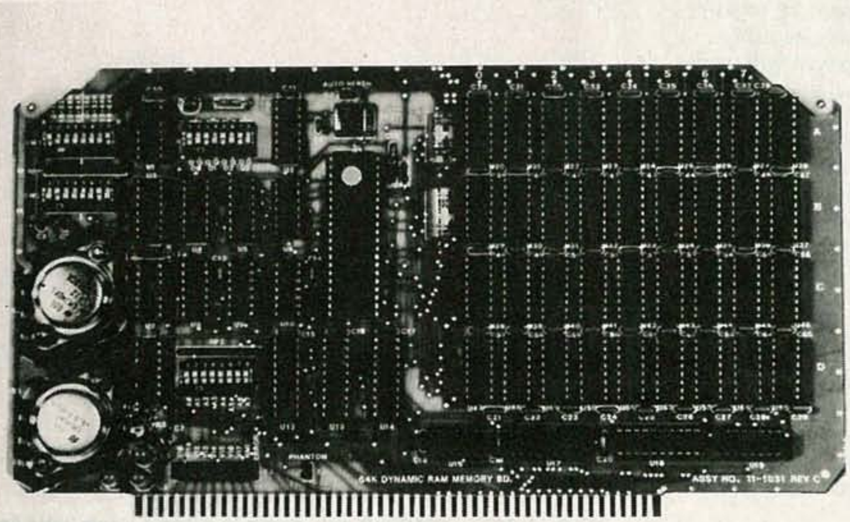


FIG. 1—BEFORE YOU BUY an accessory board for your computer, try to see it in action and make sure that it won't conflict with other boards you have installed in your computer.

Compatibility and Standards

With so many different computers, peripherals, and types of software to choose from, how can you be sure of putting together a system in which everything will work together?

ABE ISAACS

THE BIG QUESTION THESE DAYS, AFTER YOU UNPACK YOUR computer, is not "Will it work?" or "What can I do with it?" but "Will it work with all the other stuff I bought to go along with it?"

If all your equipment—let's say your computer, printer, and disk drives—as well as your software came from the same manufacturer, everything *should* have been designed so there would be no conflicts, and you should be merrily on your way in no time at all to whatever it is you are going to do with your computer.

If, on the other hand, you decided that you liked the features of the "Brand Y" printer over those of the printer available from the manufacturer of your "Brand X" computer, you may find that the two refuse to communicate with each other, despite claims from both sides about their supposed compatibility.

Similarly, you may find that the word-processing software you bought by mail order: a) generates a display too wide for your video screen, b)won't output to your printer, or c) won't even run on your computer!

After you've asked the *big* question—Why?—the next question should be "What did I do wrong—and how can I avoid doing it again." What follows will, we hope, guide you in selecting a computer system all of whose parts will work together smoothly and without giving you cause to regret your investment.

Compatibility

If one piece of equipment is described as being compatible with another, that is usually taken to mean that the two will work together without problems. In the world of computers, however, that is not always the case.

Consider, for instance, the case of a computer with a "Centronics-type" printer port and a printer from another manufacturer that is "Centronics compatible." Centronics, a pioneer in microcomputer printers, uses a parallel interface where each specific line brought out for connection to the computer serves a specific function and, if there are timing requirements, as is the case with the strobe lines, the characteristics of the timing pulses are strictly defined. Centronics also uses a special connector on its printer cables. All Centronics printers use the same scheme.

Centronics, however, does not manufacture computers—or other printer brands. If a computer manufacturer claims that the parallel printer port on his computer is Centronics-compatible, you would assume that he has carefully studied Centronics own specifications and matched his device to them. That is frequently not the case. There are a number of possibilities.

His timing could be different from that specified by Centronics, which would cause the printer to print "garbage," if, indeed, it printed anything at all. His pinout—the way the functions of the various lines are assigned to the pins of a connector—may be different from Centronics'. Again, more garbage, or nothing at all. He may not use a Centronics-type connector. In fact, the closest that some Centronics-compatible interfaces may come to being Centronics compatible is the fact that they are parallel rather than serial!

In the world of microcomputers—a world that is splintered into a large number of so-called standards, each of which is considered by its proponents to be the best—true compatibility is something more often dreamed of than accomplished.

A few standards really do exist in the industry: the RS-232 serial communications protocol (along with a frequently adhered to definition of which line is used for which purpose), the S-100/IEEE-696 bus used in a number of "serious" computers, the IBM 3740 format for single-sided, single-density eight-inch floppy disks, the CP/M operating system, and a few others.

Unfortunately, while those standards have been defined, they are not always adhered to. Add to that fact all the other "standards"—many of which are used by only one manufacturer—and you have a situation best described as...chaotic.

Our advice to the innocent is: **Never believe anything you're told or that you read!** No matter how "standard" something is claimed to be, or how compatible it is supposed to be with something else, don't believe that's the case unless you actually see proof of it for yourself.

Hardware

Fortunately, hardware compatibility is not a big problem these days. If you buy an I/O (*I*nput/*O*utput) or memory board (see Fig. 1) that's claimed to work in an Apple or IBM computer, it probably will.

Of course, there may be a requirement that the board reside in a particular slot (receptacle) in the computer. Be sure that that you don't require that slot for something else. Also, make sure that the memory space that the board occupies, if it requires a memory location, doesn't conflict with the memory requirements of other hardware—or software—you may be using.

How can you be sure that one piece of equipment will work with another? You can't, at least not from the manufacturer's or vendor's descriptions. The only guaranteed way to know whether board "Y" will work in computer "X" is to see that board in action for yourself in the computer in question. Then, and only then, can you begin to feel safe about buying it for yourself. Don't forget though, that you may own a board "Z" that can upset the applecart. If at all possible, find a vendor who can show you the piece of equipment you're interested in actually working in an exact duplicate of your own system.

One of the big hardware "gotcha's" (as in "Aha! Got ya!") is connectors and cables. In the first place, be aware that many items that require cables, such as disk drives and printers, are frequently sold without them. Make sure when you place your order that all the cables required to use a device are either included in the purchase price, or are available optionally. If they are options, find out exactly what you need, and order it with the equipment.

Do not assume that a salesperson knows what type of cables you require. Spell it out. Indicate that you have a Brand-X computer (and add, if necessary, that the cable will be connected to a Brand-Y board within the computer). Tell him how long the cable has to be. And, if there are any "funny" connectors involved, give him that information, too.

Disks

Floppy disks come in two diameters: 8-inches and 5¼-inches. (There's batch of under-4-inch disks coming over the horizon, but until they start to show up in force, and a "standard" is established—there are at least three different sizes being offered for sale—don't worry about them.) That really doesn't present much of a problem when you have to go out and buy disks—if there's any doubt in your mind as to what size your system needs, use a ruler.

The fun begins when we start looking at how the disks are set up for sectoring. (Sectoring is the process that divides the surface of the disk into small—usually 128-byte—sections that the computer can easily keep track of). Disks can be hard sectored or soft sectored. Examples of both types can be seen in Fig. 2.

All floppy disks have an index hole. That hole tells the computer when the rotating disk has come full circle and indicates the beginning of the first sector on it. That is the only hole found in soft-sectored disks (a soft-sectored disk is shown in Fig. 2-a). The actual sectoring is performed by the computer when the disk is formatted (a process we'll mention briefly below). Perhaps because the operation is performed by software, those single-hole disks are referred to as soft sectored.

Hard-sectored disks, however, in addition to having an index hole, have sector holes that serve to indicate where the sectors begin. The term "hard sectored" may have originated because the sector determination is done by hardware. As can be seen from Fig. 2-b, there are several types of hard-sectored disks. Eight-inch ones have 32 sector holes, but 5¼-inch hard-sectored floppies can have either 10 or 16 holes. It is important for you to know which type of disk your system requires, because if you try to use the wrong one, it just won't work.

Fortunately, with a few exceptions, most systems these days use soft-sectored disks. Sometimes you have the choice of buying blank floppies formatted or unformatted. Formatting determines the number of tracks on the surface of the disk—sort of like the grooves on phonograph records—that will be used for writing and reading data. (In the case of soft-sectored disks, it also performs the sectoring operation). Since your computer will undoubtedly come with a program that formats blank disks, your best bet is to buy unformatted ones. Not only can you save a little

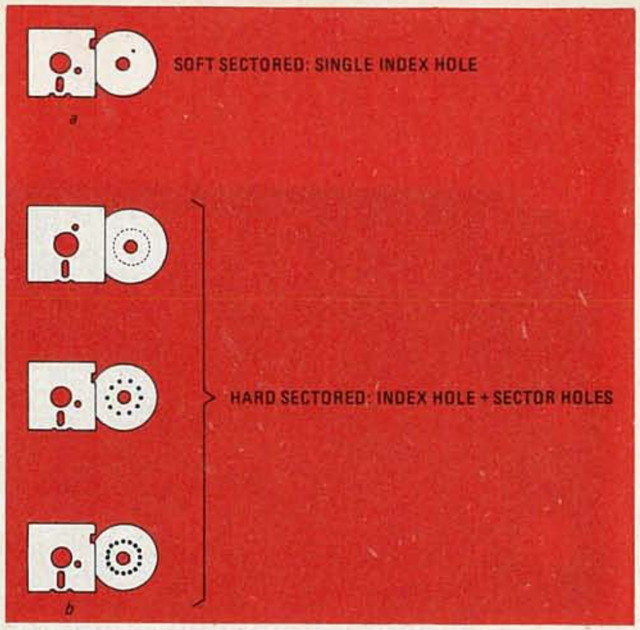


FIG. 2—A SOFT-SECTORED disk, shown in *a*, has a single index hole. However, the number of sector holes in a hard-sectored disk varies. Shown in *b* is a hard-sectored 8-inch disk with 32 sector holes, a 5¼ disk with 10 sector holes and another with 16 sector holes.

money, but, by having your computer do the formatting job to its own specifications, you will always get what you need.

You should also know whether your computer uses single-sided or double-sided disks, and whether it can record (and read) both single- and double-density disks, or single-density ones only. Double-sided, and double-density, disks both have twice the capacity of their single-sided or single-density counterparts. A disk that is both double-sided and double-density will have four times the capacity of a single-sided, single-density one.

A computer that can make use of the higher-capacity media can almost always use the simpler ones, but the reverse is not true. A double-sided disk will be of no use in a single-sided drive. In fact, it may not work at all! And, while a blank disk that's certified for double density recording will work in a single-density drive, it's a waste of money. It's alright to spend money for high-quality disks, but it's ridiculous to waste it on features you can't use.

Software compatibility

Assuming that you have not encountered any hardware problems, or that you have overcome the ones you have run into, you are are now ready to face the question of software compatibility. That is—will a particular program work with your system? There are both hardware and software aspects to the problem, and they sometimes tend to overlap. Bear with us, though, and we'll try to make things clear.

The first obstacle we'll deal with concerns *machine dependency*, and it, too, can be broken down into two parts. The first has to do with the type of microprocessor used by the computer. There are several different microprocessors used in personal computers—among them the Z80, 6502, and 8088—and not one of them is directly compatible with any of the others! A program written for a computer like the *IBM PC*, which uses an 8088, will not work at all on a computer like the *TRS-80 Model IV*, which uses a Z80, or on the *Apple IIe*, which uses a 6502. While there are a few exceptions (programs written for the 8080 microprocessor will run on a Z80, for instance; the reverse, however, is not necessarily the case), it is safe to assume that if a program does not specifically indicate that it is intended for use on the type of computer you own, it will not run.

CP/M software (see the article on the CP/M operating system in last month's **Radio-Electronics** and the discussion of CP/M below) will run both on computers using 8080's and Z80's. That is, most of it will. Some of it is written using Z80 instructions that the 8080 can't understand...and the ads don't always advise you of the fact. If you're not sure whether a program will work with your computer, ask! Better yet, get someone to show it to you running on a system like yours.

The second part of the machine-dependency problem has to do with the computer's physical configuration—particularly the way its display is set up. As an example, let's consider a *TRS-80 Model III* and another Z80-based computer. But, while the keyboard and video screen of the *TRS-80* are an integral part of the computer, the other computer uses a separate terminal connected to it through an RS-232 serial communications port.

What's the difference between the two? First, the TRS-80 uses what's called a memory-mapped display—every one of the 1024 individual locations on its 64 × 16 display has a corresponding byte of memory allocated to it. That means that you can make characters or graphics symbols show up in any one of those locations by putting data directly into the corresponding memory address.

You can't do that with an ordinary terminal. It has its own, more complex, system for displaying information, one that has nothing to do directly with the contents of the computer's memory.

The other big difference is that while the *Model III's* display is an array of 64 columns by 16 lines, most terminals are set up to display at least 80 columns by 24 or 25 lines.

Now imagine that you buy a program with graphics that you want to use on both computers. How do you do it? You can't! If the program was written for the *TRS-80*, the method used to generate the graphics won't work on the terminal. If, on the other hand, it was written for use on an 80-column terminal, the lines won't fit on the *TRS-80's* 64-column screen; they'll break at the wrong places, and columns of figures won't line up.

There's not much you can do about incompatibilities caused by machine-dependency except to try to avoid them from the start by choosing your hardware and software with great care.

Machine dependency: software

The other big computer-compatibility problem stems from computers that are supposed to be compatible with other computers, and it, too, involves both hardware and software. For example, even if a program is stated to be "IBM-compatible," and you own an "IBM clone"—a computer that claims it works just like the IBM—there is no guarantee that it will run on your system. Why should that be? After all, the displays are the same, the disk sizes are the same, even the expansion buses are the same. Why shouldn't it work?

The answer lies in the fact that, while IBM made public many specifications of its computer, it did not divulge the full details of the operating system contained in its ROM (*R*ead-*O*nly *M*emory). And, while IBM made no fuss over other companies' bringing out IBM-compatible memories, I/O boards, and the like, it would certainly have a fit if someone were to duplicate its copyrighted operating system. (That, by the way, is why Apple is so upset about the *Apple II* look-alikes that are finding their way into this country from overseas—the ROM's contained by many of those computers are exact duplicates of Apple's own.)

Much software for the IBM *PC* depends heavily on what's in IBM's ROM's. This is particularly true for graphics, but applies to a number of other areas as well. And, since the IBM clones can't duplicate IBM's ROM's, a lot of that software doesn't work. If you want to buy a program for your IBM clone, make sure that you see it running on a machine like yours before you commit yourself.

Another thing to watch out for is programs that imply that they will run on a computer like the IBM *PC* as well as on other totally unrelated computers like the *TRS-80* family or the *Apple II* family. Each one of those families, as we mentioned earlier, uses a different microprocessor, and none can understand the language of the others.

It's possible that, if a program exists that will allow a computer using one disk format to read disks made using another format (and such programs do exist), a computer from one family will be able to load a program written for another into its memory. But that's as far as it will go. A program written for one microprocessor will be unintelligible to another.

