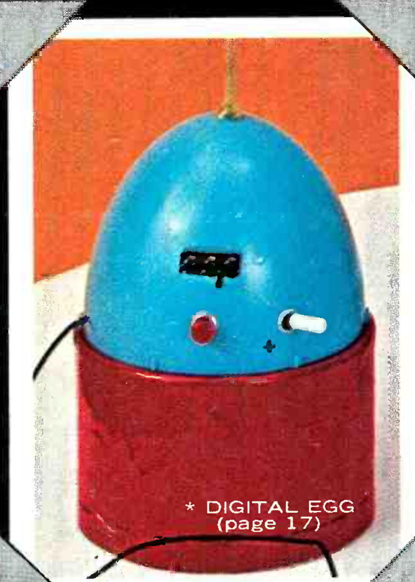
ELECTRONICS HOBBYIST

FALL-WINTER 1976 $1.35 02396

By the Editors of ELEMENTARY ELECTRONICS

Photo clips of FUN PROJECTS YOU CAN BUILD

- Digital voltmeter assembled inside a plastic egg
- CB power supply brings your mobile rig indoors
- Convert pocket calculator to an elapsed time indicator
- Foot pedal that adds the whaa-whaa sound
- Powered breadboard for rapid IC circuit mockup and testing
- Audio light-beam transmission through fiber optics
- Darkroom printing meter that takes the guesswork out
- Go/No-Go Op Amp tester that turns sweepings into gold
- Multi-Band SW antenna is the cheapest one yet
- Fool-proof photo timer does the switching for you
- Gadget that spots defective AC outlets that can kill



How to get started in CB RADIO

Inside dope, smart buys, and installation tips from a beginner who learned fast.

GERNSBACK SPECIALTY SERIES 49604

1991 Popular Electronics® ELECTRONICS HOBBYISTS handbook™

DOZENS OF PROJECTS AND KITS

- **BUILD A MINI GEIGER COUNTER**
  Find and measure nuclear radiation!
- **STEREO AMPLIFIER**
  Its 20 watts per channel packs a punch.
- **WHEEL OF FORTUNE**
  Create your own version of the popular TV game show.
- **ELECTRONIC SLOT MACHINE**
  Realistic slot-machine action.
- **LIGHTNING BOLT STROBE LIGHT**
  A brilliant xenon strobe turns your basement into a disco!
- **QUIZ MASTER**
  Add a touch of professionalism to quiz games.
- **PHOTO STROBE TRIGGER**
  You can take better pictures today!
- **CAR BATTERY/ALTERNATOR MONITOR**
  Keep tabs on your car's charging system so you don't get stranded.

HIGH-TECH FUN

- **COLOR ORGAN**
  Add 3 channels of colored lights to your music
- **SOUND SYNTHESIZER**
  Make sound effects—or even music!
- **SIMULATED LASER**
  Experiment safely with laser concepts.
- **SUPER BURGLAR CHASER**
  Protect yourself with a powerful blast of sound.
- **INSANITY ALARM**
  You can hear it—but can you find it?
- **BATTERY TESTER KIT**
  Is that drawer-full of batteries good?
- **TELEPHONE AMPLIFIER**
  Now everyone can hear the conversation.
- **ELECTRONIC HOLD BUTTON**
  Place any call on hold.
- **AC OUTLET TESTER**
  Are your outlets working?
- **METAL LOCATOR**
  Find buried treasure!
- **MOISTURE DETECTOR**
  Get an early warning to a flooded basement.
- **ULTRASONIC PEST REPELLER**
  Keep pests away without chemicals!

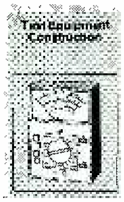
12
0 71896 49604 8

$3.50 U.S.
$3.95 CAN

Electronics Paperback Books

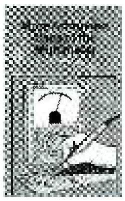
GREAT PAPERBACKS AT SPECIAL PRICES

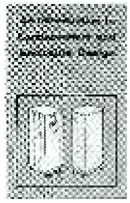
☐ **BP248—TEST EQUIPMENT CONSTRUCTION ..... $5.95.** Details construction of simple, inexpensive, but extremely useful test equipment. AF Gen, Test Bench Ampl, Audio Millivoltmeter, Transistor Tester and six more.



☐ **BP267—HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT ..... $6.95.** Mastering the oscilloscope is not really too difficult. This book explains all the standard controls and functions. Other equipment is also described.

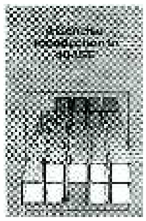
☐ **BP265—MORE ADVANCED USES OF THE MULTIMETER ..... $5.95.** Use these techniques to test and analyze the performance of a variety of components. Also see how to build ad-ons to extend multimeter capabilities.



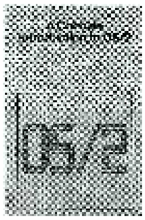


☐ **BP256—INTRO TO LOUDSPEAKERS AND ENCLOSURE DESIGN ..... $5.95.** We explore the variety of enclosure and speaker designs in use today so the reader can understand the principles involved.

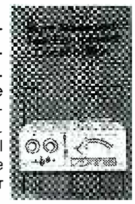
☐ **BP263—A CONCISE INTRO TO dBASE ..... $6.95.** The dBASE series of programs are probably the best known database programs for microcomputers. This book is designed to help you get started working with them.



☐ **BP260—CONCISE INTRO TO OS/2 ..... $5.95.** If you are a multitasking PC user and want to get the most out of your computer, then you must learn its OS/2 operating system. This book shows you just how to do that, quickly and easily.

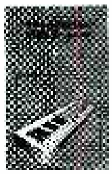


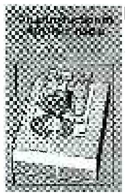
☐ **BP249—MORE ADVANCED TEST EQUIPMENT CONSTRUCTION ..... $6.95.** Eleven more test equipment construction projects. They include a digital voltmeter, capacitance meter, current tracer and more.



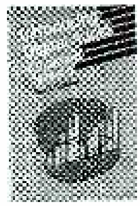
☐ **BP245—DIGITAL AUDIO PROJECTS ..... $5.95.** Practical circuits to build and experiment with. Includes A/D converter, input amplifier, digital delay line, compander, echo effect and more.

☐ **BP247—MORE ADVANCED MIDI PROJECTS ..... $5.95.** Circuits included are a MIDI indicator, THRU box, merge unit, code generator, pedal, programmer, channelizer, and analyzer.

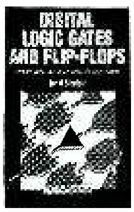




☐ **BP257—INTRO TO AMATEUR RADIO ..... $6.95.** Amateur is a unique and fascinating hobby. This book gives the newcomer a comprehensive and easy to understand guide to the subject.

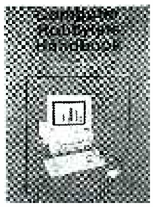


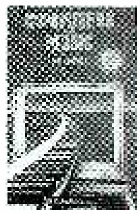
☐ **PCP102—INTRODUCING DIGITAL AUDIO ..... $9.95.** Covers all kinds of digital recording methods—CD, DAT and Sampling. Bridges the gap between the technician and the enthusiast. Principles and methods are explained.



☐ **PCP107—DIGITAL LOGIC GATES AND FLIP FLOPS ..... $10.00.** Thorough treatment of gates and flip-flops for enthusiasts, student and technicians. Only a basic knowledge of electronics is needed.

☐ **BP251—COMPUTER HOBBYISTS HANDBOOK ..... $8.95.** A wrapup of everything the computer hobbyist needs to know in one easy to use volume. Provides a range of useful reference material in a single source.





☐ **PCP108—COMPUTERS AND MUSIC ..... $9.95.** Explains the basics of computers and music with no previous knowledge of computers needed. Covers types of music software and explains how to set up your own computer music studio.

☐ **BP195—INTRODUCTION TO SATELLITE TV..... $9.95.** A definitive introduction to the subject written for the professional engineer, electronics enthusiast, or others who want to know more before they buy. 8 × 10 in.

☐ **BP190—ADVANCED ELECTRONIC SECURITY PROJECTS.....$5.95.** Includes a passive infra-red detector, a fiber-optic loop alarm, computer-based alarms and an unusual form of ultrasonic intruder detector.

☐ **BP235—POWER SELECTOR GUIDE.....$10.00.** Complete guide to semiconductor power devices. More than 1000 power handling devices are included. They are tabulated in alpha-numeric sequency, by technical specs. Includes power diodes, Thyristors, Triacs, Power Transistors and FET's.

☐ **BP234—TRANSISTOR SELECTOR GUIDE.....$10.00.** Companion volume to BP235. Book covers more than 1400 JEDEC, JIS, and brand-specific devices. Also contains listing by case type, and electronic parameters. Includes Darlington transistors, high-voltage devices, high-current devices, high power devices.

☐ **BP99—MINI-MATRIX BOARD PROJECTS.....$5.50.** Here are 20 useful circuits that can be built on a mini-matrix board that is just 24 holes by ten copper-foil strips.

☐ **BP82—ELECTRONIC PROJECTS USING SOLAR CELLS.....$5.50.** Circuits with applications around the home that are powered by the energy of the sun. Everything from radio receivers, to a bicycle speedometer, to timers, audio projects and more.

☐ **BP117—PRACTICAL ELECTRONIC BUILDING BLOCKS—Book 1.....$5.75.** Oscillators, Timers, Noise Generators, Rectifiers, Comparators, Triggers and more.

☐ **BP184—INTRO TO 68000 ASSEMBLY LANGUAGE.....$6.95.** The 68000 is a great new breed of microprocessor. Programming in assembly language increases the running speed of your programs. Here's what you need to know.

☐ **BP239—GETTING THE MOST FROM YOUR MULTIMETER..... $5.95.** Covers basics of analog and digital meters. Methods of component testing includes transistors, thyristors, resistors, capacitors and other active and passive devices.

☐ **BP97—IC PROJECTS FOR BEGINNERS.....$5.50.** Power supplies, radio and audio circuits, oscillators, timers, switches, and more. If you can use a soldering iron you can build these devices.

☐ **BP37—50 PROJECTS USING RELAYS, SCR'S & TRIACS.....$5.50.** Build priority indicators, light modulators, warning devices, light dimmers and more.

☐ **RADIO—100 RADIO HOOKUPS.....$3.00.** Reprint of 1924 booklet presents radio circuits of the era including regenerative, neutrodyne, reflex & more.

☐ **BP42—SIMPLE LED CIRCUITS..... $5.50.** A large selection of simple applications for this simple electronic component.

☐ **BP127—HOW TO DESIGN ELECTRONIC PROJECTS.....$5.75.** Helps the reader to put projects together from standard circuit blocks with a minimum of trial and error.

☐ **BP122—AUDIO AMPLIFIER CONSTRUCTION.....$5.75.** Construction details for preamps and power amplifiers up through a 100-watt DC-coupled FED amplifier.

☐ **BP92—CRYSTAL SET CONSTRUCTION.....$5.50.** Everything you need to know about building crystal radio receivers.

☐ **BP45—PROJECTS IN OPTOELECTRONICS..... $5.50.** Includes infra-red detectors, transmitters, modulated light transmission and photographic applications.

☐ **BP179—ELECTRONIC CIRCUITS FOR THE COMPUTER CONTROL OF ROBOTS ..... $7.50.** Data and circuits for interfacing the computer to the robot's motors and sensors.

CHECK OFF THE BOOKS YOU WANT

☐ **BP185—ELECTRONIC SYNTHESIZER CONSTRUCTION ..... $5.95.** Use this book to learn how to build a reasonably low cost, yet worthwhile monophonic synthesizer and learn a lot about electronic music synthesis in the process.

ELECTRONIC TECHNOLOGY TODAY INC.
P.O. Box 240, Massapequa Park, NY 11762-0240

Name ____________________
Address ____________________
City __________ State __________ Zip __________

HHB91

SHIPPING CHARGES IN USA AND CANADA

$0.01 to $5.00	$1.25
$5.01 to 10.00	$2.00
$10.01 to $20.00	$3.00
$20.01 to $30.00	$4.00
$30.01 to $40.00	$5.00
$40.01 to $50.00	$6.00
$50.01 and above	$7.50

SORRY No orders accepted outside of USA & Canada

Number of books ordered ☐

Total price of merchandise .... $ ________
Sales Tax (New York State Residents only) .... $ ________
Shipping (see chart) .... $ ________

All payments must be in U.S. funds

Total Enclosed . . $ ________

Countersurveillance

Never before has so much professional information on the art of detecting and eliminating electronic snooping devices—and how to defend against experienced information thieves—been placed in one VHS video. If you are a Fortune 500 CEO, an executive in any hi-tech industry, or a novice seeking entry into an honorable, rewarding field of work in countersurveillance, you must view this video presentation again and again.

Wake up! You may be the victim of stolen words—precious ideas that would have made you very wealthy! Yes, professionals, even rank amateurs, may be listening to your most private conversations.

Wake up! If you are not the victim, then you are surrounded by countless victims who need your help if you know how to discover telephone taps, locate bugs, or "sweep" a room clean.

There is a thriving professional service steeped in high-tech techniques that you can become a part of! But first, you must know and understand Countersurveilance Technology. Your very first insight into this highly rewarding field is made possible by a video VHS presentation that you cannot view on broadcast television, satellite, or cable. It presents an informative program prepared by professionals in the field who know their industry, its techniques, kinks and loopholes. Men who can tell you more in 45 minutes in a straightforward, exclusive talk than was ever attempted before.

Foiling Information Thieves

Discover the targets professional snoopers seek out! The prey are stock brokers, arbitrage firms, manufacturers, high-tech companies, any competitive industry, or even small businnesses in the same community. The valuable information they filch may be marketing strategies, customer lists, product formulas, manufacturing techniques, even advertising plans. Information thieves eavesdrop on court decisions, bidding information, financial data. The list is unlimited in the mind of man—especially if he is a thief!

You know that the Russians secretly installed countless microphones in the concrete work of the American Embassy building in Moscow. They converted what was to be an embassy and private residence into the most sophisticated recording studio the world had ever known. The building had to be torn down in order to remove all the bugs.

CALL TOLL FREE

1-800-522-6260

HAVE YOUR VISA or MC CARD AVAILABLE

Stolen Information

The open taps from where the information pours out may be from FAX's, computer communications, telephone calls, and everyday business meetings and lunchtime encounters. Businessmen need counselling on how to eliminate this information drain. Basic telephone use coupled with the user's understanding that someone may be listening or recording vital data and information greatly reduces the opportunity for others to purloin meaningful information.

RADIO-ELECTRONICS VIDEO OFFER HHB
500-B Bi-County Blvd.
Farmingdale, NY 11735

Please rush my copy of the Countersurveillance Techniques Video VHS Cassette for $49.95 plus $4.00 for postage and handling.

No. of Cassettes ordered ____________
Amount of payment $____________

Bill my ☐ VISA ☐ MasterCard
Card No. ____________
Expire Date ______ / ______

Signature ____________
Name ____________
Address ____________
City ____________ State ______ ZIP ______

All payments in U.S.A. funds. Canadians add $4.00 per VHS cassette. No foreign orders. New York State residents add applicable sales tax.

The professional discussions seen on the TV screen in your home reveals how to detect and disable wiretaps, midget radio-frequency transmitters, and other bugs, plus when to use disinformation to confuse the unwanted listener, and the technique of voice scrambling telephone communications. In fact, do you know how to look for a bug, where to look for a bug, and what to do when you find it?

Bugs of a very small size are easy to build and they can be placed quickly in a matter of seconds, in any object or room. Today you may have used a telephone handset that was bugged. It probably contained three bugs. One was a phony bug to fool you into believing you found a bug and secured the telephone. The second bug placates the investigator when he finds the real thing! And the third bug is found only by the professional, who continued to search just in case there were more bugs.

The professional is not without his tools. Special equipment has been designed so that the professional can sweep a room so that he can detect voice-activated (VOX) and remote-activated bugs. Some of this equipment can be operated by novices, others require a trained countersurveillance professional.

The professionals viewed on your television screen reveal information on the latest technological advances like laser-beam snoopers that are installed hundreds of feet away from the room they snoop on. The professionals disclose that computers yield information too easily.

This advertisement was not written by a countersurveillance professional, but by a beginner whose only experience came from viewing the video tape in the privacy of his home. After you review the video carefully and understand its contents, you have taken the first important step in either acquiring professional help with your surveillance problems, or you may very well consider a career as a countersurveillance professional.

The Dollars You Save

To obtain the information contained in the video VHS cassette, you would attend a professional seminar costing $350-750 and possibly pay hundreds of dollars more if you had to travel to a distant city to attend. Now, for only $49.95 (plus $4.00 P&H) you can view ***Countersurveillance Techniques*** at home and take refresher views often. To obtain your copy, complete the coupon below or call toll free.

CB SPECIAL—9 Simple Circuits You Can Use Today

ELECTRONIC PROJECTS

101 ELECTRONIC PROJECTS

For Under $15 - All Easy To Build

1976 EDITION $1.35 02272

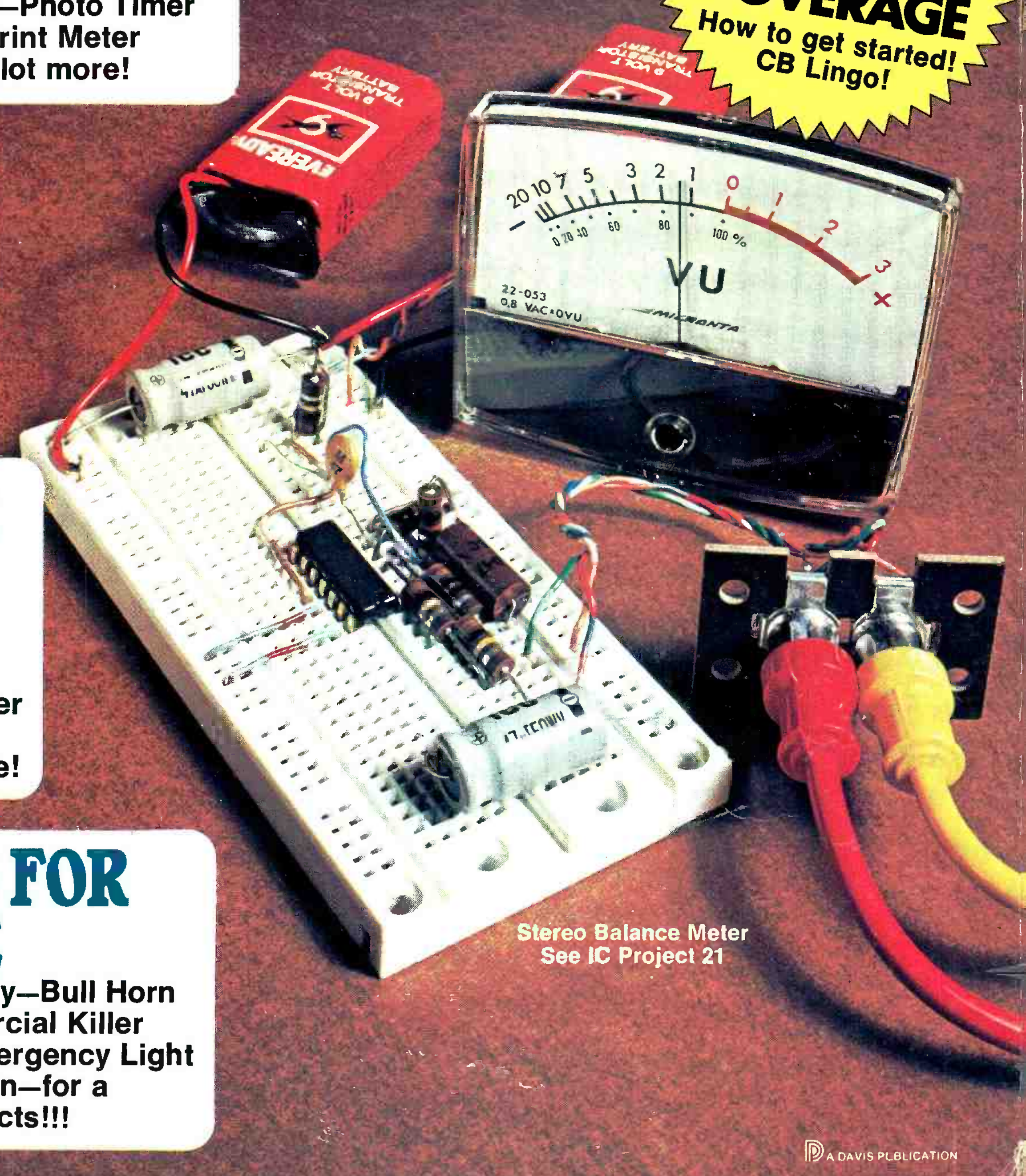
SPECIAL CB COVERAGE
How to get started!
CB Lingo!

For PHOTOGRAPHERS
Remote Flash Trigger—Photo Timer
Flash Tester—Photo Print Meter
NiCad Charger and a lot more!