The last area of software compatibility—if you still believe in such a thing—brings us back to hardware. We briefly discussed disk formats earlier, regarding the various types of disks that are available. What we didn't mention was the fact that almost every computer manufacturer has his own system for recording on the disks. A recent look at an ad from a major software distributor showed at least 20 different formats available, and there were many computers that weren't included in the list.

Fortunately, you'll probably find your computer on the list of some software distributor. In addition, some computers, like the *Kaypro II*, (see Fig. 3) can read disks written in several different formats. Once again, don't buy anything unless you *know* that it will work with your system.

BASIC

BASIC (*B*eginner's *A*ll-purpose *S*ymbolic *I*nstruction *C*ode) has become the *de facto* high-level microcomputer programming language. There are plenty of others available—Pascal, C, and Pilot, to name a few—but the majority of the high-level-language programs around are written in BASIC.

As you may have guessed, there are almost as many dialects

FIG. 3—THE KAYPRO II, shown here, can read several different disk formats.

of BASIC as there are computer manufacturers. That is especially true of computers that have BASIC built into their ROM's. Those BASIC's are heavily machine-dependent, and a program written for one system will not run on another. Interestingly enough, most of those BASIC's have the same origin, a company called Microsoft. However, each computer manufacturer who contracts with Microsoft to create his BASIC also specifies the "peculiarities" of his system (what math functions he'll need, what graphics functions he'll want, what addresses his display memory occupies, etc.). It makes for a real can of worms, and there's no easy solution, at least for "budget" computer systems.

If you can get a listing of a program you want to run, but it doesn't quite fit your BASIC, you may be able to make it work by referring to a book called *The BASIC Handbook*, by David A. Lien (Compusoft Publishing, 535 Broadway, El Cajon, CA 92021). It's an encyclopedia of BASIC statements and, if you come across one that is unfamiliar to you (and your computer), the book frequently suggests a substitute that may work.

For CP/M-based systems there are several BASIC's that are "standard," and software originators almost always specify which BASIC is needed to run their programs.

Disk operating systems

Every computer that uses disk drives also uses a disk operating system, or DOS. It allows the computer to store data on, and retrieve it from, the disk. It also provides a number of useful facilities, such as the abilities to list a directory of all the files (programs and collections of data) on the disk, to copy files from one disk to another, and to erase files that are no longer needed.

Almost without exception, DOS's are machine-dependent. An Apple DOS will not work with an IBM computer, and neither IBM's nor Apple's DOS's will work with, say, one of Commodore's computers.

Most of the time that will not be a problem for you—you'll purchase programs that were written to run with your DOS on your computer. Lately, though, a number of programs have been advertised that would appear to run under the various DOS's used by IBM and the companies that make IBM work-alikes.

IBM's DOS is known as PC-DOS or MS-DOS (the "MS" stands for "Microsoft"—who else?). A similar DOS used by the Heath/Zenith *H/Z-100*-series computers is called Z-DOS. You can be led to believe that the two are compatible, but in a number of ways they are not. Again, the problem appears to lie in the computers' ROM's. Still, software is advertised that would lead you to believe that it can be run on either computer. Beware! See the program running before you buy it. In some cases you'll find that there are several versions of a program, each tailored to a particular computer. Make sure you buy the one intended for yours and, if there's any question, don't make your purchase until you know it will work for you.

There are a number of IBM-type systems around, but they don't all work like PC's.

CP/M

Believe it or not, there *is* a DOS that is compatible with a large number of computers, that has a vast library of programs available to run under it, and that is recognized as a standard. It's the CP/M operating system that we've mentioned here from time to time.

CP/M stands for *C*ontrol *P*rogram for *M*icrocomputers. (Actually, it originally stood for *C*ontrol *P*rogram/*M*onitor, but as its popularity grew, it changed its name.) It will run on any computer that uses an 8080, 8085, or Z80 microprocessor. Its universality lies in that fact that it does not rely directly on ROM-based routines to communicate with the computer or with its peripheral devices like printers and terminals.

Instead, it treats such peripherals as what are known as "logical devices." A logical device can be considered to be a generalization. In other words, a program running under CP/M does not have to be told that you are using a Brand-A terminal and a Brand-B printer connected to a Brand-C computer. When the time comes for the program to direct its output to your printer, it tells CP/M to take care of it. A CP/M-based program doesn't care whether you're using a terminal or a memory-mapped video display. If the output is to go to a modem connected to a telephone, CP/M knows how to get the data there—such tasks no longer become the responsibility of the program or of the computer, and, for that reason, CP/M software is *transportable*—it can be used on any CP/M-based system.

The CP/M operating system itself must, of course, be tailored to your system so that *it* knows how to communicate with the computer and whatever peripherals you may have. That job is usually done by the company that supplies the CP/M for your system; it may be the manufacturer, or it may be the company that sold you the computer. In any case, you hardly ever have to worry about setting it up yourself and, once you learn to use it, a world of programs of every sort opens itself up to you.

CP/M is available for just about any computer you can name. If the computer doesn't use an 8080, 8085, or Z80, there is usually a Z80 adaptor available for it. Microsoft makes one for the *Apple II* series, and a company called Microlog makes a board containing a Z80 for the IBM *PC*. Several manufacturers supply modification kits that allow Radio Shack's Z80-based *TRS-80* computers to run CP/M. And, as we'll see, there are versions of CP/M for other types of computers, too.

Different CP/M's

The original CP/M, which runs on computers using the 8080, 8085, or Z80, is known as CP/M version 2.2. (That is the most recent version—there was originally a version 1.0, and later versions 1.4 and 2.0.) It is frequently offered as part of a package included in the price of a number of computers. If your version bears a number like 2.21, the last digit refers to the latest revision made by the company that supplied you with the CP/M. You may also see CP/M 2.2 advertised as CP/M-80.

Digital Research, the originator and supplier of CP/M, recently introduced a CP/M version 3.0, more commonly known as CP/M Plus. It is intended for use on large systems, or for the serious programmer. In addition to having an on-screen HELP function, CP/M Plus also allows you to "stamp" your files with the time and date you work on them. It can also address larger amounts of memory than CP/M 2.2 and, in the case of floppy disks, is faster.

If you should see CP/M Plus advertised by itself, and not already configured for a specific system, *don't buy it!* Configuring CP/M Plus is a job only for someone who has a thorough knowledge of assembly-language programming, and is on intimate terms with his system.

There is also a CP/M-85. This is, as far as we can tell, identical to CP/M-80. The reason for adding the numbers to the different CP/M's is to indicate which microprocessor family they work with. CP/M-80, as we've said, works with the 8080 and Z80 microprocessors (and the 8085). Manufacturers marketing 8085-based systems sometimes call the CP/M they offer CP/M-85, presumably in honor of their equipment.

CP/M-86, on the other hand, *is* quite different from the versions we have mentioned so far. It is a higher-performance version of CP/M than version 2.2 (CP/M-80) but is specifically designed for 16-bit 8086- and 8088-based computers like the IBM *PC*, which uses an 8088. It is faster than CP/M-80, and takes advantage of the 16-bit microprocessor's ability to address large amounts of memory.

It is compatible with CP/M-80 only to the extent that both use the same system for keeping files on disk. That means that a file—like a document created using a word processor—can be created on a Z80 computer, for example, and read by an 8088-based one. It does not mean, as some advertisers may lead you to believe, that a *program* written for a computer using an 8080 or Z80 and running CP/M will work on an 8088 based system. That won't work! If you're using an 8088-based computer, stick to 8088 software!

Concurrent CP/M-86 is a version of CP/M-86 for use on single-user systems that allows the computer to perform more than one task at a time.

MP/M II, for 8080/Z80 computers (MP/M-86 for 8086/8088 computers), not only allows a computer to perform several tasks at once, it also permits several people to use the same computer at the same time. It is called a multi-user, multi-tasking operating system and can support up to 16 users, 16 printers, and 16 disk drives with 512 megabytes of storage each.

Two other types of CP/M are CP/M-68K and CP/NET. Due to space restrictions we won't discuss them. But suffice it to say that there's a CP/M for almost everyone, and thousands of programs of every sort to go with it. This article was written on one CP/M-based computer, and the material stored on disk was edited on another one from a different manufacturer. The edited material was transmitted by modem to still another CP/M system (from a third manufacturer), where it was prepared for typesetting.

Don't be frightened by all the examples of incompatibility you've read here. Instead, just be aware such pitfalls exist, and that—knowing in advance what to watch out for—you're likely to wind up with a smooth-running system that does everything you intended it to, and *nothing* that you hadn't expected. **R-E**

HOBBY CORNER

Sensing circuits

EARL "DOC" SAVAGE, K4SDS, HOBBY EDITOR

THIS MONTH, WE'LL BEGIN OUR DISCUSsion with three related questions. The first one is from George Rodriguez (FL) who is looking for a device that will give an indication when a certain circuit in his car is activated. We assume that he has considered all the obvious ways to do so, which would include using a mechanical relay, an SCR or a Triac.

The related questions are from S. Kinsey (NY) and Kelly Walder (FPO, NY), who asked about using a coil to detect the presence of current in a circuit. A part of the answer to George's inquiry applies to the needs of those fellows, which brings into play three more ways to detect an activated circuit. Those methods are: (1) a phototransistor switch, (2) a sensing coil, and (3) a series dropping resistor. We'll give you the basic ideas behind each of the three so that you can choose the one that best suits your needs.

Phototransistor switch

If the circuit contains a light-producing device (panel lamp, trunk light, or overhead light) you can couple a phototransistor switch to it. Here, the phototransister is activated when the light goes on and that, in turn, switches on an alarm circuit or other such device. That is a straightforward application and you should need no further details.

Sensing coil

The second sensing method uses a coil to take advantage of the relationship between current and magnetism. (Kelly and Kinsey, are you reading?) What we're going to do is to make a simple transformer. Take a look at Fig. 1-a: As you can see, coil L1 is carrying a current and that current generates a magnetic field about the coil. Now, let's put another coil, L2, right next to L1, as shown in Fig. 1-b. The second coil, L2, is affected by the magnetic field (lines of force) that surround L1.

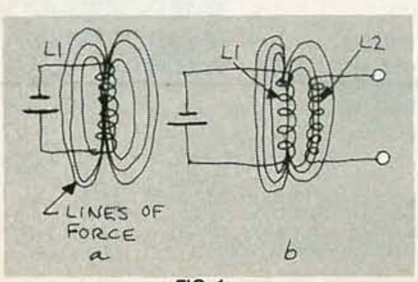


FIG. 1

Every time the lines of force from L1 *cut* across the wires in L2, a voltage is generated or induced in L2. (Note that the key word here is "cut".) If neither the coil nor the lines of force are moved, there'd be no voltage generated in the second coil. In other words, when more or fewer lines cut across the wire (or the field intensity is varied) a voltage is induced in the second coil. (A mechanical generator moves the coils, but a transformer moves the lines of force.)

Let's try a little experiment. It's not much trouble and it will help you to understand the principles involved here. Besides, nothing beats "hands-on" experience. In addition, you'll have a head start in designing a circuit to suit your specific needs. All that's needed is a flashlight battery; a flashlight bulb; a couple of coils, and a low-range voltmeter. The coils can be made, bought, or salvaged from almost anything—we've used coils from relays, RF chokes, hand-wound coils of few or many turns, and even two spools of hook-up wire. (Incidentally, you can wind a coil easily by putting a nail or wooden dowel in a drill and feeding the wire on as it turns.)

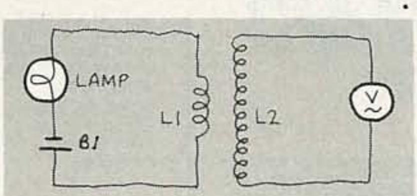


FIG. 2

Place the coils side-by-side and wire-up the circuit as shown in Fig. 2. Let the larger coil (the one with the greater number of turns of wire) be the output coil. Have it all done? What's happening? Nothing! Remember that L2 must be cut by the lines of force that surround L1. As you can see, at this point L2 is just lying there in the magnetic field and the result is nil (as far as this experiment is concerned).

One way to cause the cutting action is to move one of the coils. Let's very quickly move coil L2 away from L1, you should see an indication on the meter. Now, put it back and you will see another indication. Say, that's fun, but it's a heck of a way to get an output and very tiring, to say the least! Let's get the cutting action another way. With the coils side-by-side again, make and break the current path by turning the bulb on and off (the bulb acts as the switch in the circuit). Each time the bulb is turned on or off you will get an indication on the meter. Obviously, the wires of the coil are being cut by the magnetic lines of force. How?...When the current in L1 is turned off, the lines collapse into (or tighten-up around) L1, cutting across the wires of L2 in the process. When the current in the circuit is turned on, the magnetic field around L1 expands and L2 is again cut by the lines of force. Another way of saying that is: When the field around L1 is varied in intensity the magnetic lines of force cut across the wires of L2 and thus induce a voltage in L2.

Now, take the bulb out of the circuit (temporarily) and make and break the circuit. The meter will jump higher because there is a greater current flow in the circuit without the bulb to limit it. Actually, you've made a crude transformer and that experiment has also shown why a transformer will not work on DC current (no cutting of wires by lines of force). As you know, AC current reverses itself with each half-cycle, in effect, turning the current on and off with each alternation.

There are several variations of that experiment that you should try while you have the circuit set up. First, add an automatic "maker/breaker" to the circuit. That can be done in either of two ways. One way is to put L1 in series with an LED and connect it to the output of a 555 astable oscillator (see past issues of the "Hobby Corner" for 555 circuits). The 555 will turn the current on and off faster and more regularly than you can, without getting tired. An easier way is to apply an AC voltage to the input as shown in Fig. 3. Either method will give a constant input and enable you to get a meaningful output measurement.

Here are the variations you should try. Don't forget to make a record of the output measurements. If either or both of your coils do not have iron cores, stick a nail through the center and watch the effect that that has on the output. Try the coils in various positions—side-by-side, end-to-end, parallel, perpendicular, close, and not-so-close. Exchange those coils for others that you have on hand and try them in various combinations.

One final experiment: Wrap a dozen or so turns of wire around your output coil and use those turns for the input coil. Measure the output of the base coil. Now take off all but three or four turns of the input coil. Measure the output and compare it with the previous measurement. By this time you have learned a lot by observing the results of your experimentation.

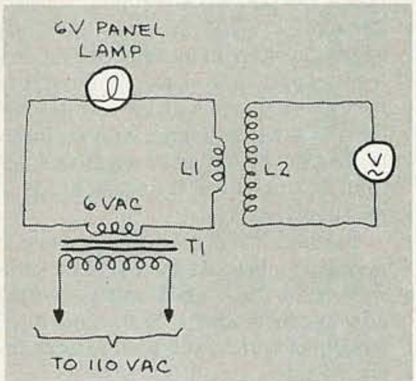


FIG. 3

Let's summarize:

1. Iron cores give greater output than air cores.
2. The closer the coupling of the coils—that is, the closer the input and output coils are positioned—the greater the output.
3. The closest coupling (and greatest output) is obtained when one coil is wound on top of the other.
4. The greater the ratio of the number of turns on the coils (output to input), the greater the output.
5. The greater the current through the input coil, the greater the output.
6. DC current produces output only when it is turned on or off.