RADIO GADGETS
For Better
Listening on
AM/FM-Stereo &
Shortwave Bands

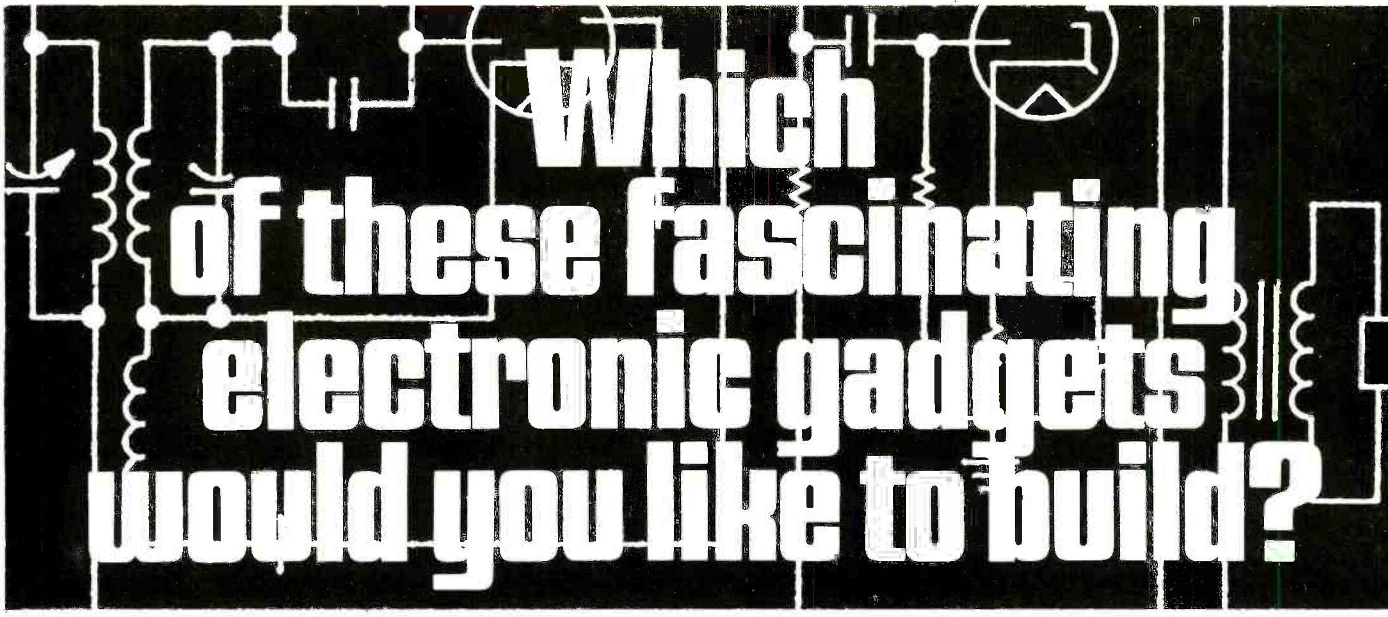
TEST GEAR YOU CAN BUILD
CB Modulation Checker
Appliance Tester
Logic Probe + 25 more!

PROJECTS FOR EVERYONE
CB Base Power Supply—Bull Horn
Lie Detector—Commercial Killer
SCA Adaptor—AC Emergency Light
Fish Lure—Color Organ—for a
total of over 135 projects!!!



Stereo Balance Meter
See IC Project 21

A DAVIS PUBLICATION



Which of these fascinating electronic gadgets would you like to build?

A photo print-timer that does everything but turn out the lights! Designed by a darkroom craftsman, it features instant reset, backlighted digit-set dials, pushbutton stop and start.

A battery-operated dickey flasher—guaranteed to liven up **any** party! Suddenly, your shirt buttons start flashing sequentially! Some people laugh. Others just stare. But it's funniest when they try to ignore you!

A shortwave station finder/ marker. Suppose you pick up an interesting but elusive station in Papeete, Kuwait or Kinshasa. This stable wide-band oscillator lets you relocate it any time you like—**without** hours of searching.

A nostalgic crystal radio set—just like the one your grandad had. You make it with a Quaker Oats box.

A futuristic pulse-width modulated mini-audio amplifier. It can boost the volume of a pocket radio to dancing level!

A solid-state wind-chill factor meter that can tell you instantaneously just how cold you feel!

A compact, portable gas alarm for home, trailer, car or boat. It detects many kinds of dangerous fumes—and could easily save your life!

Elementary Electronics features low-cost, practical projects like these in every issue!

Mail coupon today for your complimentary copy!

Yes, every issue of ELEMENTARY ELECTRONICS brings you step-by-step instructions, with photos and diagrams, for all kinds of devices you'll enjoy building—and be proud to own!

But that's not all. You also get instructive articles on electronics, CB and shortwave. Lively columns. Exciting features that make ELEMENTARY ELECTRONICS America's most absorbing, down-to-earth magazine for the electronics and radio hobbyist.

Invaluable Basic Courses in electronic theory!

For example, you get the fundamental training you need to construct your projects successfully—or lay the groundwork for an electronics career.

Each issue presents a Basic Course that helps you master an important aspect of electricity or electronics. Recent subjects included: *Resistors in Combination. Understanding Transformer Action. Introduction to Alternating Current.* And *Understanding Semiconductors.*

Our readers tell us these Basic Courses are one of the magazine's most popular and valued features.

A magazine with a personality all its own!

You'll meet a lot of interesting people in the pages of ELEMENTARY ELECTRONICS Like Hank Scott, our Workshop Editor. He conducts a regular letters-from-readers column called "Ask Hank, He Knows!" If you have any trouble on a project—or with *anything* electrical—just ask Hank. He knows!

And Kathi Martin, KGK3916, our Citizens Band Editor. She writes "Kathi's CB Carousel"—the most entertaining and informative CB feature you'll find anywhere!

Plus the people who contribute our columns on shortwave, antique radio, new products, electronics news tid-bits—and much, much more!

All our writers, editors and columnists know their stuff backwards and forwards. And they know how to make it interesting! With the same kind of straightforward language you use yourself when discussing electronics or radio.

What's more, they have fun. Which means *you'll* have fun, too!

SPECIAL INTRODUCTORY OFFER:

Just mail this coupon, and we'll send you a complimentary copy of ELEMENTARY ELECTRONICS.

Send no money now. We'll bill you later for a year's subscription—a total of six bimonthly issues for $3.49. But if you don't agree the magazine is everything we say it is, simply write "Cancel" across the face of the bill. Send it back to us, keeping the complimentary copy. And you won't owe a cent.

Act today. We're confident that once you see your first copy of ELEMENTARY ELECTRONICS, you'll wonder how you did without it for so long!

ELEMENTARY ELECTRONICS
P.O. Box 2600
Greenwich, CT 06830 H6A351

YES! Please send, without cost or obligation, my get-acquainted copy of ELEMENTARY ELECTRONICS. If I find it is everything you say it is, bill me for a year's subscription (5 additional issues, for a total of 6 in all) at just $3.49. If I don't wish to subscribe, I will write "Cancel" across your bill, return it, and that will end the matter. Either way, the complimentary copy is mine to keep.

Name (please print)

Address

City

State Zip

NO-RISK GET-ACQUAINTED COUPON
SEND NO MONEY!

COMPUTER NERVE CENTER LINKED TO YOUR HOME—Page 7

ELECTRONICS HOBBYIST

FALL-WINTER 1977 $1.35 02396

By the Editors of ELEMENTARY ELECTRONICS

Sounds Do Things You Never Thought Possible—

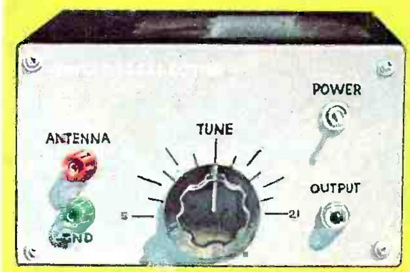
SIMPLE-SYN

Imitate a beagle or a bugle with Simple-Syn, the Music Machine—Page 41

TONE TO PHONE

Push-button dialing when you Add Tone to Your Phone—Page 21

SW BOOSTER



Cover the globe with the hottest new Shortwave Booster—Page 68

Plus

Lissy, the TV Light Pen **makes the boob tube** ***really*** **weird**

Always win on the red with ***Las Vegas LED*** **electronic roulette**

Smooth FM without slick sales from ***Super Soother SCA***

Alternator Tester **keeps your car all charged up**

Lone Ranger **light meter rides again**

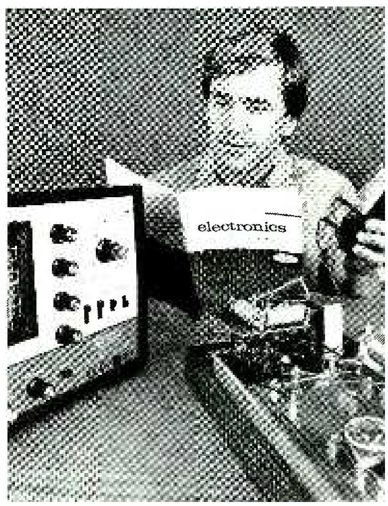
0 71486 02396

A DAVIS PUBLICATION

The chances are excellent that...

You have a talent other people are willing to pay for!

You're "handy" around your house, have the ability to fix things, and "make them work right"... that's why there may be a rewarding career for you in Electronics.



A career in Electronics?

Absolutely. Because you're interested in *things*. How they work. Why they work. How to take them apart and put them back together. Plus . . . you've got a head for detail work.

Your chances are excellent

With the right kind of *specialized* technical training, you can have a challenging, financially rewarding future waiting for you in Electronics. Think of the career opportunities . . . computers, aerospace, 2-way radio communications, radio/TV broadcasting, medical electronics, to name just a few.

And, surprisingly, you don't need a college degree!

All you need to do to qualify for one of these exciting career fields is to build upon the technical aptitude you already have . . . just put your hands and your head to work with a CIE Electronics career course.

You learn by doing

The CIE method of instruction is the refinement of over 40 years of Electronics, independent home-study experience. It works. And you don't need *any* prior electronics experience. A CIE *career* course can take you from ground zero right up to training in Lasers, Microminiaturization, Radar, Analog Computers, and various applications in Communications.

In some CIE courses, you'll perform "hands-on" experiments and tests with your own CIE Experimental Electronics Laboratory. And, if TV technology and digital Electronics are your main interest, you can select from several courses that involve working with and troubleshooting a TV. (And the TV is yours to keep, too!) This combination of "head and hands" learning *locks in* your understanding of the crucial principles you'll use on-the-job in your new career. But, don't kid yourself . . .

Electronics is not an "easy" science and CIE courses are not "snaps." Subject matter is technical, thorough, and challenging. It has to be. We're training you for a *career*. So the presentation of ideas is logical, written in easy-to-understand language . . . you progress step-by-step, at your own pace.

CIE Education by mail

There is no need to "go back to the classroom" with CIE. Because you learn at *home* or wherever else is convenient. You keep your present job and income. No cross-town commutes. *You* decide when and where *you* study best.

Your eventual success . . . at CIE and in your electronics career . . . will be determined by your own motivation and self-discipline. You *can* do it. And CIE can show you how.

Patterns shown on TV and oscilloscope screens are simulated.

NRI offers you five TV/Audio Servicing Courses

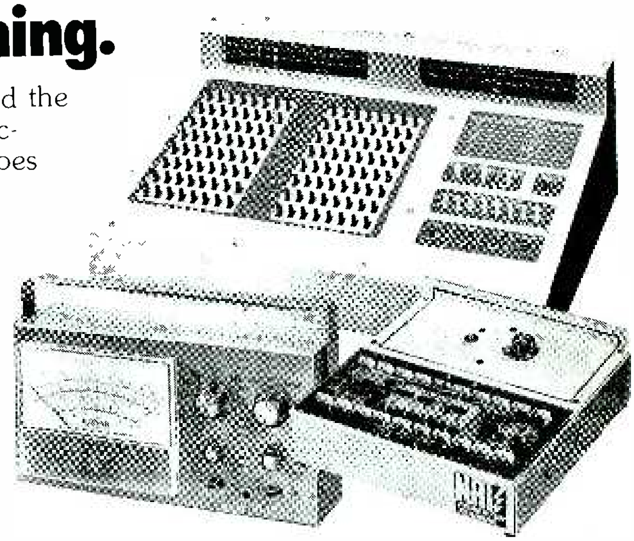
NRI can train you at home to service TV equipment and audio systems. You can choose from 5 courses, starting with a 48-lesson basic course, up to a Master Color TV/Audio Course, complete with designed-for-learning 25″ diagonal solid state color TV and a 4-speaker SQ™ Quadraphonic Audio System. NRI gives you both TV and Audio servicing for hundreds of dollars less than the two courses as offered by another home study school.

All courses are available with low down payment and convenient monthly payments. All courses provide professional tools and "Power-On" equipment along with NRI kits engineered for training. With the Master Course, for instance, you build your own 5″ wide-band triggered sweep solid state oscilloscope, digital color TV pattern generator, CMOS digital frequency counter, and NRI electronics Discovery Lab.

™Trademark of CBS Inc.

NRI's complete computer electronics course gives you real digital training.

Digital electronics is the career area of the future . . . and the best way to learn is with NRI's Complete Computer Electronics Course. NRI's programmable digital computer goes far beyond any "logic trainer" in preparing you to become a computer or digital technician. With the IC's in its new Memory Kit, you get the only home training in machine language programming . . . experience essential to trouble shooting digital computers. And the NRI programmable computer is just one of ten kits you receive, including a TVOM and NRI's exclusive electronics lab. It's the quickest and best way to learn digital logic and computer operation.



You pay less for NRI training and you get more for your money.

NRI employs no salesmen, pays no commissions. We pass the savings on to you in reduced tuitions and extras in the way of professional equipment, testing instruments, etc. You can pay more, but you can't get better training.

More than one million students have enrolled with NRI in 62 years.

Mail the insert card and discover for yourself why NRI is the recognized leader in home training. No salesman will call. Dc it today and get started on that new career.

APPROVED UNDER GI BILL
if taken for career purposes Check box on card for details

NRI SCHOOLS
McGraw-Hill Continuing Education Center
3939 Wisconsin Avenue,
Washington, D.C. 20016

the exception that the downlead is in the approximate center of the antenna section. The flattop antenna should be at least a half wavelength (492/f MHz) at the lowest operating frequency. The advantage of the flattop antenna over other designs is that it allows maximum use of available space in the configuration shown.

It is also possible to build vertically polarized shortwave receiving antennas; Fig. 10 shows one such version. The support structure (a tree or building) should be at least a quarter-wavelength high on the lowest operating frequency. The vertically polarized antenna is fed at the base with coaxial cable. The center conductor goes to the antenna element, while the coaxial cable's shield gets connected to the ground rod at the base of the support structure.

It's possible to install the wire (or multiple wires of different lengths) inside a length of PVC plumbing pipe. The pipe serves as the support, and the conductors go inside. If you use a heavy pipe gauges of PVC, then the antenna support can be disguised as a flag pole (townhouse dwellers take note)!

Different conductor lengths (L = 246/f MHz) are required for different operating bands. In Fig. 11, several bands are accommodated from the same feedline using the same support. In fact, eight different antenna elements are supported from the same tee-bar. Be sure that you insulate them from each other, as well as from the support; again, PVC piping can be used for the support structure. Figure 12 shows a method for accommodating several bands by tying the upper ends of each antenna wire to a sloping rope.

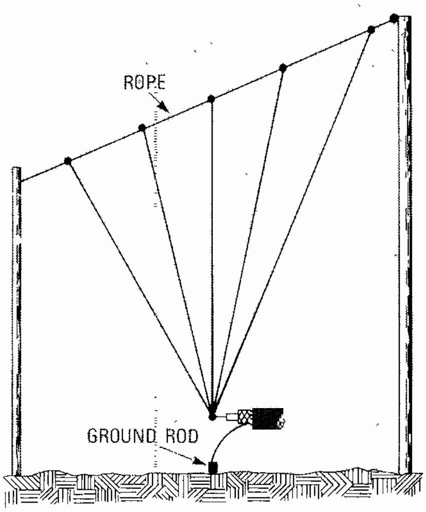


FIG. 12—BY USING A SLANTED ROPE, you can tied together any number of antennas tuned to different wavelengths.

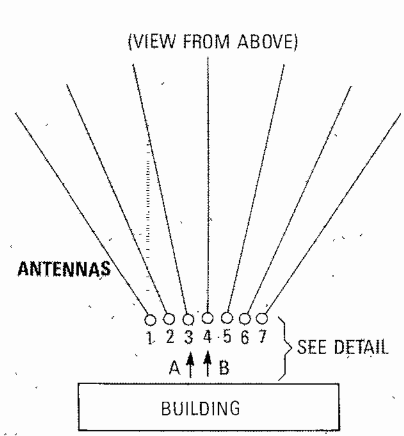


FIG. 13—SELECT THE DIRECTIONAL pattern of the antenna system by interchanging antenna elements of different wavelengths and position.

Directional wire antenna

A directional antenna has the ability to enhance reception of desired signals, while rejecting undesired signals arriving from slightly different directions. Although directivity normally means a yagi beam, a wire-quad beam, or at least a rotatable dipole, certain designs and techniques allow fixed antennas to be more or less directive. One crude but effective approach uses pin plugs or a rotary switch to select the direction of the antenna's reception.

Figure 13 shows a number of quarter-wavelength radiators fanned out from a common feedpoint at various angles from a building. At the near end of each element is a female banana-jack. A pair of balanced feedlines from the receiver (300-ohm twin-lead, or similar) are brought to where the antenna elements terminate. Each wire in the twin-lead has a banana plug attached. By selecting which banana jack is mated to which banana plug, you can select the directional pattern. If the receiver has a balanced antenna input, then connect the other end of the twin-lead directly to the receiver; for receivers with unbalanced inputs, you will have to use a balanced-to-unbalanced (balun) antenna coupler.

Figure 14-*a* shows a balun antenna coupler tuned to the receiving frequency. The coil is resonantly tuned by the interaction of the inductor and capacitor. Antenna impedance is matched by selecting the inductor taps to which the feedline is attached. A simple RF broadband coupler is shown in Fig. 14-*b*. The transformer is wound over a ferrite core using 12 to 24 turns of No.26 enameled wire, with more turns for lower frequencies, and fewer turns for the higher frequencies. Experiment with the number of turns to determine the correct value.

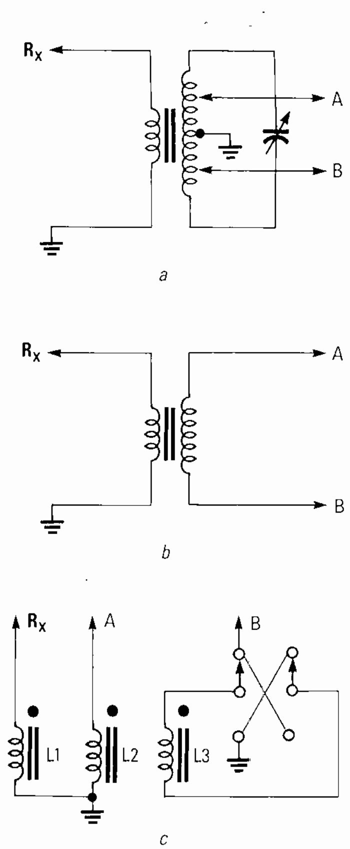


FIG. 14—MATCH A BALANCED ANTENNA with an unbalanced receiver input using any of three methods, *(a)*, *(b)*, or *(c)*.

By combining the right antenna and matching network, the best of both worlds can be had. For example, the antenna in Fig. 13 works by phasing the elements so as to null or enhance the reception in certain directions.

The nulling operation becomes a little more flexible if you build a phasing transformer, like the one in Fig. 14-*c*. Windings L1, L2, and L3 are wound trifilar style on a ferrite toroidal core using 14 turns of No.26 enameled wire. The idea is to feed one element from coil L2 (the A port), the same way all the time; that port becomes the 0-degrees phase reference. Port B is fed from a reversible winding, so it can either be in-phase, or 180-degrees out-of-phase with port A. **R-E**

SPECTRUM MONITOR

continued from page 54

horizontal amplifier (the y-axis). The spectrum monitor outputs have +5-volts DC bias and 5-volts AC maximum swing. If the oscilloscope can't be offset enough in the DC mode, use AC coupling.

If the oscilloscope has no x-y mode, use the VERT OUT (J3) alone. It contains the positive blanking pulse mentioned earlier, and the oscilloscope can then use that as the trigger in a free sweep. If you're running the spectrum monitor off an AC line, it'll synchronize with the 60-Hz line voltage, so line triggering will suffice. Don't overload the RF input, otherwise the display will tend to clip on strong signals, and the front end of the tuner will then either generate modulation products which will appear on the oscilloscope, or it'll be damaged. The spectrum monitor can be used with either a marker or RF generator of known output frequency to mark a specific value.

To use the spectrum monitor as a continuously tuned FM receiver, turn-off sweep potentiometer R20. The signal in the center of the oscilloscope screen will then be demodulated, which is often very useful in identifying an offending carrier, or in hearing FM noise. You'll then be able to listen to signal levels that even some really good consumer FM receivers would have trouble with.

Some modifications

A couple of changes can make the tuned-receiver approach more useful. The first is to extend the frequency range downward. Converters typically contain high-pass filters to remove frequencies below 50 MHz, which can be shorted out with a piece of jumper wire and cutting the relevant foils on the board.

Tapping the IF OUT (J2) lets you use the spectrum monitor as a cable converter. Use two 50-ohm resistors and a switch as a "Y" to feed both the TDA7000 (IC6) and a back-panel "F"-type jack. One way to find the center frequency is to tap pin 4 of the tuner (the FIRST LOCAL-OSCILLATOR TUNING VOLTAGE) to an outside pin jack for a high-impedance VOM or DMM. That lets you graph known frequencies and voltages to find unknown ones. **R-E**

REMOTE A/B SWITCH

continued from page 76

remember to place the components as close together as possible to keep stray capacitance low. If you use the PC board, follow the parts placement in Fig. 9, making sure that the IC's and components that are polarity-sensitive are correctly orientated. Mount Q1 with enough lead length to be positioned directly behind the bubble lens. The collector (flat side) of Q1 is connected to the positive supply. The cathodes of LED1 and LED2 (flat side) are connected to IC4-b and IC4-c, respectively.