Now, fellows, you're ready to make your sensing device. All you have to do is to make a coil out of some of the wire in the automobile (or other) circuit that you want to cause the action. The number of turns needed in the coil will be determined by the amount of current going through it and the amount of output you need to operate your signalling device. If the input circuit is straight DC, you will get only a pulse in the output. If it is AC or pulsating DC (as in the small 12-volt line to the distributor of a car), you will get a constant voltage output that can be rectified to operate the signaling device.

One further word on this sensing method: if the input current is very heavy, as in the case of a car-battery cable when using the starter, one turn may produce enough output for your needs.

Series dropping resistor

The third sensing method mentioned earlier, uses a series dropping resistor. As shown in Fig. 4, you can place a resistor in any circuit and a "voltage drop" will develop across it. That voltage can be picked off and used to operate another device. Of course, that voltage is subtracted from the

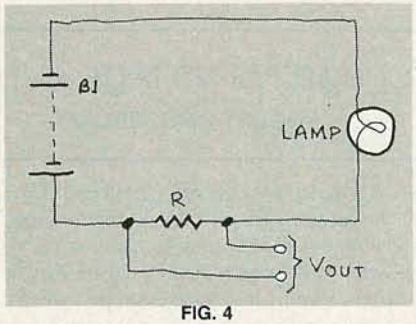


FIG. 4

voltage that would otherwise be available to the normal load (the lamp in the illustration). The amount of voltage dropped across the resistor can be determined experimentally or by using Ohm's Law ($E = I \times R$). Depending upon the nature of the circuit, you may have to exercise special care to determine the power rating (wattage) necessary for the resistor. That's best found by using the formula $P = I^2 \times R$. Also it's a good idea to allow a safety margin by using a resistor with a power rating that's about 50% greater than the formula indicates. R-E

DESIGNER'S NOTEBOOK

A negative-voltage supply

ROBERT GROSSBLATT

THE MOST VALUABLE TOOL ANY DESIGNER can have is his personal notebook. It's filled with all the results of his past experience—everything from shortcuts in design, to handy circuits, to easy ways to avoid production problems. The contents of the book all have one thing in common...they're the results of bitter experience and often expensive mistakes. The more experienced the designer, the fatter his notebook. You probably have one of your own even though it may not be as neatly organized as you'd like it to be.

Every month we're going to give you another page that you can add to your own personal notebook. None of the things will be a finished circuit or complete idea. Each of them will, however, be useful in designing larger systems and will save gallons of midnight oil. They'll range from perfectly obvious to wonderfully elegant and they only have to come in handy *once* to make them worth remembering.

I'll cover everthing from breadboarding, to actual circuitry, to production of the finished product. If you know a way to do the same thing that's easier, faster, cheaper, safer, or slicker, drop me a line and let me know about it. Designing something is tricky enough, and one of the first things to learn is to take all the help you can get. And since the point of this page is to share more than instruct, if you have something to say that's worth listening to, I'll turn the page over to you and we'll all learn something.

ONE OF THE MOST ANNOYING SITUATIONS you can run across when you're designing electronic circuits is the need for oddball numbers in the power supply. In the "Drawing Board" columns that appeared in the May through August 1983 issues of **Radio-Electronics**, we spent a lot of time learning how to handle power-supply designs that would take care of just about any contingency you might run across in a circuit design. We found out how to make cheap regulators do expensive things and how to safely get relatively monster amounts of current from tiny, three-terminal regulators. If you check back through the series, you'll see that we even went into what is ordinarily a real bear of a problem—namely, designing a variable supply that could go all the way down to zero-volts output.

There was a hitch, however. You can only get zero volts out if you can provide the circuit with a real negative reference-voltage—and therein lay the rub. It's always frustrating to need a few measly milliamps from a negative supply when all you have to work with is a supply that's giving you a positive voltage. Now, there are all sorts of schemes for generating something that can be used as a negative voltage or arranging for the rest of the circuit to bias itself halfway up the supply rail. All those things will produce a negative-like voltage, but they're a far cry from having a voltage that really lies below ground level.

A better way

Well, for all of you who have run up against that problem, and for anyone who might, here's a handy way to take care of it. The parts count is really low and the components are ones you probably have lying around.

The heart of the circuit shown in Fig. 1 is the 555 timer. For this application, that timer is set up in its astable mode—in other words, it's an oscillator. With the values shown, the frequency will be about 45 kHz and the duty cycle is pretty close to 50%. (We'll have more to say about that later.) Basically, the components that are connected to the output of the 555 are set up as a voltage-doubling rectifier. Diodes D1 and D2 work as steering diodes much the same as they would on any AC/DC converter.

On the positive half of the 555's output swing, D1 is forward biased, D2 is reverse biased, and C1 charges up. When the 555 goes into the negative half of its output cycle, capacitor C1 dumps its stored charge through D1 and charges up C2. Diode D2 prevents C2 from discharging through C1. What we wind up with is a negative voltage at the anode of diode D2 with respect to system ground and that voltage is renewed with every full cycle of the 555's output swing. With no load on the output you will get a negative voltage from the circuit that is just about equal to the supply voltage.

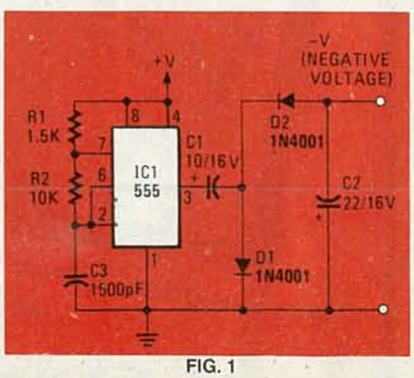


FIG. 1

But that's with no load. In practice, the negative voltage available will be several volts below the supply voltage—exactly how much below will depend on the amount of current you want to draw from the circuit.

The 555 can easily supply 200 milliamps but the most you can safely expect from the negative supply is about 60 milliamps since we're only renewing the charge on C2 during half the output swing of the 555. If you study the schematic closely, you'll see that capacitor C2 is only being used to store the charge originally on C1..

Now you can see why the frequency of the 555 is set fairly high—we have to renew the charge on capacitor C2 fairly often if we want to power anything remotely useful with the circuit. The duty cycle of the 555 has been set close to 50% because we have to allow time for capacitor C1 to discharge.

If you only need a small amount of current from a negative supply for your application—to power something like an op-amp, for instance—you'll find that circuit to be just what the doctor ordered. On the other hand, be aware that if you're looking for really serious amounts of power, that approach won't help and you'll actually need a split supply.

There's no reason why you can't regulate the negative supply by using a series regulator (any of the 79xx series). Since they only use a few milliamps to operate, there won't be any undue load on the circuit—there will be about a 2-volt loss, however.

The next time you design something that has to have a split supply, add up the current you'll need from the negative side and see whether this circuit can supply it. If so, why not give it a try; it's easy to put together and a lot cheaper than a center-tapped transformer. **R-E**

COMMUNICATIONS CORNER

Changes in communication technology

HERB FRIEDMAN, COMMUNICATIONS EDITOR

CALL IT HIGH-TECHNOLOGY SHOCK, OR whatever you choose, the rapidly changing ways in which we communicate has finally shaken those who own and operate our present communications systems, as well as the politicians who regulate them.

Since we all use some type of communications system, we thought you might be interested in knowing what's going on in the communications industry.

First, in case you haven't heard, on July 22, 1983 virtually all restrictions came off the FM broadcast-station SCA (*S*ubsidiary *C*ommunications *A*uthorization) subcarriers. Simply stated, what that means is that the operators of common-carrier, paging systems and the like, are no longer required by regulations to carry program material on the main channel to carry programming on the SCA subcarrier. As long as the station-identification is given on the hour, the main channel can be dead, with only the SCA subcarriers in operation. (How long will the FCC permit that to continue?)

Reminiscent of the forty-niners rushing to get to the goldmines of California, the modern-day prospector rushed to put almost everything imaginable on the FM subcarriers. Everything from travel tips, to computer data, to common-carrier services, and even radio paging for Mom, Dad, and the tots may be carried via your local FM station. Say, for example, you want to call Junior and Sis in from the sandbox, or have them meet at one of those umpty-ump-acre theme parks: Just dial a phone number and your local FM station will make their pocket pagers go beep beep. Of course, the next step is sure to be some sort of code (One beep means come home, two beeps: pick up a dozen eggs, and three beeps: bring home a hot-fudge sundae, etc.).

All joking aside, we haven't begun to comprehend the effect that FM-broadcast paging will have on our lives. With the stacking of calls permitted by digital signaling, the gradual movement away from VHF services, and high-tech designs pushing the cost of a pocket pager to below $50; we may soon be buying our personal pager at the local supermarket. It will probably be sold like The Source and Dow Jones information services for computers.

Don't think that SCA digital signals are limited to just paging. Straight data such as stock-market quotes, and even computer programs for the home can be provided—though no one has figured out a cheat-proof billing system yet. However, the potential is so great that VHF operators must restudy where their service stands as the new age of personal communications unfolds.

The second group to suffer the aftershock was the politicians. In some areas, cable-TV was the politician's pot of gold; they've taxed the cable services for just about everything possible. They've even gone so far as to push them into providing so-called free public-access channels along with studio facilities. Very often the politicians were so busy trying to find new ways to tax the cable industry that years dragged by before the cable was ever installed. For example: in New York City, the leading center for communications, cable TV outside of Manhattan (what visitors usually consider to be the entire city) was ten years behind the times because the politicians tried to squeeze blood from a stone. In fact, until they saw the specter of high technology on the wall, nearly four million people had no hope of receiving cable TV in their homes. Unfortunately, the system they'll get will probably be outdated before it's ever installed.

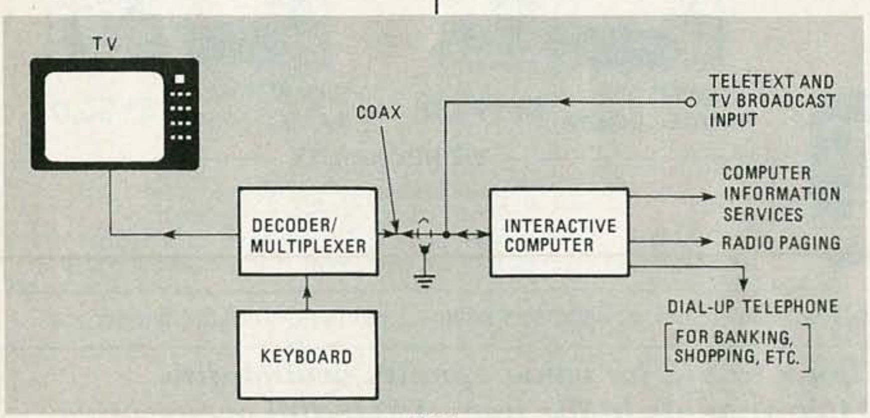


FIG. 1

What is the specter on the wall? It's DBS (Direct Broadcast Satellite). Only three years ago there was no such thing as DBS, not even the concept. For those not familiar with DBS, it works in the following way. Imagine a small microwave-dish antenna (under two feet in diameter) on everyone's rooftop. That antenna could possibly receive 100 channels directly from a satellite. For encoded pay-TV, viewers could order a decoding signal transmitted through the telephone system and have the costs for the service charged to their credit cards.

The idea of DBS broadcasts completely free of local and state control really shook-up the politicians. In fact, it resulted in a hard-hitting letter to the *New York Times* by a state legislator who feared that DBS would eventually eliminate the need for interactive cable service. That was the first time the general public learned that there was a state committee looking into cable service and not from the viewpoint of TV reception. (What's happening in your state?)

The reason for interest on the state level is that cable TV is presently the most advanced form of interactive communications. Since almost anything you want or do will wind up on some form of TV display, the easiest thing to do is to integrate it into a home system. The general idea is that two-way digital communications could be multiplexed on the cable in addition to regular TV programs. That would allow viewers to transmit requests for specific TV shows, computer programs, videotex or teletext data, and even pay their bills through the bank using a home computer system. An example of what a DBS setup might look like in your home is shown in Fig. 1. For simplicity we won't go into the transmission of digital TV pictures.

How it works

That setup could consist of a TV receiver, a digital keyboard, and a multiplexer (as shown). The multiplexer would encode and decode digital information. The digitized instruction (or data) is generated at the keyboard and encoded by the multiplexer. That signal would then be transmitted to the head-end (cable service) using standard coaxial cable that handles signals in both directions. At the head-end, the digitized instructions (received from your home) are sent to a central computer that can handle any number of specialized services. That computer would do the routing to the bank, control the electronic lock on your TV (so you can view a pay-TV program), or even make your doctor's pager go beep because your blood pressure is too high. The customer could also order computer programming that would keep personal records, tutor the tots, or whatever is desired.

Aside from the loss of tax revenue, what worries politicians is that DBS might mean the death of interactive cable. After all, DBS can provide all the non-interactive services such as TV; while the interactive functions could easily be accomplished through the telephone system, using personal computers, as is presently being done by some local banks. Then, why have interactive cable? The *why* is what bothers the politician, because it means the *loss of information*.

Politicians foresaw the ability to learn everything there was to know about their constituents through the interactive cable-network. How you ask? Say, for instance that you pay your doctor, lawyer, bank, charge account, etc. by interactive cable (which is what the bankers envisioned): Now, add to that information on what kind of movies you order (adventure, triple-X, or PG): Couple that to the kind of programs you're willing to pay for, and whether you've made a contribution to a political party through an interactive fund-raiser. And you'll find that a single billing computer has an almost perfect profile on you and your family. That's one heck of a lot of personal data, worth more than the cost of the cable service (to the politician).

As you can see, if DBS systems were used for TV reception; the whole cable system would not be necessary. With a small personal computer connected to the telephone system you could handle your own communications directly with the bank, the doctor, the computer service, or anyone. Also, there'd be no centralized records on you or your family.

Right now, FM subcarriers and the interactive cable system represent the leading edge of high technology for personal and family communications. But keep an eye on DBS. It can do a lot more than just transmit TV pictures. R-E

COMPUTER CORNER

IBM's new computer

LOU FRENZEL

IBM HAS BEEN IN THE PERSONAL-COMPUTER business for only a little over two years. However, in that short period of time it has managed to capture approximately 25% of the total market. That's an incredible amount and the greatest percentage held by any one manufacturer. Apple is second with over 20%, while the rest of the market is divided up among well over a hundred others including Texas Instruments, Commodore, Radio Shack, and Atari.