3. Figure 10 shows what the relay module should look like. If you choose to hard wire the relay module, use a double-sided copper board, and a shielded enclosure such as a LMB box chassis, Model No. *M00*. Another RFI shield should be constructed out of copper tape, and should enclose jacks J3, J4, and J5. Constructing that RFI shield isn't easy. With a small file, remove the plating from the top flat of the nuts securing the coax jacks in place. Figure 11 shows you how that's done. Apply some solder to the flats, and secure a piece of copper-shield tape at a 90-degree angle across the flats, then heat the tape so that the solder melts and adheres to the tape. Be sure to leave enough tape at the ends to bend down and solder to the copper-tape ground shield created earlier.

Now drill and mount the three coax jacks, J3–J5. One in the center and the other two ¾-inch to the right and left of center. Label the center jack "To TV" and the other jacks "A" and "B." Drill a hole in the opposite panel for the relay's DC supply line.

If you use a single-sided PC board, Fig 12, it may be necessary to shield the non-copper side with ½-inch copper tape to hold down the RFI. Apply two copper-tape strips across the board's length; however, be sure to scrape the copper tape—using an *Exacto* knife—so that the relay pins don't get shorted out. Drill feed-through holes for the relay pins and the DC voltage line. The ground pin on the relay remains grounded to the shield. Install RY1 on the tape side of the board. Be sure that the relay is properly orientated before soldering into place.

The DC line to the relay can be made out of any two-conductor wire. Be sure to leave enough wire length to place the relay module behind the TV set. The positive wire to the relay is connected to the center conductor of PL1.

Calibration

Apply power to the receiver and make sure that nothing gets hot. If something does, that indicates trouble, so immediately turn the power off and check the board for incorrectly placed parts such as diodes, capacitors, and IC's.

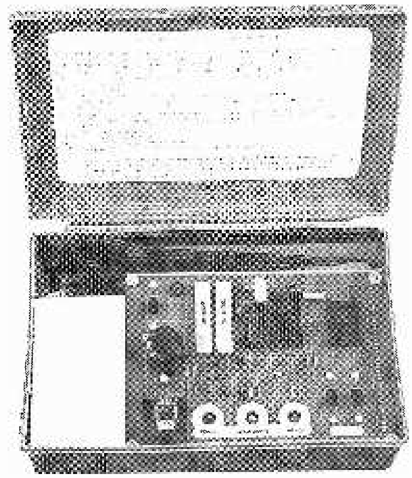
Calibration should be made with RY1 connected to the circuit. Attach a DC voltmeter or oscilloscope to IC2 pin 8. Hold the transmitter approximately one foot from the receiver, aiming it directly at the lens. While depressing the transmitter switch, adjust R17 until IC2 pin 8 drops low. Release the switch and IC2 pin 8 should return high. If you don't have a meter handy, then watch the indicators LED1 and LED2. If the circuit is working properly, the indicators will light alternately each time S1 is pressed. After 10 seconds or so, both indicators should turn off. Place your finger on the relay module and you should feel a click each time S1 is pressed. Vary the adjustment of R17 to find the limits at which IC2 will respond, then center the adjustment between the two limits. Adjust R18 to match the brightness of LED1 to LED2. If more brightness is needed, lower the value of R13 and then readjust R18. The timing cycle of IC5 can be made longer or shorter by varying R12 and C8.

Other relays

A power relay can be used instead of an RF relay (RY1). Although the power relay won't require shielding, a metal enclosure is recommended to provide a proper chassis ground. Make sure that the power relay has a high enough rating for your appliance; contacts rated at 10 amps are usually sufficient. If the relay coil requires more current than Q2 can deliver, replace Q2 with a 2N3053 or TIP 31, which can handle the extra load current and dissipate the heat generated by the power requirement. A general-purpose relay module can be hardwired in an unshielded plastic enclosure. Q2 should be able to energize the relay coil. **R-E**

68705 MICROCONTROLLER

How to build a single-IC microprocessor system



THOMAS HENRY

Sophisticated burglar alarms, stage-lighting controllers, digital music synthesizers, frequency counters, and other test instruments—they all have one thing in common. Designing each of those circuits (and others) using microprocessors is fast and easy if you use the right technology.

That technology needn't consist of expensive ICE's (In-Circuit Emulators) and the like. In fact, by using a single-chip Motorola microcontroller and building a low-cost (well under $100) programmer, you can create custom designs as fast as you can think them up!

The MC68705P3 is a complete microcomputer on a chip. It contains CPU, ROM, EPROM, RAM, timer, interrupt input, clock, and twenty bidirectional I/O lines. Magically, it's all contained in a 28-pin package, which means that the data and address buses are completely hidden from the designer, so circuit-board layout becomes trivial.

In this article we'll discuss the 68705's architecture, its register structure, and programming considerations. Then we'll go on to build a programmer that burns your software into the 68705's internal EPROM. Next time, we'll put theory into practice when we design a two-IC digital alarm clock.

Hardware overview

To use the 68705 in your own projects, you must understand both its hardware and its software capabilities. Let's examine the hardware first. Figure 1 shows a block diagram of the main subsystems that comprise the 68705. First, note the CPU, which is itself composed of an ALU (*A*rithmetic *L*ogic *U*nit) and a controller. Every instruction that the 68705 can execute (addition, subtraction, etc.) is performed by the ALU under direction of the controller. The controller provides the timing necessary to carry out the microinstructions (even basic operations such as addition are composed of smaller steps called "microinstructions"), and ensure that they are performed in the correct order.

The 68705 has several types of memory. For starters, there are 112 bytes of RAM. That may not sound like much, but keep in mind that it is used only for storing variables and the stack; the application program itself is stored elsewhere. Typical microcontrollers seldom use even 30 or 40 variables, so the 68705 has plenty of RAM to handle almost all situations.

The 68705 also contains ROM. Actually, it has both ROM (*R*ead Only *M*emory) and EPROM (*E*rasable *P*rogrammable *R*ead Only *M*emory). The ROM, comprising 115 bytes, contains the EPROM burner program, which Motorola calls the "bootstrap." That means that the means for programming the EPROM is built right into the chip itself!

The EPROM itself consists of 1804 bytes; it is used to hold your application program and constant data. Since EPROM is nonvolatile memory, even if you interrupt power to the IC and later reapply it, your program is still there ready to be executed.

In addition, many I/O lines are available. Logically they are grouped into three ports (parallel groupings of I/O lines). Port A and Port B are each eight bits wide; Port C is four bits wide. To send a message to the outside world, you simply store a byte in the desired port register, and the associated lines will reflect what was written. In an analogous way, the outside world can talk back; a byte placed on the lines of a port may be read by the CPU. I/O in the 68705 is memory-mapped, unlike the case in the Intel family, which has a separate address space and separate instructions for reading I/O ports.

Electrically speaking, the three ports are easy to use. They're all TTL compatible for both input and output. Also, Port B can sink as much as 10 mA, so it can drive LED's directly.

Associated with each port is a DDR (*D*ata *D*irection *R*egister). It is the duty of the DDR to configure the associated I/O lines for either input or output operations. The DDR itself is programmed by writing to special memory locations.

Referring to Fig. 1 again, note that there is an external interrupt line ($\overline{INT}$). Normally, the 68705 executes some sort of program. But there may be times when you wish to temporarily halt execution of the main program and then continue execution in a subsidiary program. An external signal (a fire sensor or burglar alarm) applied to $\overline{INT}$ might cause such a change. Most microprocessors and microcontrollers have interrupt inputs, but what makes $\overline{INT}$ especially useful is the fact that it can accept both digital and analog inputs!

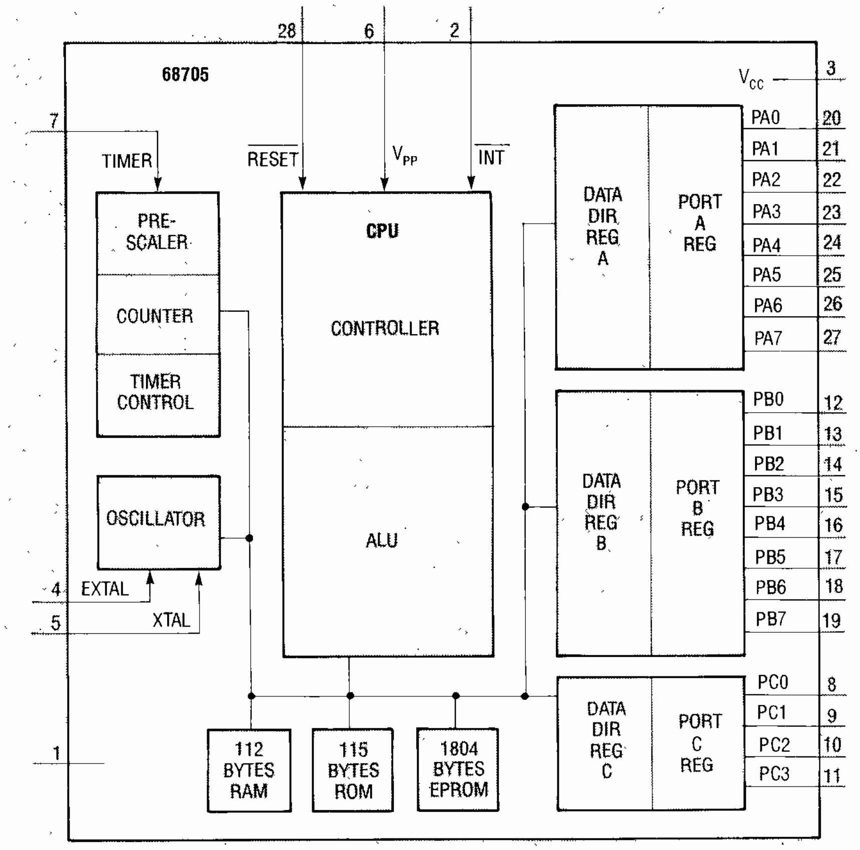


Fig. 1. *THE 68705 IS A 28-PIN MICROCONTROLLER with RAM, ROM, EPROM, and 20 bytes of I/O.*

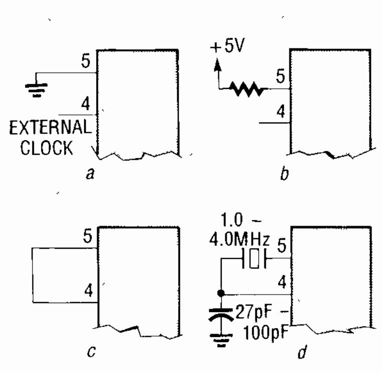


Fig. 2. *CLOCKING THE 68705: (a) using an external clock, (b) using a resistor, (c) using the default clock, and (d) by crystal control.*

The reason is that the 68705 has an internal Schmitt trigger, which means that it can detect zero-crossings of an analog signal. That capability might be useful in frequency-counter applications, in which a timebase is derived from a 60-Hz AC signal.

The 68705 also contains a timer with an optional prescaler. The timer, which is actually an 8-bit countdown register, can be loaded with a number. The register will then proceed to decrement at the processor's internal clock rate; when the register hits zero, an interrupt is generated that causes the processor to continue execution at a special program location. The prescaler allows for longer periods between timeouts. The timer can also be clocked from an external source, if desired.

Of course, all computers must have some sort of clock to synchronize activities (access I/O ports, execute the microinstructions in the CPU, etc.) The 68705 has quite versatile clocking options. In fact, as shown in Fig. 2, it can be clocked in four distinct ways.

In Fig. 2-*a* we see how the 68705 can be clocked by an external source; you would use that method when a master clock is present in existing circuitry with which the microcontroller must interface. Figure 2-*b* shows how an external resistor can be used to set up the internal clock, and Fig. 2-*c* shows how installing a jumper will allow the internal clock to run at a default rate. Last, in Fig. 2-*d*, a crystal is used for best accuracy and reliability.

Software overview

Now let's change focus and consider the software side of the 68705. If you've any experience with the 6800 or other 8-bit microprocessors, the 68705 will appear quite similar. Figure 3 shows the programming model. Both the accumulator and the index register are eight bits wide. As the name suggests, the results of most arithmetical and logical instructions "accumulate" in the accumulator. The index register, on the other hand, is typically used to access individual elements of tables and lists; it does so using special address modes discussed shortly.

The program counter is 11 bits wide, giving the 68705 a total address range of 2048 ($0800) locations. Those locations include all the RAM, ROM, EPROM, DDR's, and I/O ports.

Also included in the programming model is the stack pointer. The stack is a LIFO (*L*ast *I*n, *F*irst *O*ut) type; it's maintained in the user area of RAM, and its pointer always aims at the next usable

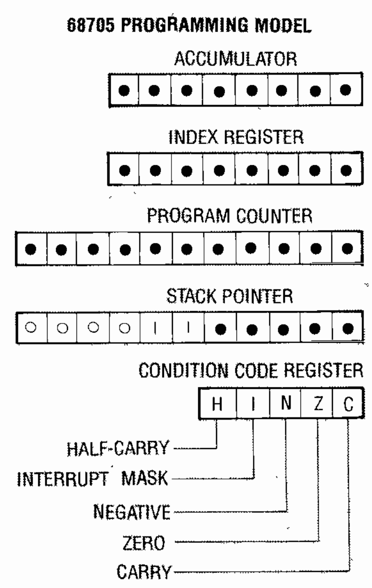


Fig. 3. *THE 68705 consists of an eight-bit accumulator and index register, an 11-bit program counter and stack pointer, and a condition-code register.*

TABLE 1—68705 MEMORY MAP

\$000	Port A
\$001	Port B
\$002	Port C (low order nibble only)
\$003	Not used
\$004	Data direction register, Port A
\$005	Data direction register, Port B
\$006	Data direction register, Port C (low order nibble only)
\$007	Not used
\$008	Timer data register
\$009	Timer control register
\$00A	Not used
\$00B	Program control register
\$00C - \$00F	Not used
\$010 - \$07F	RAM
\$080 - \$783	EPROM
\$784	Mask options register
\$785 - \$7F7	Bootstrap ROM (EPROM burner program)
\$7F8 - \$7F9	Timer interrupt vector
\$7FA - \$7FB	External interrupt vector
\$7FC - \$7FD	SWI interrupt vector
\$7FE - \$7FF	Reset vector

location. The stack pointer is shown in the model to be 11-bits wide, but the highest six bits are fixed in such a way that the stack pointer always points into the RAM area. The maximum depth of the stack is 32 bytes, which may not seem like much, but which should suffice for most controller applications.

Also, a condition-code register keeps track of the results of various operations. For example, one bit of the register is set whenever a negative number appears in the accumulator; another is set whenever a value of zero appears in the accumulator. Another bit informs us if a carry or borrow was required to complete an arithmetic operation (addition or subtraction, respectively). The half-carry flag is set if a carry results from adding two BCD (*B*inary *C*oded *D*ecimal) numbers. The interrupt mask lets us tell the 68705 to ignore interrupt signals applied to $\overline{\text{INT}}$.

The 68705's memory map is shown in Table 1. Note that all of RAM sits in page zero, while EPROM addresses start in page zero and continue to higher addresses. The I/O ports and DDR's are also located in page zero, as are the timer's control registers.

At the highest memory locations you will find a set of vectors (pointers) that tell the microprocessor where to continue program execution in the event of an interrupt. It is the designer's responsibility to program the correct values into the EPROM.

Interrupts in the 68705 can take one of four forms: (1) $\overline{\text{RESET}}$ is generated at power up; it is used to start the processor from a known condition. (2) $\overline{\text{INT}}$ (external interrupt) occurs when there is activity on pin 2 of the 68705, as discussed earlier. (3) An SWI, or *S*oft*W*are *I*nterrupt, happens when the CPU executes an SWI instruction, which is typically used for debugging purposes. (4) The last type of interrupt is triggered when the internal timer times out.

One additional location in the memory map is interesting: the mask options register (\$784), which is a location in EPROM that allows the designer to determine how the 68705 operates. For example, by burning various bits in the location low or high, you can specify what type of clock you're using, how the timer is used, whether the prescaler is used, etc.

Address modes

The 68705 has ten address modes; many instructions are functional in several address modes. Unfortunately, we haven't space to discuss operation of each instruction in detail; consult the appropriate Motorola data sheets for more information. We will, however, discuss the basic address modes and several unusual instructions.

The immediate addressing mode is concerned with constants. For example, LDA #20 says to load the accumulator with the decimal constant 20. The pound sign is what indicates immediate mode.

Contrast that with the direct-address mode instruction LDA 20, which says to load the accumulator with the number contained in memory location 20. Here the accumulator loads a variable, not a constant. The direct mode can only access locations in page zero, because the operand (the address) is specified by a single byte.

The extended-address mode overcomes that liability by allowing two-byte operands. For example, LDA 450 says to load the accumulator with the contents of location 450. Of course, extended-mode instructions take more space and execute slower than direct-mode instructions.

The relative-address mode is used in branching instructions. Rather than specifying a precise location to branch to, the relative mode allows the programmer (or the assembler program) to designate an address relative to the current address at which execution should continue. For example, BRA 10 would move execution to the tenth location following completion of the current instruction.

There are three types of indexed addressing modes available. The no-offset indexed mode takes its argument from the index register. For example, LDA (X) says to load the accumulator with the contents of the location pointed to by the index register.

The one-byte indexed mode extends that concept. For example, LDA 20,X1 tells the processor to add the number 20 to the contents of the index register and then access the resulting location. If the index register contained the number 35, say, then the contents of location 55 would be fetched (20 + 35 = 55).

The two-byte indexed mode extends the concept even further by

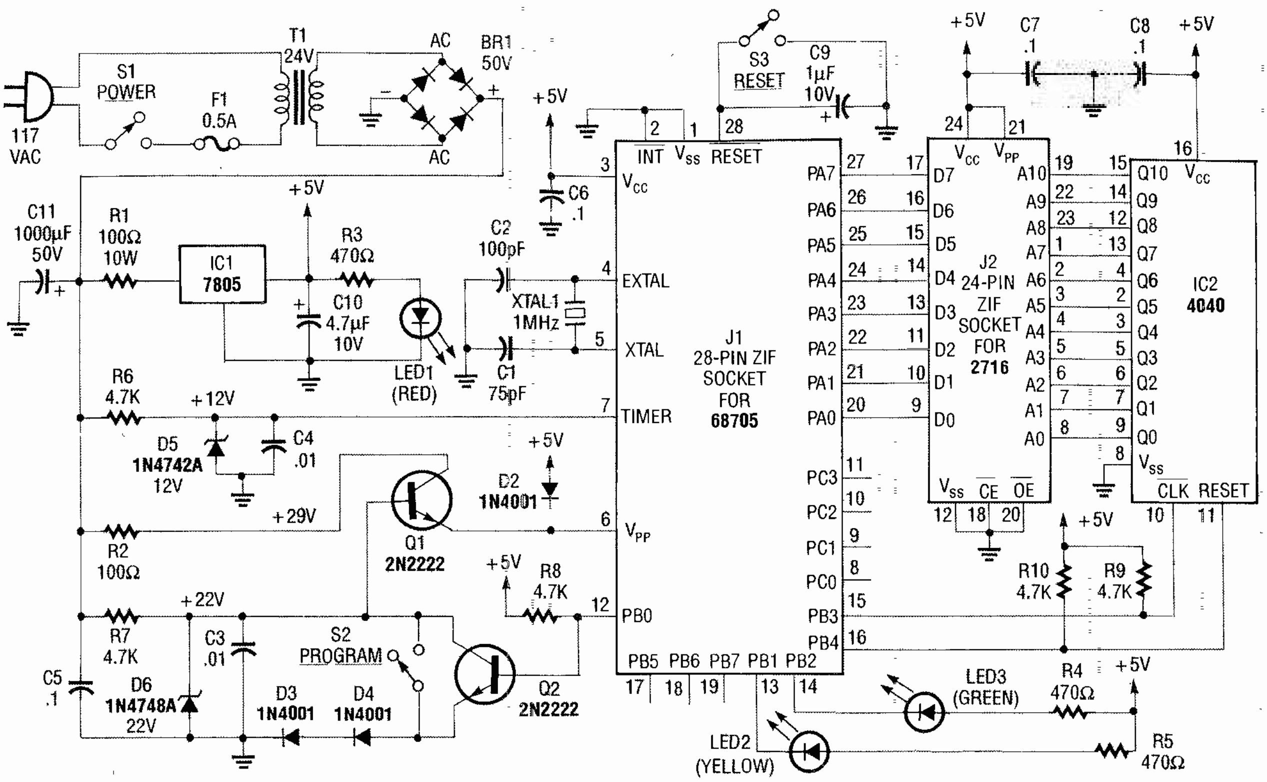


Fig. 4. *EPROM BURNER FOR THE 68705: IC2 decodes sequential memory locations in the EPROM (J2), whose outputs are applied to Port A of the 68705 (J1).*

allowing a larger number to be used. For example, LDA 450,X2 adds the two-byte number 450 to the contents of the index register and then accesses the location specified by that sum.

The inherent addressing mode covers one-byte instructions whose operand is implied in the nature of the instruction. For example, CLR A says to clear (reset to zero) the accumulator; obviously, no external memory locations are involved. Unusually, the 68705 also allows the inherent mode with the index register. So, for example, CLR X would clear the index register.

Bit twiddling

Although we don't have space to discuss the entire instruction set, it's worthwhile mentioning several special instructions. With most microprocessors, to access individual bits within a byte, you must "mask" that byte; AND and OR it with constants. The 68705 has four special instructions that allow you to get at bits directly. BRSET allows your program to branch if a bit is set, and BRCLR allows your program to branch if a bit is clear. For example, BRSET 7,20,46 says to test bit 7 of location 20. If that bit is set, then branch forward 46 locations and resume program execution there.

BSET and BCLR allow you to set and clear bits individually. For example, BSET 4,20 sets the fourth bit of location 20, and BCLR 4,20 clears that bit.