IBM's success is attributed to two major factors. The first is that the IBM *PC* is a fine machine. It is powerful, flexible, and can be configured and expanded to almost any application.

Of course, the other reason is IBM's well-known name and reputation. It's a big company that one can trust. Consumers like that.

The IBM *PC*, however, is really no home computer. By that we mean that it is an expensive machine that few individuals can afford for home applications. While the *PC* can play games with the best of them, it is not the kind of machine one buys for entertainment alone; it is a serious computer for business applications.

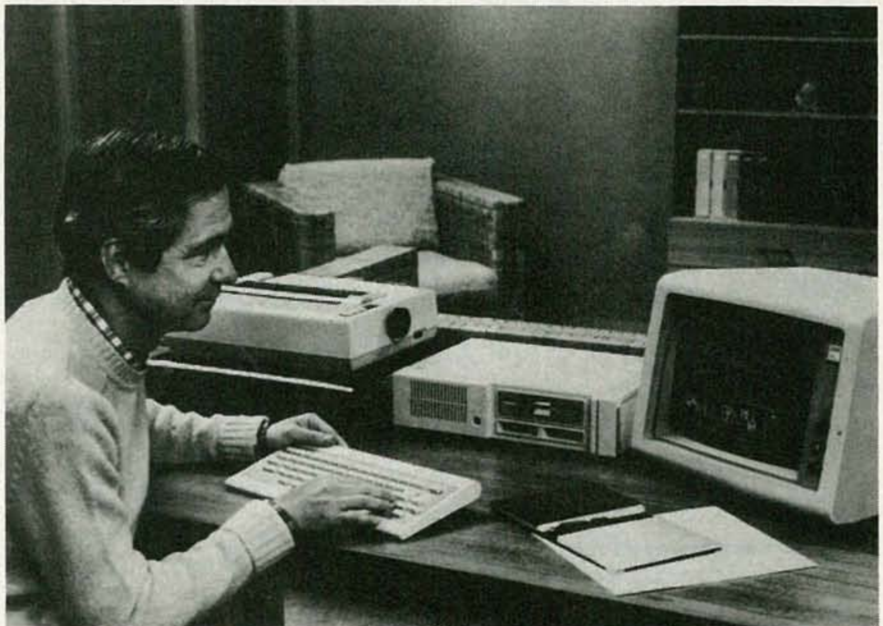


FIG. 1

The new machine

On November 1, 1983, IBM announced a new home computer called the *PCjr* (see Fig. 1). Rumors about that new home computer, which had been code-named Peanut, have been around for almost a year. Unlike the *PC*, IBM's new machine is a product that's aimed directly at the home-computer marketplace.

The rumors about the *PCjr*, which IBM would neither confirm nor deny, greatly affected the home-computer industry. The most significant effect that it has had was to hold prospective buyers in place to wait for the new product. Competitors claim that that took away a lot of sales. Now that the new computer is available, perhaps the home-computer marketplace will settle down for a while. Then again, maybe it won't.

So what is the new *PCjr* like? First of all, it uses the popular 8088 microprocessor. The original rumors indicated that the machine would use Intel's latest variation of the 8088 known as the 80188. However, large-scale production problems and/or high price levels could have been what made IBM change its mind.

The *PCjr* comes in two basic forms. In its lower price form it contains 64K of RAM and no disk drive. It does have provision, however, for two plug-in ROM cartridges.

In its expanded form, the *PCjr* comes with 128K of RAM and a single 360K disk drive. (The basic model can be upgraded to the enhanced version.) To use the disk drive, you must have IBM's latest version of the PC-DOS operating system, version 2.1. That updated and revised version of PC-DOS 2.0, which was introduced in March 1983, is used by the IBM *PC/XT*. The *PCjr* cannot run PC-DOS 1.1, which is the primary operating system for most IBM personal computers.

One of the most interesting features of the new machine is its keyboard. The unit uses its own specially designed 62-key keyboard. It is unique because it's cordless. The keyboard communicates with the base unit via infrared, using an arrangement similar to that used with most remote control units on TV sets. The keyboard has a range of about 20 feet and, of course, contains its own built-in battery supply. That cordless feature gives great flexibility in using the machine and should make it popular in a home environment. A cord is available at extra cost for those who want one, or for those instances where more than one unit is in use.

That's not to say that all is well regarding the keyboard. Rather than using a standard typewriter-type keyboard, IBM has chosen to go with calculator-type keys. That type of keyboard is just not suitable for applications such as word processing or any other task where productivity is important. The reasons for IBM's choice of keys is not clear. Cost may have been a factor, or perhaps the company was worried that the *PCjr* would cut into the sales of *PC's* to business.

Like most other personal computers, the *PCjr* comes with BASIC. Here, a version of Microsoft's BASIC interpreter is stored in ROM. Also stored in ROM is a cassette-tape operating system that lets you use a cassette recorder for mass storage. The ROM also contains a short tutorial on how to use the keyboard.

Many of the applications programs for the *PCjr* are supplied in plug-in ROM cartridges. Most of those are games and simple educational programs. Included among those cartridges is a 32K BASIC enhancement that allows you to use a joystick or lightpen. It also upgrades the BASIC's graphics and music capability.

For more advanced applications, the software is, of course, available on disk. Among the disk software currently available for the machine is *PFS:File*, *PFS:Report*, and *Time Manager*.

Note that most of the disk software available for the *PCjr* is not compatible with the original *PC* and vice versa. It would have been foolish of IBM to make the two machines compatible. IBM would lose millions in sales of their big machine to the *PCjr* if that were the case. While many of the available programs can be run on both, they come in versions that are specially adapted to the particular machine.

Finally, the *PCjr* displays 40 columns (80 columns in its enhanced version) on a standard TV set, color video monitor, or RGB monitor.

With regard to accessories and peripherals, IBM offers an internal modem module for communications applications, joysticks, and a parallel interface for a printer. IBM is also offering a compact thermal printer that will accommodate 80-character lines and graphics. At a suggested price of $169, it is one of the lowest priced printers on the market.

It's anybody's guess how popular the IBM *PCjr* will be. But if the popularity of IBM's original *PC* is any indication, you can expect it to be an overwhelming success. It'll probably be tough to beat. With a huge number of sales expected, third-party software and accessories companies will spring up everywhere to provide software and hardware of all types. If you are shopping for a home computer to play games, or to use for educational purposes, the *PCjr* is a good one to look at. In its basic form it sells for $695. The enhanced disk-drive model sells for $1295.

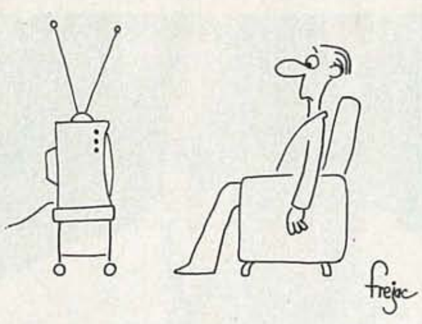
Long Live the Competition.

The *PCjr* will obviously make a dent in the home-computer market. However, it is high priced for a home computer, leaving ample marketing opportunities for other manufacturers. Popular home computers like the Commodore *64* and Radio Shack's *Color Computer* models may not be severely affected by the *PCjr*. Most of those machines sell in the $200 to $300 category and, as a result, are a lot more affordable than the up-scale *PCjr*. There are still millions of people who want a low priced entry-level machine. For instance, for those just coming to personal computers, an inexpensive introductory product is desirable since it limits their outlay should they find that they don't like computing. Better to have a $200 machine on a closet shelf than a $600 or $1200 one.

IBM's new entry seems to be targeted at more affluent entry-level customers. It is also aimed at home users looking for their second machine. The *PCjr* is certainly a step up from the low-end machines, but it does not require the cash commitment that a machine like the *PC* does.

Another area that the machine should do well in is education. In fact, the *Wall Street Journal* recently reported that Virginia Polytechnic Institute has ordered 1600 units for use by their engineering students.

IBM, then, has chosen an interesting niche for its new machine, one that will guarantee them incredible volume but also one that will not destroy the competition or their booming *PC* business. **R-E**



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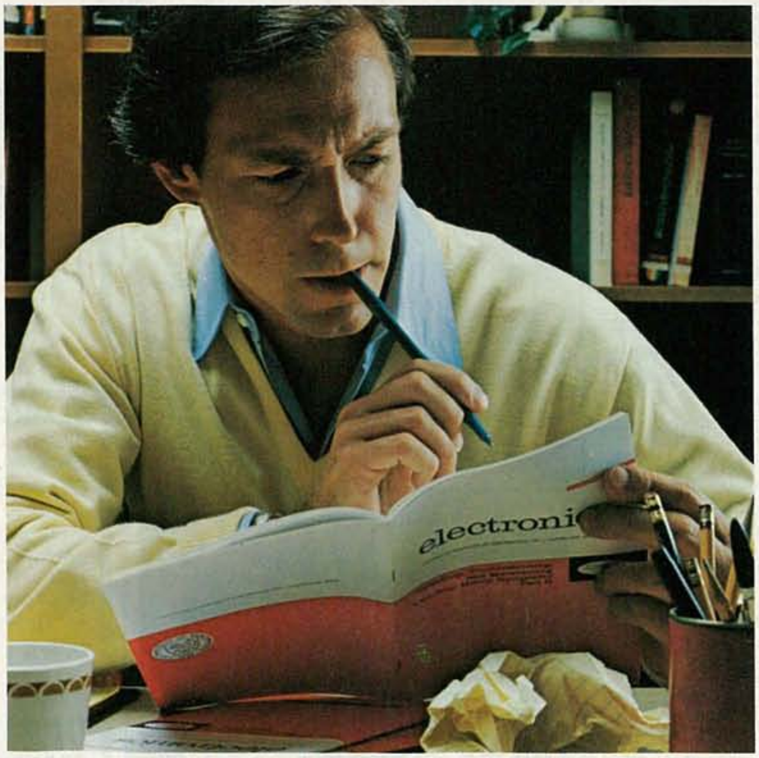

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STATE OF SOLID STATE

Telephone ringer IC's

ROBERT F. SCOTT, SEMICONDUCTOR EDITOR

FOR YEARS, MANY OF US HAVE FOUND THE strident tones of a telephone bell annoying and have wished for something with a more pleasant tone. Others have wanted an extension telephone ringer in the garage, workshop, or similar location, but never got around to having one installed by the telephone company. Now, Motorola has introduced the MC34012 telephone bell ringer IC, a simple solid-state device that can be used as a solution to both problems. A pinout of that device is shown in Fig. 1.

Let's see what the pin functions are: Pin 1 (RG) is the negative output of the internal diode bridge. Pins 2 and 3 (AC_1 and AC_2) are the input terminals for the AC telephone-line ringing signal. Pin 4 (RO) is the ringer output terminal. Pin 5 (RI) is the positive supply terminal for the oscillator, frequency divider, and buffer/amplifier circuits. Pin 6 (RS) connects to an external sense resistor, pin 7 (RF) connects to a filter capacitors, and pin 8 (RC) connects to an external R-C circuit that controls the frequency of the internal oscillator.

The MC34012, a monolithic I²L linear device, is housed in an 8-pin plastic DIP. That IC is used to drive a piezoelectric ceramic sound transducer to produce a pleasant warbling tone at a suitably high audio level. It is available in three output-frequency ranges, and those ranges are indicated by the suffixes -1, -2 and -3 that identify the 1-kHz, 2-kHz and 500-Hz devices, respectively.

The MC34012-1 has a base frequency of 4 kHz and produces 800-Hz and 1000-Hz tones. Similarly, the MC34012-2 oscillator operates at 8 kHz and generates 1600 and 2000-Hz tones. The MC34012-3 has a 2-kHz oscillator and produces a 400- and 500-Hz tone. The warble frequency of the devices is 13 Hz. The tone ringer output can source or sink 20 mA with an output-voltage swing of 20 volts peak-to-peak.

The input impedance presented to the telephone line by the devices meets Bell and EIA requirements. Typical performance characteristics of the three devices are given in a table available from the manufacturer. Now, let's look at how those devices work.

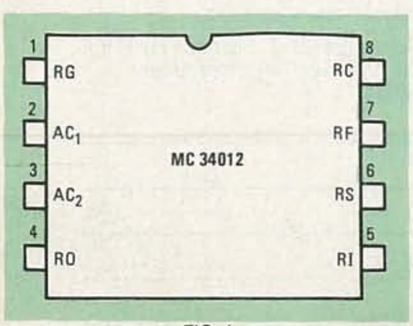

FIG. 1

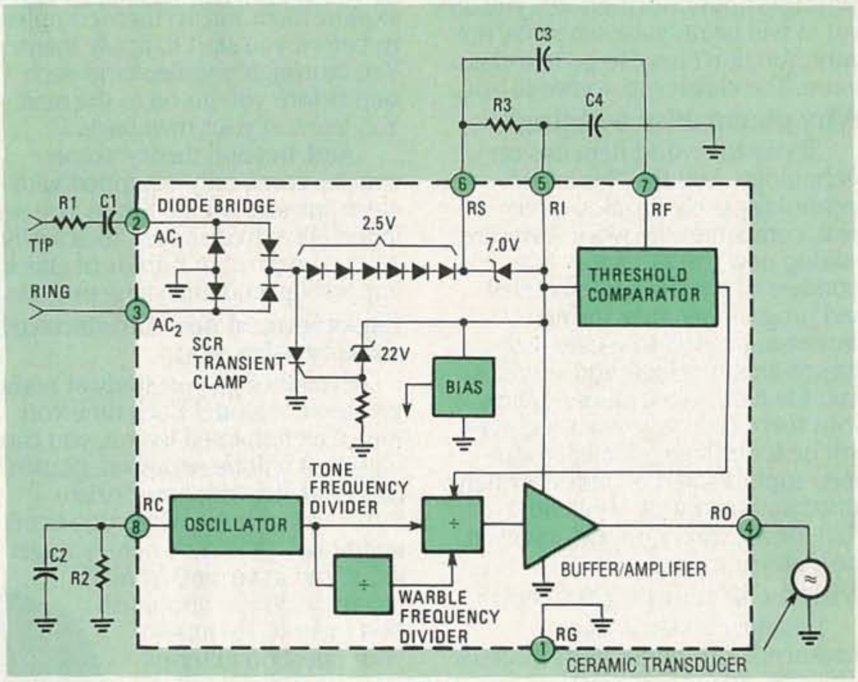

FIG. 2

How the ringer works

Figure 2 shows the functional block diagram of the MC34012. It consists of a relaxation oscillator and two frequency dividers that provide the high- and low-frequency segments of the warble tone, as well as the 12.5-Hz warble rate. The IC is connected across the telephone line through the series network consisting of R1 and C1. The line-input resistor, R1, controls the ringer's input impedance as seen by the telephone line. That resistor also limits potentially harmful current surges caused by line transients, and influences the ringing-threshold voltage. The value of R1 can range from 2000 to 10,000 ohms. Capacitor C1 provides AC coupling between the line and the IC, and also controls the ringer's input impedance at low frequencies. The value of that capacitor can range from 0.4 to 2.0 μF.