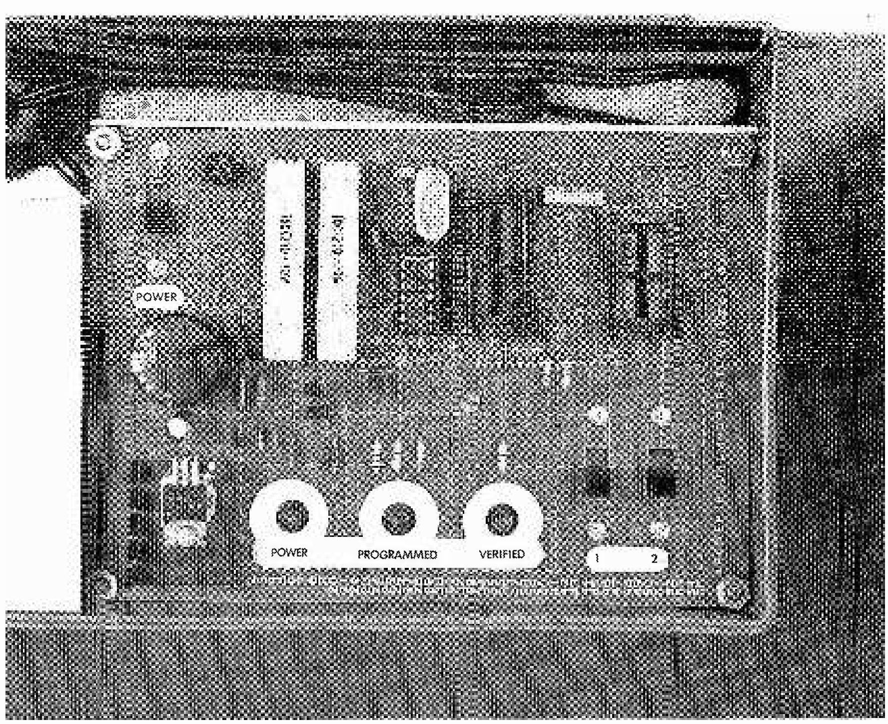


Fig. 5. *PROTOTYPE OF THE EPROM BURNER. The author used wirewrap and point-to-point wiring techniques.*

Parts List

Resistors

All resistors are ¼-watt, 5% unless otherwise noted.

R1 ..... *100 ohms, 10 watts*
R2 ..... *100 ohms*
R3–R5 ..... *470 ohms*
R6–R10 ..... *4700 ohms*

Capacitors

C1 ..... *75 pf, silver dipped mica*
C2 ..... *100 pf, silver dipped mica*
C3, C4 ..... *0.01 µF disk*
C5–C8 ..... *0.1 µF disk*
C9 ..... *1 µF, 10 volts, electrolytic*
C10 ..... *4.7 µF, 10 volts, electrolytic*
C11 ..... *1000 µF, 50 volts, electrolytic*

Semiconductors

BR1 ..... *50-volt bridge rectifier*
D1 ..... *not used*
D2–D4 ..... *1N4001*
D5 ..... *1N4742A 12-volt Zener*
D6 ..... *1N4748A 22-volt Zener*
LED1 ..... *red*
LED2 ..... *yellow*
LED3 ..... *green*
Q1, Q2 ..... *2N2222 NPN, general purpose*
IC1 ..... *7805 5-volt regulator*
IC2 ..... *4040 CMOS counter*

Other components

F1 ..... *0.5-amp fuse*
J1 ..... *28-pin ZIF socket*
J2 ..... *24-pin ZIF socket*
S1–S3 ..... *SPST switch*

Designing with the 68705

The question now is how to get a program into the 68705's internal EPROM. The process is actually quite simple. First, you need to write the desired program. If it is a short program, you can hand-assemble it (that is, look up the instructions and find the appropriate opcodes). Of course, it's faster and more accurate to use a cross-assembler, a translator that runs on one computer, say a PC, and converts the ASCII source code into 68705-compatible object code (hex bytes). You can either buy a commercial cross-assembler or write one yourself in BASIC or PASCAL.

After writing and assembling the program, it takes two steps to burn the program into the 68705. First you must burn the code into a 2716 EPROM (a common device for which burners are likewise commonplace). Then the program is transferred from the 2716 to the 68705 using the bootstrap program in the latter. A circuit for doing that is shown in Fig. 4. The basic idea is that under direction of the bootstrap program, the bytes in the 2716 are sent one at a time to I/O Port A, where the 68705 reads them and then burns them into the appropriate locations of its EPROM.

In the schematic, J1 and J2 are *Zero Insertion Force* (ZIF) IC sockets for the 68705 to be burned and the 2716 containing the program, respectively. The 4040, IC2, is a counter that is clocked by PB3 of the 68705. The 4040's outputs allow locations in the EPROM to be accessed sequentially. The data outputs of the EPROM are then read by Port A of the 68705.

How does the 68705 know to execute the bootstrap program? Note that the TIMER input (pin 7) of the 68705 is tied to +12 volts. Pin 7 normally acts like a standard TTL input, but if the voltage on this pin rises to +12V, the CPU halts all other activity and starts executing the bootstrap program.

How to burn

To understand the remaining circuitry, let's trace through the sequence of steps involved in actually burning a 68705. Start by assuming that S1 is open (no power applied), and that S2 and S3 are closed. After inserting a 68705 and a 2716, close S1, which powers up the device. Now +12V is applied to the timer input, so the CPU knows that it must execute the bootstrap program. However, since S3 is still closed, the microprocessor is stuck in a reset condition, so nothing happens yet. In addition, since S2 is closed, Q1 is off, so only +5 volts is applied to the V_{PP} input, rather than the +22-volt programming voltage. Also, both programming indicators (LED2 and LED3) are extinguished.

Now open switch S2. That allows Q1 to turn on, which allows it to pass the regulated +22V. Thus the programming voltage, not +5V, appears at V_{PP} Now open S3; that brings the CPU out of the reset condition and allows it to execute the bootstrap program. After all bytes have been transferred, LED2 lights up, indicating that the internal EPROM has been burned.

However, the bootstrap isn't done yet. As a check, it goes back and compares each byte in its internal EPROM with the associated byte in the 2716. If they match successfully all the way down the line, then LED3 lights up, indicating that verification is complete. At this point, you would close S3, close S2, and then open S1. At this point the 68705 is ready for use.

Construction

The 68705 programmer uses only garden-variety components and is easy to build. Figure 5 shows the author's prototype; it was built ordinary wirewrap techniques; the entire unit is housed in a plastic pencil box.

Now we'll put our theory to work and build a digital alarm clock. The project is not just an educational exercise; you'll find that it is useful and that it incorporates several features not found in commercial units. By studying the example, you'll find numerous hints for designing with the 68705.

Design goals

We want a four-digit readout for hours and minutes, a blinking colon to indicate seconds, fast and slow display-set buttons, clock- and alarm-set buttons, an AM/PM indicator, an enable switch and a volume control for the alarm, the ability to show either hours and minutes or minutes and seconds, a power-outage warning, and the ability to display either a 12- or a 24-hour clock.

Those may seem like ambitious design goals. As it turns out, however, the 68705's versatility lets us build the project using only two IC's. And one of them is a dedicated sound generator, which means that the clock really requires only the 68705!

The basic plan of attack is to derive the 60-Hz timebase from the 117-VAC power lines. In most communities, that frequency is accurate to 0.02 Hz, or 3 parts in 10,000. By using the AC lines (which are more than accurate enough for a clock), we can simplify the design tremendously, and even eliminate the need for a crystal oscillator. (See part one of this story for more information on clocking the 68705.)

To simplify things even further, we multiplex the four seven-segment LED displays. Doing so means we need no latches or decoders, reducing the number of passive components as well. Port B of the 68705 can sink 10 mA of current directly, so no display drivers are needed either. Decoding is handled by means of a look-up table burned into the internal EPROM. Since we don't use a commercial display decoder, we can create our own alphanumeric characters and display textual messages.

The clock uses the interrupt capabilities of the 68705 to keep track of the passage of time. Normally, the CPU runs a program that updates the display LED's, scans for switch closures, and checks to see if the alarm time has been met. But while all that is happening, the 60-Hz AC signal interrupts the main program every 1/60th of a second. After 60 such interrupts, a memory location in RAM is incremented to indicate that another second has elapsed. In a similar fashion, other RAM locations keep track of passing minutes and hours. Generally speaking, the two-program approach (a main program used in conjunction with an interrupt program) is a powerful technique with many applications in modern electronics.

Hardware

Now let's examine the schematic and see how the hardware works. As shown in Fig. 1, only two IC's are used (or three if you count the voltage regulator). First

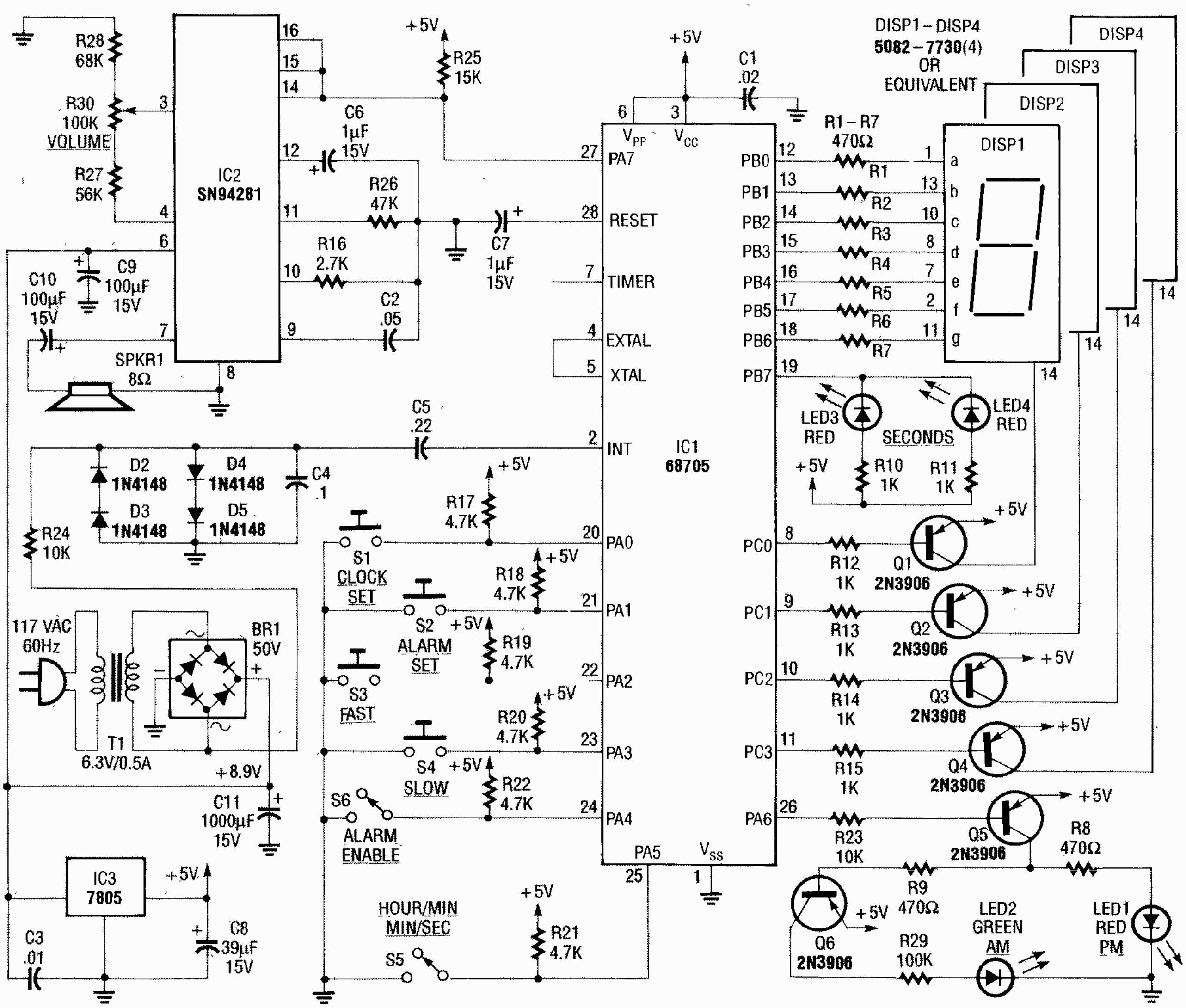


FIG. 1—THE ALARM CLOCK USES THREE IC'S: The microcontroller, a sound generator, and a voltage regulator.