The base frequency of the relaxation oscillator, which can range between 1 kHz and 10 kHz, is determined by the values of R2 and C2. The capacitance value of C2 may range between 400 pF and 2000 pF. Frequency-determining resistor R2 may be a selected value between 150 and 300 kilohms. The frequency of the warble tone at the ringer output terminal (pin 4) switches between $f_0/4$ and $f_0/5$ at a 12.5-Hz rate.

The DC voltage needed to power the IC is obtained by rectifying and filtering the 20-Hz AC ring-signal voltage (60 to 90 volts RMS). That DC voltage supplies power to the tone generator and the circuits needed to drive the ceramic transducer. The ringing-signal voltage is rectified by the full-wave bridge and develops currents along two paths. In one path, an

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THE DRAWING BOARD

Using the 4018

ROBERT GROSSBLATT

LET'S CONTINUE THE DISCUSSION OF THE 4018 that we began last time.

Before we see what's necessary to make the 4018 start to do things in the real world, it's a good idea to spend a little time going over the circuitry we need to make the device programmable. The first thing you should realize if you start playing with the IC is that the JAM inputs and Q outputs are complimentary—when an input is low, the corresponding output is high. The reason for that apparent bit of insanity has to do with the internal design of the device and is just one of those things we'll have to live with. In passing, it should be mentioned that there are ways to take care of that if you regard it as a problem.

Remember that that IC is really a series of daisy-chained flip-flops; i.e. a shift register with parallel and serial inputs. When we make it programmable, all we're doing is preloading the flip-flops. That fact, coupled with the fact that the zero count has all highs on the outputs, makes the coding of the 4018 unique. Table 1 is a listing of the code to keep in mind when you use the JAM inputs.

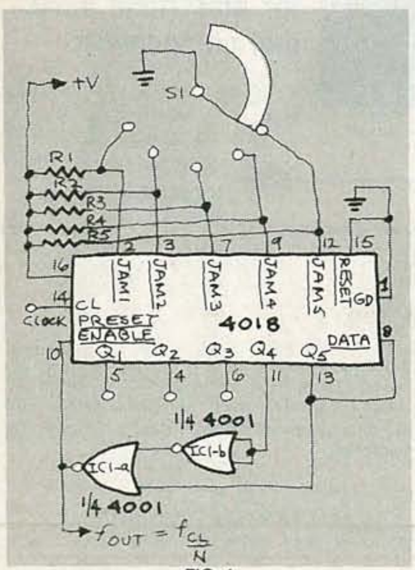

FIG. 1

In Fig. 1 we have the circuitry we talked about last month. Resistors R1 and R5 hold all the JAM inputs high. They're selectively brought low with S1, a rotary switch that encodes all the inputs properly. The 4018 won't pay any attention to the JAM inputs unless the PRESET ENABLE pin, pin 10, is brought high. That is taken care of by IC1-a and IC1-b, half of a 4001 quad NOR gate. If you look at the data in Table 1 you'll see that Q4 and Q5 can be decoded when the count reaches nine and we can use that to flash a high at the PRESET ENABLE. If that looks strange compared to the 4017, remember that preloading the 4018 at the JAM inputs means that we're telling the IC what number to start the count with; on the 4017 we were telling the IC what number to end the count with. That may seem a bit strange but such are the peculiarities of things in the digital world. Seriously though, it's really a very important point and you should make sure you understand it.

TABLE 1

JAM1	JAM2	JAM3	JAM4	JAM5	COUNT	Q1	Q2	Q3	Q4	Q5
0	0	0	0	0	0	1	1	1	1	1
1	0	0	0	0	1	0	1	1	1	1
1	1	0	0	0	2	0	0	1	1	1
1	1	1	0	0	3	0	0	0	1	1
1	1	1	1	0	4	0	0	0	0	1
1	1	1	1	1	5	0	0	0	0	0
0	1	1	1	1	6	1	0	0	0	0
0	0	1	1	1	7	1	1	0	0	0
0	0	0	1	1	8	1	1	1	0	0
0	0	0	0	1	9	1	1	1	1	0

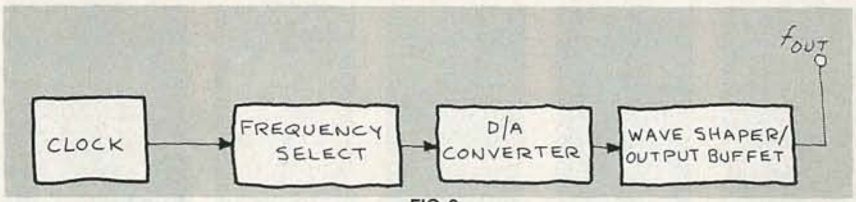

FIG. 2

There is a fundamental difference in the 4018's fixed and programmed modes. Obviously the hardware is different, but there's also a difference in just how the IC goes about actually dividing a frequency. In the fixed mode, the data on the selected output pins is constantly being recirculated through the internal flip-flops.

When the count reaches the number you've chosen for division, a logic one (high) is force-fed to the DATA input and appears at the Q1 output with the arrival of the next incoming clock pulse. What is really happening here is that a particular stream of ones and zeros are trapped in the IC. Division, then, is being done by starting with a count of zero and working our way up the ladder.

Fixed mode division, as we've already seen, is quite a different thing. We preload the beginning number and let the device count from there to ten. The output frequency in that case can be picked off the DATA input just as it was in the fixed mode, but the waveforms are very different in the two cases. With fixed-mode division we wind up with a 50/50, or nearly 50/50, duty cycle. In the programmed mode, symmetry is out the window.

What, you may very well ask, is the advantage in using that IC? Well, the parts count is lower in circuits using the 4018 than in circuits using the 4017—only two external gates are needed as opposed to four—and we have a means of programming the IC that is completely independent of the outputs. If you think about that for a moment and take another look at Fig. 1, you'll realize that the rotary switch there could easily be replaced by something much more exciting and versatile, namely a microprocessor. We'll get back to that in a few months or so.

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SERVICE CLINIC

An easy and accurate IFT test

JACK DARR, SERVICE EDITOR

SEVERAL YEARS AGO, THE FIRST INTEGRATED flyback transformers (IFT) began to appear. Those first IFT's gave many technicians quite a bit of trouble, so it was very natural that they weren't too fond of them! However, over the years they've been dramatically improved and today are used in many modern TV sets. Because of that, we thought you might be interested in an easy and very accurate test method that we've recently run across.

The method that we'll describe here doesn't use any test equipment that you don't already have (or should have!). All that's needed is a variable transformer, a scope (either single or dual trace), an AC ammeter, and a couple of short clip-leads. Basically, all you have to do is to arrange things so that the horizontal oscillator runs. Then monitor the prescribed test points (with a scope) while gradually increasing the line voltage to approximately ⅓ of its normal value.

Procedure

The first thing to do is to connect the variable transformer and ammeter as shown in Fig. 1. The ammeter should have a range of at least 5 amps.

Figure 2 shows a partial schematic of Sylvania's C3 color-TV chassis that we talked about last month. While we'll talk specifically about that chassis, the method we'll use can be adapted to others. Assuming that you're using a dual-trace scope, first connect Channel A of the

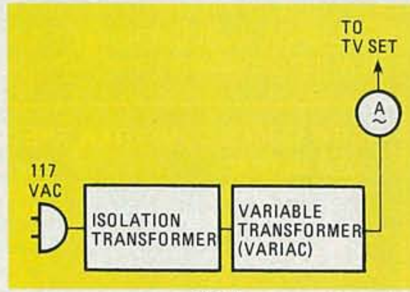

FIG. 1

scope to the output of IC500, the horizontal oscillator. (That IC isn't shown in the figure, but its output is—at the input of Q400.) Set the Channel A attenuation to 5 volts and the timebase to 10 μs-per-divi-

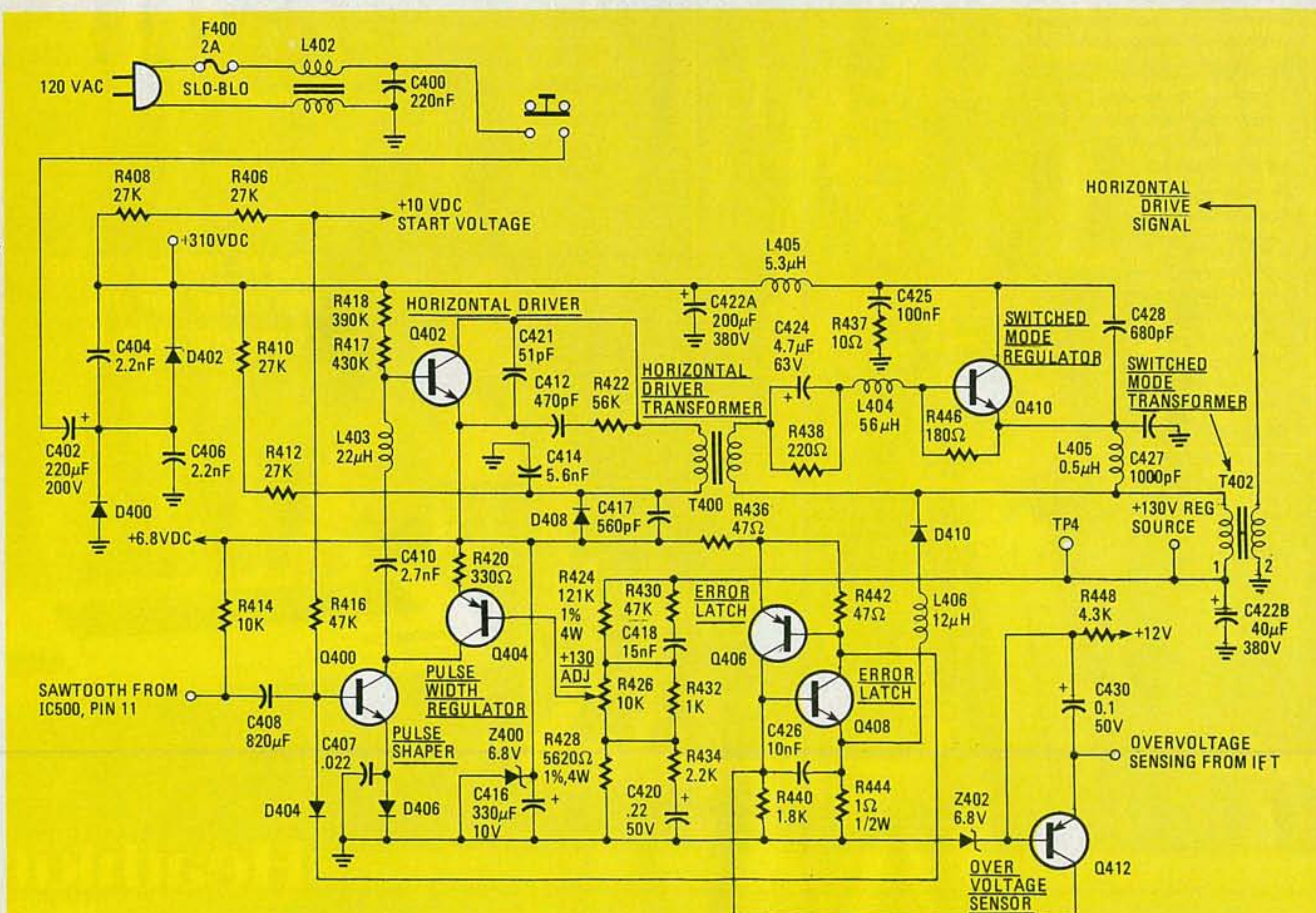

FIG. 2

sion. Now, connect Channel B to the collector of Q452, the horizontal-output transistor. (That transistor also isn't shown. The horizontal drive signal—from T402—is fed to its base.) Set the scope to 10 μs-per-division and the attenuation to 100 volts.

Next, connect a clip lead across R406 in the starter circuit. Doing so raises the start voltage to a level that will maintain the operation of the horizontal oscillator. That voltage is normally 10-volts DC, but at the reduced line voltage you should read about +5.6 volts. Note: Our tests were made with the line voltage as low as 40-volts, AC; you shouldn't have to raise the voltage above 70-volts AC. Before going any further it's a good idea to disable the error latch circuit by removing R436. That's because if there's some other trouble with the set, the error latch may fire and kill the horizontal drive signal. **Caution:** be sure that the set is never plugged into full line voltage with R436 removed or you'll be inviting a mess of trouble for yourself.

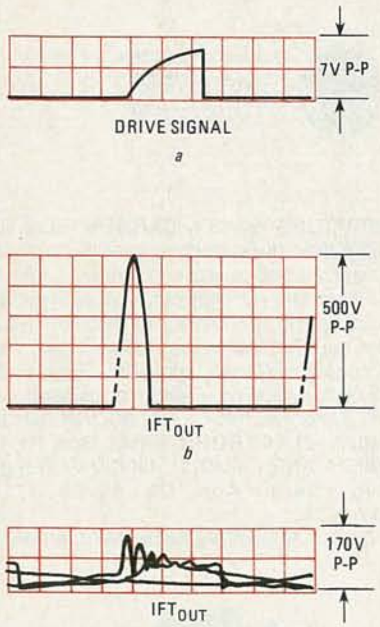

FIG. 3

Now using the variable transformer, gradually increase the line voltage until you see a 7-volt peak-to-peak sawtooth signal on Channel A of your scope. That sawtooth signal goes to the pulse-shaper and the switched-mode transformer that drives the horizontal-output circuitry. If the Channel A scope pattern is like the one shown in Fig. 3-a, you have a good drive signal. Now, look at Channel B, you should see a clean 500-volt peak-to-peak pulse as shown in Fig 3-b, if so the IFT is good. If the drive signal is good but you have a distorted or scrambled signal on Channel B, as shown in Fig. 3-c, you've got a problem.

If the signal is distorted be sure to check all rectifiers used in the numerous low-voltage supplies (there are 4 or 5 of them). Watch out for shorts. Should your measurements indicate a short, stop and check out all of the low-voltage supply circuits. A shorted diode in any one of those supplies will cause trouble. Also, check for blown fuses and burnt components. If you discover any evidence of a short, measure the resistance of the associated components and make any necessary repairs. Study the schematic carefully to see if there is a low-voltage shutdown circuit in the set. If so, disable it and follow the same procedure as before. (The same precautions apply.) If after making all the necessary checks, you still get an indication of a short circuit, you can be fairly sure that the IFT is bad and should be replaced. If you don't get the correct waveform, check the time-per-division setting of your scope. After servicing, check to see that all jumpers have been removed and all disconnected parts have been replaced.

Though the above method was developed for the Sylvania/Philco C3 chassis, we don't see why the basic procedure couldn't be adapted to other manufac-

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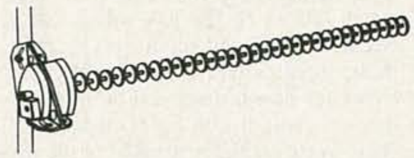

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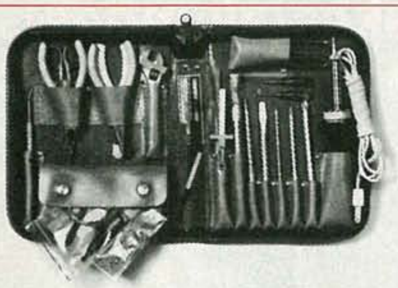

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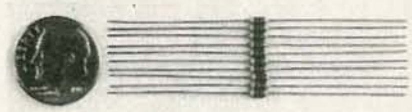

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SERVICE CLINIC

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turer's sets using the same type circuitry with a little ingenuity. That is, provide a start-up and run voltage to the horizontal oscillator with an external low-voltage DC supply. You don't have one? How about the bias box in your alignment setup? They have the right voltage and most of them will supply the full current needed! If you don't have one, but your sweep generator or marker/adder has one or two built-in, that's fine (my Heathkit *IG-57* does).

Why not try looking for other ways to use that test setup; it just might turn out to be a handy-dandy idea! R-E

SERVICE QUESTIONS

SYNC PROBLEMS

I am having trouble tracking down the cause of a problem with an RCA EQ-335W. The set works fine until there is a dark

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STATE OF SOLID STATE

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internal Zener diode between pin 5 and ground provides 22 volts to operate the oscillator, frequency dividers, and buffer/amplifier output stage. Capacitor C4 (1.0 to 10.0 μF) filters the supply voltage for the tone-generator circuits and provides an AC-current path to ground for the 10-volt RMS ringer signal when the phone ringer is not driving a load. Potentially harmful line transients trigger the SCR when the Zener regulator current exceeds about 50 mA. When the SCR fires, it diverts current from the shunt regulator and reduces the power dissipated within the IC.

In the second current path the rectified ring-signal voltage produces a current flow through R3, the input-current sense-resistor, to control the ringing-threshold voltage. The design range for R3 is 800 to 2000 ohms; increasing that resistor decreases the ring-start voltage. Capacitor C3 filters the voltage across R3 at the input to the threshold comparator and also filters out the transients developed by the telephone dialer. When the voltage across C3 exceeds 1.7 volts, the threshold comparator enables the output buffer/amplifier so that the warbling tone-ringer output signal reaches the ceramic transducer. Suitable values for C3 range between 0.5 and 5 μF.

The MC34012 telephone tone ringer is available from Motorola distributors, and wholesale and retail parts suppliers and is priced at $1.24 each in lots of 100 to 999. Suitable piezoelectric transducers include the PT-7 and PT-8 models from **Mallory Distributor Products Co.** (Box 1284, Indianapolis, IN 46206) and some of the transducers from **L&M Components**, (PO Box 25110, Portland, OR 97225).

New microelectronics data book

Microelectronics Data Catalog is a new (1983) 559-page edition that provides detailed technical and design data on General Instrument's line of integrated circuits. The nine families of digital microcircuits presented are dedicated to the computer and communications industries. Product categories listed by chapter, include ROM'S, EAROM'S (*E*lectrically *A*lterable *R*ead-*O*nly *M*emories), Microcomputer, Audio, Telephony, Data Commuications, ULA's (*U*ncommitted *L*ogic *A*rrays), Video, and Tuning. It is offered free and may be obtained through world-wide sales offices **General Instrument,** Microelectronics Div., 600 W. John St., Hicksville, NY 11802. **R-E**

DRAWING BOARD

continued from page 90

A sinewave generator

For the moment, however, let's get back to the reason we started playing around with the 4018. Look back at the timing diagram that appeared in February's column, the first thing that comes to mind is that the symmetry of the outputs is perfect for generating sinewaves. As a matter of fact, that is one of the most common uses for the 4018. Before we actually start doing the design, let's lay down the design criteria.

1. The parts count will be as low as possible.
2. Battery operation will be possible.
3. The bandwidth will be at least 100 Hz to 100 kHz.
4. The output frequency will be controlled by a potentiometer.

There are all sorts of additional bells and whistles that we could add to that list—readouts, keyboard frequency-selection, and so on. All those sorts of things are design problems on their own and are really beside the point. Once we've described the basics we can spend a bit of time exploring the extras.

If you stop and think about it for a moment, the basic method behind generating a sinewave with a 4018 is simple. Of course, that's just the basic method. Just as with anything in electronics, once you get past the beginning, things have a nasty habit of getting incredibly hairy. How sharp your razor has to be in order to cut through it all depends on a lot of things ranging from the depth of your interest to the extent of your need.

As you should all know by now, the first step in any design is to make sure you know what you want to do and then work out the bare bones of the problem on paper. You can't talk about components and circuitry unless and until you've got a clear idea of your objectives and a block diagram of a possible solution in front of you. Since we know what we want to do, our next step is to draw a block diagram.

Figure 2 is a representation of what we want to design. It looks simple because the problem is simple—don't forget that we've already decided, at least for the moment, to drop a lot of the bells and whistles.

All of our discussions the last few months have been aimed at laying the groundwork for an understanding of the design of the D/A converter shown in the block diagram. All we're talking about there is using the 4018 to convert a stream of clock pulses into something that can be made into a sinewave. How we would go about doing that should be evident after a quick look at the 4018 timing chart in February's column. All that wonderful regularity at the outputs is just perfect for what we have in mind. It's a matter of adding the outputs together in some way to create an up and down staircase that we can iron smooth with the wave shaper.

As with any D/A conversion, the more digital steps you start with, the better the analog signal you wind up with. Since the 4018 has five internal flip-flops, we'll use them all. Not only will that give us the maximum number of digital steps, but it helps us satisfy the first of our design criteria—keeping the parts count down. Using all the flip-flops in the device means that we're setting it up to divide by ten. Again, take a look at February's column if you're not clear about that. When you use the 4018 for fixed division by ten, the external parts count is exactly zero! You can't do much better than that.

If the IC is going to be dividing by ten, it follows logically that the input clock has to run ten times faster than the maximum frequency we want for our sinewave. Criterion 3 means that we're going to need an input clock that can put out everything from a minimum of 1 kHz to a top of at least 1 MHz.

When we continue next time, we'll work out the details of the circuit and see what we have to do to make it work. **R-E**

VIDEO GENERATOR

continued from page 48

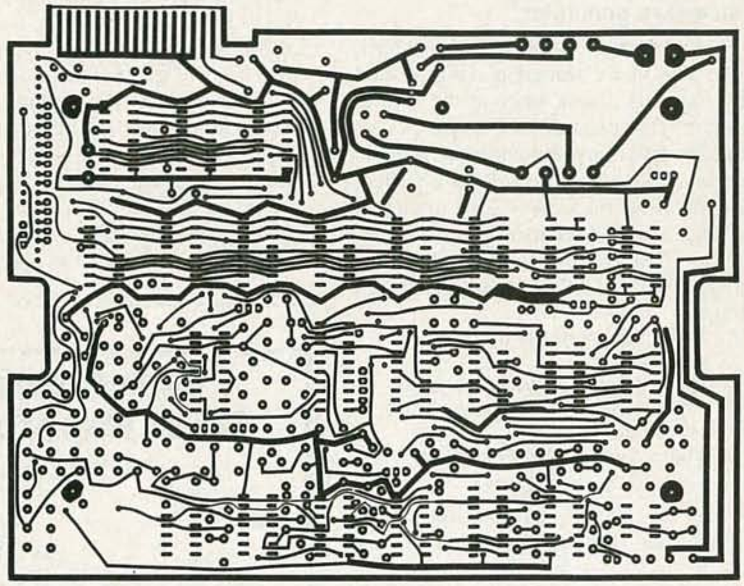

FIG. 5—THE SOLDER SIDE of board A is shown here, also at half its actual size.

IC21, IC27–IC31, IC36, and IC42. The IC's in the TO-220 cases (IC43, IC45, and IC46) mount with the metal tab either to the top of the board (IC46,) or to the right of the board (IC43 and IC45) as shown in the parts-placement diagrams.

We'll assume that you have all of the on-board components mounted on both boards. The next step is to install the 37 jumpers on board A, using No. 26 wire. Their connections are marked on the parts-placement diagram in Fig. 10. Some of the jumper ends, as indicated, also serve as test points. Leave some extra bare wire protruding through the component side of the board for that purpose.

When all the board-A jumpers are mounted, the inter-board jumpers should be installed. Of course, before you install the jumpers, you must decide how you will mount the boards in a cabinet. Figure 11, not shown in this issue, shows how the boards are mounted in the author's prototype. Board A is mounted on the bottom half of the cabinet on ⅛-inch spacers, and board B mounts without spacers in a complimentary fashion on the top half. The 26 inter-board signal wire connections (No. 26 wire) are 3¼ inches long; and the two inter-board power wire connections (No. 20 wire) are 4 inches long. If you keep the connections to that length, they will fold neatly when the two halves of the cabinet are joined. Yet you will still have easy access to both boards (for alignment and service) when the cabinet is open. Note that IC44 is mounted on the rear panel of the cabinet. Be sure to use a heat sink and a TO-3 mounting kit. Apply silicone grease between case and heat sink for good thermal transfer, and use at least No. 22 wire for connection to the board.

The other off-board connections include the front-panel components: switches S1–S4, and jacks J1–J5. Use No. 26 wire for those, except J2; use a short piece of minicoax (RG-174) for that connection. Use a strain relief for the power cord on the back panel and your construction should be complete.

When we continue, we'll discuss how to check out and align the generator, and we'll show you Figs. 6–11. **R-E**

"It looks as if his horizontal hold needs some adjusting."

NEW BOOKS

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ELECTROSTATIC DISCHARGE CONTROL: Successful Methods for Microelectronics Design and Manufacturing, by Tarak N. Bhar & Edward J. McMahon; Hayden Book Company, Inc., 50 Essex Street, Rochelle Park, NJ 07662; 194 pages including references and index; 6⅛ × 9 inches; hardcover; $14.95.

Static electricity is familiar to us all as lightning, static cling of clothing, and sparking when we touch a doorknob or other metallic objects in cool, dry weather. Static voltages up to and sometimes exceeding 15,000 volts can be generated by simple motions such as getting up from a chair, walking across a room, rubbing of clothing, and hundreds of other normal, everyday movements.

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CIRCLE 121 ON FREE INFORMATION CARD

PASCAL PROGRAMS IN SCIENCE AND ENGINEERING, by Jules H. Gilder & J. Scott Barrus; Hayden Book Company, Inc., 50 Essex Street, Rochelle Park, NJ 07662; 339 pages — no index; 6¾ × 9¾ inches; softcover; $18.95.

This book contains 112 programs that solve problems that are encountered by students, scientists, and engineers. Each application includes a brief introduction to the program's theory and algorithm, a complete program listing, a sample run, and an explanation of the results.

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ELECTRICAL FUNDAMENTALS (Second Edition) by J. J. DeFrance; Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632; 692 pages including appendicies and index; 6⅛ × 9¼ inches; hardcover; $26.95.

This book is essentially an updated version of the author's earlier *Direct Current Fundamentals* and *Alternating Current Fundamentals;* it is intended for use as a first course in electrical/electronics technology, and is aimed primarily at the technical institute, community, and junior college level. It is written in the conversational style that proved to be successful in those earlier volumes.

The emphasis is on concepts and not on mathematical derivations, although mathematics is used whenever the material presented has quantitative aspects that the student needs to be able to evaluate. At the end of each chapter are review questions that will enable the student to evaluate his or her comprehension of the material just covered.

The student must have a foundation in the principles of algebra, and some knowledge of basic trigonometry and logarithmic functions. Calculus is used in some of the derivations, so some background there would be helpful; but it is not needed for the comprehension of electrical theory or for solving problems.

A major change in this edition is the switch from the phrase "electron flow" to "current flow."

CIRCLE 123 ON FREE INFORMATION CARD

DOING BUSINESS WITH SUPERCALC, by Stanley R. Trost; Sybex, Inc., 2344 Sixth Street, Berkeley, CA 94710; 248 pages including appendix, bibliography, and index; 7 × 9 inches; softcover; $12.95.

This book is a collection of over 40 useful applications for the SuperCalc program. SuperCalc can be used to forecast sales, prepare income-tax reports, analyze real-estate investments, create expense registers, and prepare invoices, among many other uses.

Many of the programs presented here can be used directly to meet individual business needs, or they can be modified easily to meet specific requirements.

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OSBORNE 4 & 8-Bit Microprocessor Handbook by Adam Osborne & Gerry Kane; Osborne, A McGraw-Hill Company, 630 Bancroft Way, Berkeley, CA 94710; 7 × 9¼ inches; softcover; $21.95.

This is a thick book, and not because of thick paper; its third dimension comes to 1⅝ths inches. We mention that because it is not paginated in such a way that one can tell, without counting, exactly how many pages there are. (There is a separate pagination for each of the 15 chapters, as well as for the data-sheets pages that follow the chapters.

What this book does is to give you, from an independent source, a description of virtually every 4 and 8-bit microprocessor on the market. It can be used to supplement the *Osborne 16-Bit Microprocessor Handbook* (formerly *An Introduction to Microcomputers: Volume 2 — Some Real Microprocessors*).

Subjects covered in this volume include electrical characteristics, applications, supply current, reset operation, external interrupts, data-input timing, signal sequences, clock periods, direct-memory access, logic, test circuits, manufacturers data sheets, instruction sets, slow memory, bus-expander signals, and a host of others.

CIRCLE 125 ON FREE INFORMATION CARD

ELECTRONIC INSTRUMENTATION (Third Edition) by Sol D. Prensky & Richard L. Castellucis; Prentice-Hall, Inc., Englewood Cliffs, NJ 07632; 7 × 9¼ inches; 465 pages; hardcover; $26.95.

This new edition retains the style and approach of the first two editions, presenting the latest refinements in technique, accuracy, and operation to be found in the field of electronic instrumentation.

Although the latest instruments are discussed, the authors concentrate upon the most representative, describing each category of instrument in terms of its fundamental technique and approach, and the particular way in which it offers improved capability of measurement.

CIRCLE 126 ON FREE INFORMATION CARD

SCIENCE AND ENGINEERING PROGRAMS FOR THE IBM PC, by Cass Lewart; Micro Text Publications, Inc., Prentice-Hall, Inc., Englewood Cliffs, NJ 07632; 132 pages, including appendicies, references and further reading, and index; 6 × 9 inches; softcover $12.95 (also available in hardcover, $18.95).

This book presents 19 programs designed to make optimum use of the personal computer for scientific and engineering applications. There is thorough documentation, sample runs, and formulae. The programs include: graph for plotting and interpretation; function generator for numerical function evaluation; azimuth and elevation for geosynchronous satellites; bit-error rates for various modulation schemes; system-reliability evaluator; any base to any base conversion, and finding resonant L-C circuit parameters.

All programs are written in IBM PC BASIC and are compatible with BASIC versions 1.10 and 2.0.

CIRCLE 127 ON FREE INFORMATION CARD

SIMPLE INTERFACING PROJECTS, by Owen Bishop, Prentice-Hall, Inc., Englewood Cliffs, NJ 07632; 168 pages, no index; 6 × 9 inches; softcover $10.95 (also available in hardcover, $17.95).

This book is directed to the microcomputer owner and presents projects through which he or she can make that microcomputer more powerful.

In addition to complete, step-by-step instructions for constructing the 12 interfacing projects presented, there are guidelines for testing, troubleshooting, and programming, as well as flow charts. All of the projects can be adapted for use on *any* microcomputer.

The 12 projects are: electric-kettle controller, real-time clock, bleeper, graphic tablet, music generator, ROM board, mains remote control, voice-operated controller, sound processor, digitiser pad, telephone modem, and alarm-clock timer. R-E

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POWER SUPPLIES

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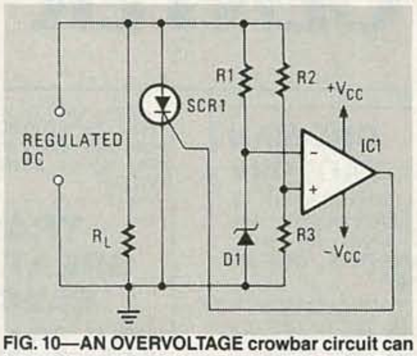

FIG. 10—AN OVERVOLTAGE crowbar circuit can be used to protect the power supply and the load in the event that an excessively high voltage is applied to the load.

output from the op-amp is positive. That positive voltage is applied to the gate of the SCR, turning it on. When on, the SCR acts like a short circuit across R_L, protecting both the load and the supply.

If the connections to the inverting and non-inverting inputs to the op-amp in Fig. 10 were interchanged, we would have an undervoltage protection circuit. The load and regulated supply would be shorted by the SCR when the voltage across R_L drops below a specific level. **R-E**

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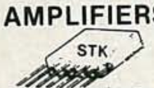

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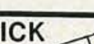

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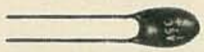

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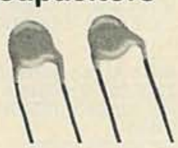

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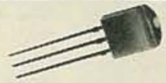

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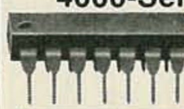

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SERVICE QUESTIONS

continued from page 95

scene. When that occurs, the set loses its vertical and horizontal sync. The problem can also be induced by reducing the brightness and contrast using the appropriate controls; the symptoms can also be induced by adjusting the screen controls.

I have tried to trace the problem with a scope, but that did not help and only led me in circles. Any ideas?—M.S., East Meadow, NY

From the symptoms that you've described it would appear that either one or both of the resistors that feed boosted B+ to the horizontal oscillator circuit have changed value. Those are R40 and R41, and are 220K and 120K units respectively. If memory serves, those resistors have a history of doing that, with the results you have described.

One word of warning is in order here. The location, and even the values, of those resistors have been known to vary from those shown in the Sams service literature. They should be easy enough to track down however. Also, even if only one is bad, replace both of them. Otherwise, you'll have to go back into the set before to long to do it anyway. **R-E**

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4068	.39	74C162	1.19
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6.0 Mhz

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74LS01	.25	74LS174	.55
74LS02	.25	74LS175	.55
74LS03	.25	74LS181	2.15
74LS04	.24	74LS189	8.95
74LS05	.25	74LS190	.89
74LS08	.28	74LS191	.89
74LS09	.29	74LS192	.79
74LS10	.25	74LS193	.79
74LS11	.35	74LS194	.69
74LS12	.35	74LS195	.69
74LS13	.45	74LS196	.79
74LS14	.59	74LS197	.79
74LS15	.35	74LS221	.89
74LS20	.25	74LS240	.95
74LS21	.29	74LS241	.99
74LS22	.25	74LS242	.99
74LS26	.29	74LS243	.99
74LS27	.29	74LS244	1.29
74LS28	.35	74LS245	1.49
74LS30	.25	74LS247	.75
74LS32	.29	74LS248	.99
74LS33	.55	74LS249	.99
74LS37	.35	74LS251	.59
74LS38	.35	74LS253	.59
74LS40	.25	74LS257	.59
74LS42	.49	74LS258	.59
74LS47	.75	74LS259	2.75
74LS48	.75	74LS260	.59
74LS49	.75	74LS266	.55
74LS51	.25	74LS273	1.49
74LS54	.29	74LS275	3.35
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74LS162	.69	74LS688	2.40
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7812K	1.39	7915K	1.49
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7410	.19	74151	.55
7411	.25	74153	.55
7413	.35	74154	1.25
7414	.49	74155	.75
7416	.25	74157	.55
7417	.25	74159	1.65
7420	.19	74160	.85
7421	.35	74161	.69
7425	.29	74163	.69
7427	.29	74164	.85
7430	.19	74165	.85
7432	.29	74166	1.00
7437	.29	74167	2.95
7438	.29	74170	1.65
7442	.49	74173	.75
7445	.69	74174	.89
7446	.69	74175	.89
7447	.69	74177	.75
7448	.69	74181	2.25
7451	.23	74184	2.00
7473	.34	74185	2.00
7474	.33	74191	1.15
7475	.45	74192	.79
7476	.35	74193	.79
7482	.95	74194	.85
7483	.50	74195	.85
7485	.59	74197	.75
7486	.35	74198	1.35
7489	2.15	74221	1.35
7490	.35	74246	1.35
7492	.50	74247	1.25
7493	.35	74259	2.25
7495	.55	74273	1.95
7497	2.75	74276	1.25
74100	1.75	74279	.75
74107	.30	74366	.65
74109	.45	74367	.65
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H = TO-5 CAN   T = TO-220   K = TO-3

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CA 3039	1.29	CA 3083	1.55
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75150	1.95	75454	.39
75154	1.95	75491	.79
75188	1.25	75492	.79
75189	1.25	75493	.89
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TL083	1.19	LF356	1.10
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★ DIMENSIONS 8⅝ x 5 15/16 x 3 15/16"
★ COLOR MATCHES APPLE
★ FITS STANDARD 5¼" DRIVES, INCL. SHUGART
★ INCLUDES MOUNTING HARDWARE AND FEET

CABINET #2 $79.00

★ COMPLETE WITH POWER SUPPLY, SWITCH, LINE CORD, FUSE & STANDARD POWER CONNECTOR
★ DIMENSIONS: 11½ x 5¾ x 3 15/16"
★ +5V @ 1 AMP, +12V @ 1.5 AMP
★ FITS STANDARD 5¼" DRIVES
★ PLEASE **SPECIFY** GRAY OR TAN

NOTE: Please include sufficient amount for shipping on above items.

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14 pin ST	.15	.12
16 pin ST	.17	.13
18 pin ST	.20	.18
20 pin ST	.29	.27
22 pin ST	.30	.27
24 pin ST	.30	.27
28 pin ST	.40	.32
40 pin ST	.49	.39
64 pin ST	4.25	call
ST = SOLDERTAIL		
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14 pin WW	.69	.52
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18 pin WW	.99	.90
20 pin WW	1.09	.98
22 pin WW	1.39	1.28
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4N35	1.25	ILQ-74	2.75
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MPS918	.25	2N3772	1.85
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2N2218	.50	2N3904	.10
2N2218A	.50	2N3906	.10
2N2219	.50	2N4122	.25
2N2219A	.50	2N4123	.25
2N2222	.25	2N4249	.25
PN2222	.10	2N4304	.75
MPS2369	.25	2N4401	.25
2N2484	.25	2N4402	.25
2N2905	.50	2N4403	.25
2N2907	.25	2N4857	1.00
PN2907	.125	PN4916	.25
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3055T	.69	PN5129	.25
2N3393	.30	PN5139	.25
2N3414	.25	2N5209	.25
2N3563	.40	2N6028	.35
2N3565	.40	2N6043	1.75
PN3565	.25	2N6045	1.75
MPS3638	.25	MPS-A05	.25
MPS3640	.25	MPS-A06	.25
PN3643	.25	MPS-A55	.25
PN3644	.25	TIP29	.65
MPS3704	.15	TIP31	.75
		TIP32	.79

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20	.65	5.70	1.25	11.00
25	.75	6.60	1.32	11.60
26	.75	6.60	1.32	11.60
34	.98	8.60	1.65	14.50
40	1.32	11.60	1.92	16.80
50	1.38	12.10	2.50	22.00

D-SUBMINIATURE

DESCRIPTION	SOLDER CUP MALE	SOLDER CUP FEMALE	RIGHT ANGLE PC SOLDER MALE	RIGHT ANGLE PC SOLDER FEMALE	IDC RIBBON CABLE MALE	IDC RIBBON CABLE FEMALE	HOODS BLACK	HOODS GREY
ORDER BY	DBxxP	DBxxS	DBxxPR	DBxxSR	IDBxxP	IDBxxS	HOOD-B	HOOD
CONTACTS 9	2.08	2.66	1.65	2.18	3.37	3.69	—	1.60
15	2.69	3.63	2.20	3.03	4.70	5.13	—	1.60
25	2.50	3.25	3.00	4.42	6.23	6.84	1.25	1.25
37	4.80	7.11	4.83	6.19	9.22	10.08	—	2.95
50	6.06	9.24	—	—	—	—	—	3.50

For order instructions see "IDC Connectors" below.

MOUNTING HARDWARE 1.00

IDC CONNECTORS

DESCRIPTION	SOLDER HEADER	RIGHT ANGLE SOLDER HEADER	WW HEADER	RIGHT ANGLE WW HEADER	RIBBON HEADER SOCKET	RIBBON HEADER	RIBBON EDGE CARD
ORDER BY	IDHxxS	IDHxxSR	IDHxxW	IDHxxWR	IDSxx	IDMxx	IDExx
CONTACTS 10	.82	.85	1.86	2.05	1.15	—	2.25
20	1.29	1.35	2.98	3.28	1.86	5.50	2.36
26	1.68	1.76	3.84	4.22	2.43	6.25	2.65
34	2.20	2.31	4.50	4.45	3.15	7.00	3.25
40	2.58	2.72	5.28	4.80	3.73	7.50	3.80
50	3.24	3.39	6.63	7.30	4.65	8.50	4.74

ORDERING INSTRUCTIONS: Insert the number of contacts in the position marked "xx" of the "order by" part number listed. **Example:** A 10 pin right angle solder style header would be IDH**10**SR.

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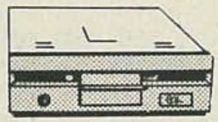

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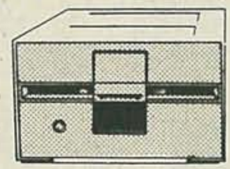

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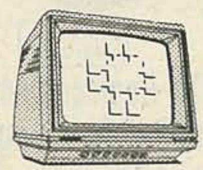

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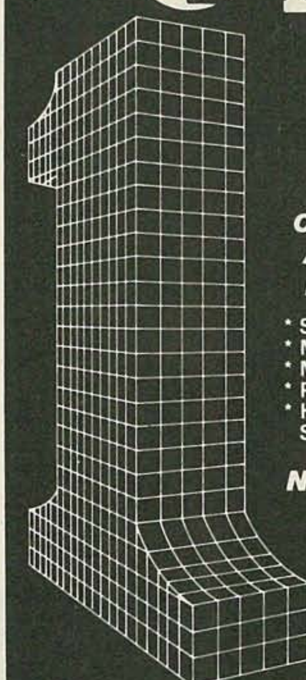

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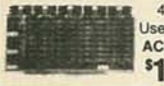

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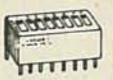
74S15	.42	74S153	1.29	74S373	3.10
74S20	.42	74S157	1.29	74S374	3.10
74S22	.42	74S158	1.29	74S387	2.75
74S30	.42	74S160	2.79	74S471	7.95
74S32	.49	74S174	1.49	74S472	7.95
74S38	1.19	74S175	1.49	74S473	7.95
74S40	.49	74S188	2.69	74S474	9.95
74S51	.42	74S194	1.89	74S475	9.95
74S64	.46	74S195	1.89	74S570	5.75
74S65	.46	74S196	1.89	74S571	5.75
74S74	.99	74S240	2.75	74S572	8.95
74S86	.72	74S241	2.75	74S573	8.95
74S112	.72	74S242	2.99	74S940	2.90
74S113	.72	74S243	2.99	74S941	2.90
74S114	.72				

DIP SWITCHES



2 Position	$ .99	7 Position	$1.39
4 Position	1.19	8 Position	1.49
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7402	.19	7479	4.60	74163	.69
7403	.19	7480	.49	74164	.69
7404	.19	7482	.95	74165	.69
7405	.23	7483	.45	74166	1.20
7406	Call	7485	.55	74167	2.95
7407	Call	7486	.35	74170	1.49
7408	.24	7489	1.75	74172	4.75
7409	.19	7490	.35	74173	.69
7410	.19	7491	.45	74174	.69
7411	.24	7492	.45	74175	.69
7412	.24	7493	.35	74176	.69
7413	.29	7494	.69	74177	.69
7414	.49	7495	.50	74179	1.34
7416	Call	7496	.69	74180	.75
7417	Call	7497	2.90	74181	1.75
7420	.19	74100	2.90	74182	.75
7421	.35	74107	.24	74184	2.25
7422	.29	74109	.37	74185	2.25
7423	1.19	74116	1.25		
7425	.29	74121	.29		
7426	.29	74122	.39	74190	1.15
7427	.25	74123	.45	74191	1.15
7429	.45	74125	.39	74192	.75
7430	.18	74126	.44	74193	.75
7432	.29	74128	.59	74194	.75
7437	.25	74132	.45	74195	.68
7438	.29	74136	.75	74196	.75
7439	1.19			74197	.75
7440	.19	74141	.65	74198	1.29
7441	.79	74142	2.95	74199	1.29
7442	.45	74143	2.95	74221	1.19
7443	.95	74144	2.95	74251	.69
7444	.65	74145	.59	74273	1.05
7445	.79	74147	1.69	74276	1.89
7446	.79	74148	1.19	74279	.75
7447	.65	74150	1.09	74283	1.40
7448	.79	74151	.49	74284	3.69
7450	.19	74152	.67	74285	3.69
7451	.19	74153	.49	74290	.89
7453	.19	74154	1.19	74298	.95
7454	.19	74155	.69	74365	.65
7459	.25	74156	.78	74366	.65
7460	.23	74157	.49	74367	.65
7470	.29	74158	1.65	74368	.65
7472	.29	74159	2.49	74390	1.45
7473	.29	74160	.79	74393	1.90
7474	.34			74490	1.90

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74LS00	$ .26	74LS113	$ .39	74LS245	$2.99
74LS01	.25	74LS114	.39	74LS247	1.10
74LS02	.25	74LS122	.49	74LS248	1.10
74LS03	.25	74LS123	1.19	74LS249	1.19
74LS04	.69	74LS124	2.75	74LS251	1.40
74LS05	.25	74LS125	.69	74LS253	1.40
74LS08	.25	74LS126	.49	74LS257	.85
74LS09	.25	74LS132	.59	74LS258	.98
74LS10	.25	74LS136	.49	74LS259	2.95
74LS11	.39	74LS138	.59	74LS260	.65
74LS12	.33	74LS139	.59	74LS261	2.49
74LS13	.39	74LS145	1.25	74LS266	.59
74LS14	.59	74LS148	1.49	74LS273	1.75
74LS15	.33	74LS151	.99	74LS275	4.40
74LS20	.26	74LS153	.99	74LS279	.59
74LS21	.29	74LS154	1.70	74LS283	.99
74LS22	.29	74LS155	1.19	74LS290	.99
74LS26	.29	74LS156	1.49	74LS293	.99
74LS27	.29	74LS157	1.49	74LS295	1.10
74LS28	.29	74LS158	1.49	74LS298	1.19
74LS30	.25	74LS160	1.49	74LS324	1.75
74LS32	.33	74LS161	1.49	74LS347	1.95
74LS33	.55	74LS162	1.49	74LS348	1.95
74LS37	.35	74LS163	1.49	74LS352	1.19
74LS38	.39	74LS164	1.49	74LS353	1.19
74LS40	.25	74LS165	1.49	74LS363	1.49
74LS42	.59	74LS166	2.48	74LS365	.99
74LS47	.79	74LS168	1.15	74LS366	.99
74LS48	.79	74LS169	1.15	74LS367	.99
74LS51	.25	74LS170	1.99	74LS368	.99
74LS54	.29	74LS173	.89	74LS373	2.99
74LS55	.29	74LS174	.89	74LS374	2.99
74LS73	.39	74LS175	.89	74LS375	.69
74LS74	.99	74LS181	2.20	74LS377	1.95
74LS75	.39	74LS190	1.15	74LS385	1.95
74LS76	.39	74LS191	1.15	74LS386	.65
74LS78	.45	74LS192	.98	74LS390	1.95
74LS83	.59	74LS193	.98	74LS393	1.95
74LS85	.69	74LS194	1.15	74LS395	1.70
74LS86	.39	74LS195	.95	74LS399	2.35
74LS90	.57	74LS196	.89	74LS424	2.95
74LS92	.49	74LS197	.89	74LS668	1.75
74LS93	.59	74LS221	1.15	74LS670	2.29
74LS95	.79	74LS240	1.99	81LS95	1.69
74LS96	.89	74LS242	1.99	81LS96	1.69
74LS107	.39	74LS243	1.99	81LS97	1.69
74LS109	.39	74LS244	1.99	81LS98	1.69
74LS112	.39	25LS2521	2.95	25LS2569	4.95

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4000	$ .29	4037	$1.95	4089	$2.95
4001	.24	4040	.75	4093	.59
4002	.24	4041	.75	4094	2.95
4006	.79	4042	.65	4098	2.29
4007	.25	4043	.85	4099	1.85
4008	.95	4044	.69	14408	12.95
4009	.39	4046	.89	14409	12.95
4010	.39	4047	.89	14410	12.95
4011	.24	4048	.99	14412	12.95
4012	.24	4049	.35	14415	8.95
4013	.35	4050	.39	14419	4.95
4014	.89	4051	.75	4501	.39
4015	.39	4052	.75	4502	.95
4016	.35	4053	.75	4503	.69
4017	.65	4055	3.95	4505	8.95
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4019	.39	4059	9.25	4507	.95
4020	.69	4060	.85	4508	3.75
4021	.69	4066	.39	4510	.79
4022	.69	4069	.28	4511	.79
4023	.25	4070	.35	4512	.79
4024	.59	4071	.28	4514	1.29
4025	.25	4072	.28	4515	1.99
4027	.45	4073	.28	4516	1.45
4028	.65	4075	.28	4518	.85
4029	.75	4076	.75	4520	.75
4030	.45	4077	.35	4555	.95
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7404	.19	7490	.35
7405	.23	7491	.79
7407	.29	7492	.55
7408	.28	7494	.60
7409	.19	7496	.69
7410	.19	74121	.29
7411	.24	74123	.78
7414	.49	74145	.59
7417	.25	74148	1.19
7420	.19	74150	1.19
7423	.59	74151	.55
7430	.25	74153	.55
7432	.29	74155	.69
7438	.29	74157	.55
7439	.59	74159	1.65
7442	.45	74160	.69
7446	.69	74165	.69
7447	.69	74170	1.29
7451	.19	74174	.69
7453	.19	74181	1.85
7454	.19	74190	.69
7472	.19	74191	.69

74LS00

74LS00	.23	74LS153	.55
74LS03	.24	74LS154	1.85
74LS04	.24	74LS157	.65
74LS05	.25	74LS162	.69
74LS08	.28	74LS163	.65
74LS10	.25	74LS164	.69
74LS11	.34	74LS170	1.45
74LS15	.35	74LS174	.55
74LS20	.25	74LS175	.55
74LS27	.29	74LS181	2.15
74LS30	.25	74LS190	.89
74LS32	.29	74LS194	.69
74LS38	.35	74LS197	.79
74LS42	.49	74LS240	.95
74LS47	.75	74LS241	.99
74LS74	.35	74LS244	1.29
74LS76	.39	74LS245	1.49
74LS86	.39	74LS253	.53
74LS90	.55	74LS257	.59
74LS92	.55	74LS273	1.49
74LS113	.39	74LS279	.49
74LS123	.79	74LS366	.49
74LS125	.49	74LS367	.45
74LS136	.39	74LS373	1.49
74LS138	.55	74LS374	1.49
74LS139	.55	74LS670	1.49
74LS151	.55		

CMOS

4000	.29	4073	.29
4001	.25	4075	.29
4002	.29	4076	.79
4007	.29	4078	.29
4009	.39	4081	.29
4010	.45	4082	.29
4011	.25	14412	8.95
4012	.25	4502	.95
4013	.38	4503	.65
4014	.79	4510	.85
4015	.39	4512	.85
4017	.69	4516	1.45
4018	.79	4518	.89
4019	.39	4520	.79
4020	.75	4526	1.25
4021	.79	4527	1.95
4023	.29	4536	4.25
4025	.29	4555	1.49
4027	.45	4556	1.15
4030	.39	4581	3.50
4034	1.95	4583	2.50
4035	.85	4584	.75
4041	.75	74C00	.35
4042	.69	74C02	.35
4043	.79	74C14	.59
4047	.95	74C15	.35
4049	.35	74C154	3.20
4051	.79	74C161	1.19
4066	.39	74C164	1.39
4069	.29	74C221	1.75
4070	.35	74C901	.39

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8273	3.25
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8T37	1.75
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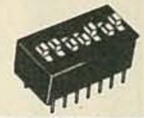

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74S32	.40	74S571	2.95
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74H01

74H01	.25	74H50	.35
74H04	.28	74H51	.35
74H08	.35	74H53	.35
74H20	.35	74H55	.35
74H21	.29	74H62	.35
74H30	.35	74H72	.55
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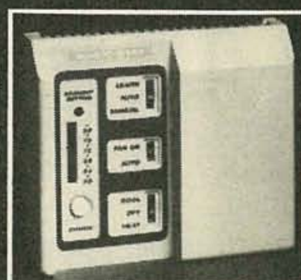

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26	D	R517-6-ND	5.51	48.99	453.19	4164.48
26	D	R517-18-ND	6.30	56.58	523.38	4809.47
26	D	R517-36-ND	7.64	67.96	628.66	5776.94
34	D	R518-6-ND	6.97	61.99	573.13	5266.68
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DIP Jumper Cable Assembly

Standard Assembly Styles

Style 2

Style 4

Style 6

Style 8

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7400

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SN7403N	14	.25	SN7475N	16	.45	SN74161N	16	.69
SN7404N	14	.25	SN7476N	16	.35	SN74162N	16	.69
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SN7459N	14	.25	SN74153N	16	.59	SN74368N	16	.55
SN7460N	14	.39	SN74154N	24	1.25	SN74390N	16	1.49
SN7470N	14	.29	SN74155N	16	.59	SN74393N	14	1.49

74LS

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74LS01	14	.25	74LS93	14	.55	74LS193	16	.79
74LS02	14	.29	74LS95	14	.79	74LS194	16	.69
74LS03	14	.25	74LS96	16	.89	74LS195	16	.69
74LS04	14	.35	74LS107	14	.39	74LS197	14	.79
74LS05	14	.29	74LS109	16	.39	74LS221	16	.89
74LS08	14	.29	74LS112	16	.39	74LS240	20	1.09
74LS09	14	.29	74LS113	14	.39	74LS241	20	1.09
74LS10	14	.29	74LS114	14	.39	74LS242	14	1.09
74LS11	14	.35	74LS122	14	.49	74LS243	14	1.09
74LS12	14	.35	74LS123	16	.89	74LS244	20	1.49
74LS13	14	.39	74LS125	14	.59	74LS245	20	1.49
74LS14	14	.59	74LS126	14	.49	74LS247	16	1.09
74LS15	14	.35	74LS132	14	.59	74LS248	16	1.09
74LS20	14	.29	74LS133	16	.59	74LS249	16	1.09
74LS21	14	.29	74LS136	14	.39	74LS251	16	.59
74LS22	14	.29	74LS138	16	.89	74LS253	16	.59
74LS26	14	.29	74LS139	16	.79	74LS257	16	.59
74LS27	14	.29	74LS151	16	.59	74LS258	16	.59
74LS28	14	.35	74LS153	16	.59	74LS260	14	.59
74LS30	14	.29	74LS154	24	1.29	74LS266	14	.59
74LS32	14	.39	74LS155	16	.69	74LS273	20	1.49
74LS33	14	.55	74LS156	16	.69	74LS279	16	.49
74LS37	14	.35	74LS157	16	.69	74LS283	16	.69
74LS38	14	.35	74LS158	16	.59	74LS290	14	.89
74LS40	14	.29	74LS160	16	.89	74LS293	14	.79
74LS42	16	.55	74LS161	16	.69	74LS298	16	.89
74LS47	16	.75	74LS162	16	.69	74LS352	16	1.29
74LS48	16	.75	74LS163	16	.69	74LS353	16	1.29
74LS49	14	.75	74LS164	14	.69	74LS365	16	.49
74LS51	14	.25	74LS165	16	1.19	74LS366	16	.49
74LS54	14	.25	74LS166	16	1.19	74LS367	16	.49
74LS55	14	.29	74LS168	16	1.19	74LS368	16	.49
74LS73	14	.39	74LS169	16	1.19	74LS373	20	1.49
74LS74	14	.49	74LS170	16	1.49	74LS374	20	1.49
74LS75	16	.39	74LS173	16	.69	74LS375	16	.69
74LS76	16	.39	74LS174	16	.69	74LS386	14	.45
74LS78	14	.39	74LS175	16	.69	74LS393	14	1.19
74LS83	16	.65	74LS181	24	2.95	74LS399	16	1.49
74LS85	16	.89	74LS190	16	.89	74LS670	16	1.49
74LS86	14	.39	74LS191	16	.89	81LS95	20	1.49
74LS90	14	.55				81LS97	20	1.49

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74S03	14	.35	74S134	16	.50	74S251	16	1.19
74S04	14	.45	74S135	16	.69	74S253	16	1.19
74S05	14	.45	74S136	14	1.39	74S257	16	1.19
74S08	14	.39	74S138	16	.89	74S258	16	1.19
74S09	14	.39	74S139	16	.89	74S260	14	1.19
74S10	14	.35	74S140	14	.55	74S280	14	1.95
74S11	14	.35	74S151	16	.99	74S287*	16	1.95
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CD4009	16	.59	CD4046	16	1.19	CD4511	16	1.19
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CD4025	14	.23	CD4072	14	.29	CD4723	16	1.19
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MICROPROCESSOR CHIPS

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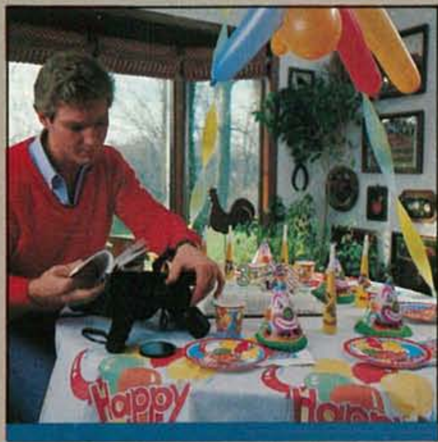

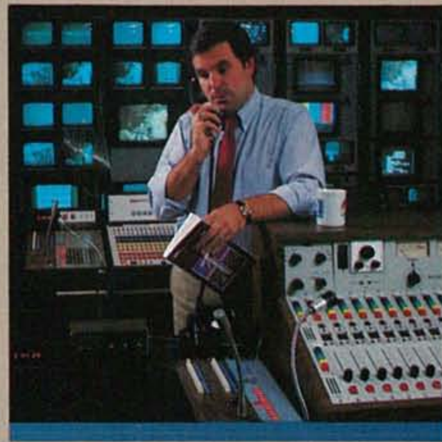

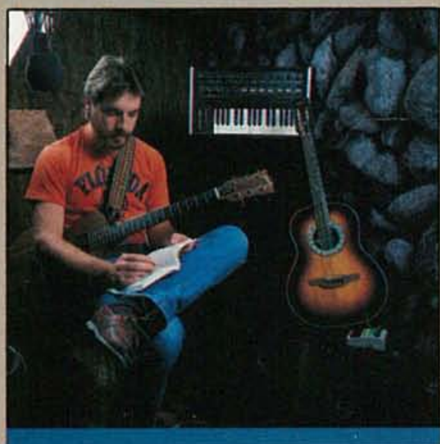

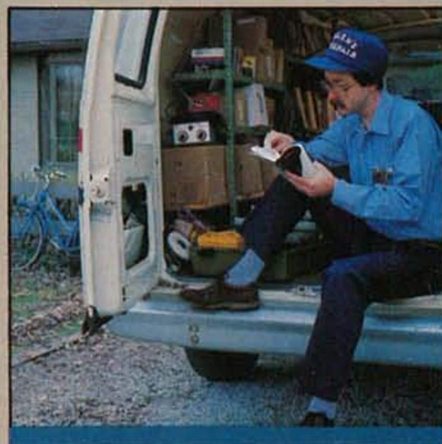

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