is IC1, the 68705. Second is a 94281 sound generator, which is used to create the alarm signal. Although it would probably be possible for IC1 to generate the alarm signal by itself, it seemed simpler to use a dedicated IC. Last is the voltage regular, IC3, a 7805.

Actually, the clock uses two voltages: an unregulated +8.9 volts for the sound generator, and the regulated +5 volts for the microcontroller and display circuitry. Note that we tap one leg of the transformer to derive the timebase. To keep the voltage to a safe level, the AC signal is clipped by diodes D2–D5, and then filtered by C4 to remove any remaining cusps. The resultant signal is then capacitively coupled to the $\overline{\text{INT}}$ input (pin 2 of IC1) by C5. A Schmitt trigger, internal to the 68705, squares up the signal.

Now let's consider the display. The secret of a multiplexed display is the concept of rows and columns. We define one set of output lines as rows and another as columns. We can supply voltage to a particular segment in a particular display by enabling specific row and column outputs of the microcontroller; the LED at the intersection thus lights up.

Transistors Q1 through Q4 function as the columns; they're enabled by four lines from Port C. Those lines can't source much current, which is why we need the transistors. However, because of its current-carrying capacity, Port B drives the row outputs (i.e., the display segments) directly.

Each segment in a display is labeled with a letter from *a* through *g*. All four *a*'s are connected to each other, and then to PB0, via R1, which limits current. Similarly, the *b* segments are tied together and connected to PB1 via R2, and so on, through PB6, which drives the *g* segment.

As for the columns, we must use common-anode displays, because of the current-sinking logic. (Incidentally, we specified Hewlett-Packard types in the schematic and Parts List, but you can substitute just about any common-anode type.) Note in Fig. 1 that the anode of each display is supplied current through a transistor (Q1–Q4). The software ensures that only one transistor is on at a time, thus only one display is enabled at a time. By successively turning on Q1, Q2, Q3, Q4, and then Q1 again (and so on), each display shows its current segment pattern. If that rotational multiplexing happens fast enough, then persistence of vision leads to the optical illusion that all four displays are illuminated continuously. And it's all handled in software, without any external logic!

We generate the blinking colon using two discrete LED's (D8 and D9), which are driven from PB7. Two other discrete LED's (D6 and D7) provide an AM/PM indicator. When PA6 goes low, Q5 turns on, so D6 (PM) lights up. However, Q6 turns off, so D7 (AM) turns off. On the other hand, when PA6 goes high, Q5 and D6 are off, and Q6 and D7 are on.

PA7 fires up the sound generator when an alarm must be sounded. The operation of IC2, the SN94281, is beyond the scope of this article, but suffice it to say, when PA7 of the 68705 goes low, IC2 emits a mighty "whooping" burst sufficient to arouse the soundest of sleepers. Alarm volume may be adjusted by potentiometer R30. However, that may be a dangerous control to leave in the hands of a confirmed late sleeper!

All the I/O lines examined so far (all of ports B and C, as well as PA6 and PA7) are used for output operations. Of course an alarm clock needs information from the user in order to be useful; S1–S6 provide that information.

For example, SPST pushbutton S1 acts as the CLOCK SET button. Pressing it along with either S3 (FAST) or S4 (SLOW) allows the user to set the proper time. The ALARM SET button (S2) works in a similar manner with S3 and S4 to set the alarm time.

Notice how simple the switch interfaces are. A pullup resistor ties a port line high until a switch pulls it to ground. Through software, the 68705 senses the change and can then take appropriate action. Note further that the switches needn't provide "clean" make/break operations; the 68705 handles the contact debouncing through software, thus eliminating yet more out-

Parts List

Resistors

All resistors are 1/4-watt, 5%, unless otherwise noted.

R1–R9	*470 ohms*
R10–R15	*1000 ohms*
R16	*2700 ohms*
R17–R22	*4700 ohms*
R23, R24	*10,000 ohms*
R25	*15,000 ohms*
R26	*47,000 ohms*
R27	*56,000 ohms*
R28	*68,000 ohms*
R29	*100,000 ohms*
R30	*100,000 ohms, audio potentiometer*

Capacitors

C1, C2	*0.02 µF, disk*
C3	*0.01 µF, disk*
C4	*0.1 µF, disk*
C5	*0.22 µF, disk*
C6, C7	*1 µF, 15 volts, electrolytic*
C8	*39 µF, 15 volts, electrolytic*
C9, C10	*100 µF, 15 volts, electrolytic*
C11	*1000 µF, 15 volts, electrolytic*

Semiconductors

IC1	*68705 microcontroller*
IC2	*SN94281 sound generator*
IC3	*7805 5-volt regulator*
BR1	*50 volt bridge rectifier*
D1	*not used*
D2–D4	*1N4148 switching diode*
DISP1–DISP4	*4082-7730 common-anode 7-segment display, or equivalent*
LED1, LED3, LED4	*red light-emitting diode*
LED2	*green light emitting diode*
Q1–Q6	*2N3906 PNP switching transistor*

Other components

SPKR1	*8 ohms*
S1–S4	*SPST pushbutton*
S5, S6	*SPST slide or toggle*
T1	*6.3 volts*

board circuitry!

Another point is that we get double duty out of the switches. Pushing both CLOCK SET and ALARM SET simultaneously toggles the display between 12- and 24-hour modes.

The remaining two slide switches are easy to fathom. The user specifies whether hours and minutes or minutes and seconds should be displayed, according to the position of S5. The minutes-and-seconds display is useful for timing household events. In addition, switch S6 enables and disables the alarm.

That wraps up the hardware side of the digital alarm clock. As you can see, the electronics are quite straightforward (and also, therefore, easy to wire). Since the electronics are so simple, it's reasonable to surmise that quite a lot must be happening in software.

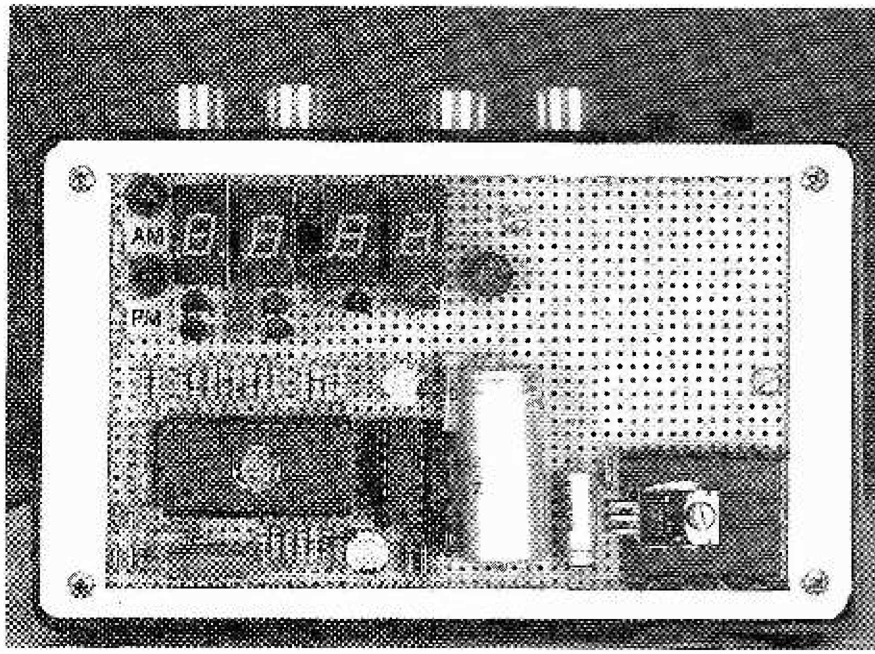


FIG. 2—THE AUTHOR'S PROTOTYPE was built using point-to-point wirewrap techniques.

Inside the software

Unfortunately, we don't have space to print the entire assembly-language listing here. However, the listing is available on the RE-BBS (516-293-2283, modem settings: 300/1200, 8N1). The source code is well annotated, so there is no reason to discuss it here in great detail. However, to simplify reading the code, we will point out some of the main features.

First we define several constants and variables. For example, there are variables (stored in RAM, of course) that keep track of the hours, minutes, seconds, and "jiffies" (1/60th of a second). Other variables keep track of the alarm time; yet others monitor the condition of the various switches.

The code itself begins in an initialization routine (INITIAL) that is called whenever power is applied to the clock. The reset vector (discussed last time) points to this location ($0100). INITIAL has two main functions: initialize all variables and display the message "HELP" while sounding the alarm.

That's a useful feature not found on commercial clocks. For example, imagine you are soundly asleep and that the AC power is interrupted. Most AC-powered digital clocks would be completely disrupted in that type of situation. When the power returned, a typical clock would be in an unknown condition, hence would not sound the wakeup alarm at the correct time. But with our clock, you'll be alerted that something has happened (by the alarm and the "HELP" message), so you can reset your clock and return to sleep.

The routine labeled MAIN (lines 2190–2290) forms the main loop of the program, sequentially checking for switch closures, updating the display, sounding the alarm if necessary, then starting over.

Most of the rest of the code is devoted to the subroutines needed to carry out the I/O activity. For example, the switches are checked by polling the associated I/O ports. When a change is detected, the change is debounced by the software.

Other areas to examine are the subroutines that update the display; those routines call other routines that convert the binary numbers used by the 68705 to binary-coded-decimal (BCD) format. Yet another subroutine converts the BCD number into the segment pattern required by the displays. The segment pattern table is found in lines 4880–5020.

One of the most important routines is the clock update routine (UPDATE, lines 3970–4210), which is driven by the 60-Hz interrupt signal.

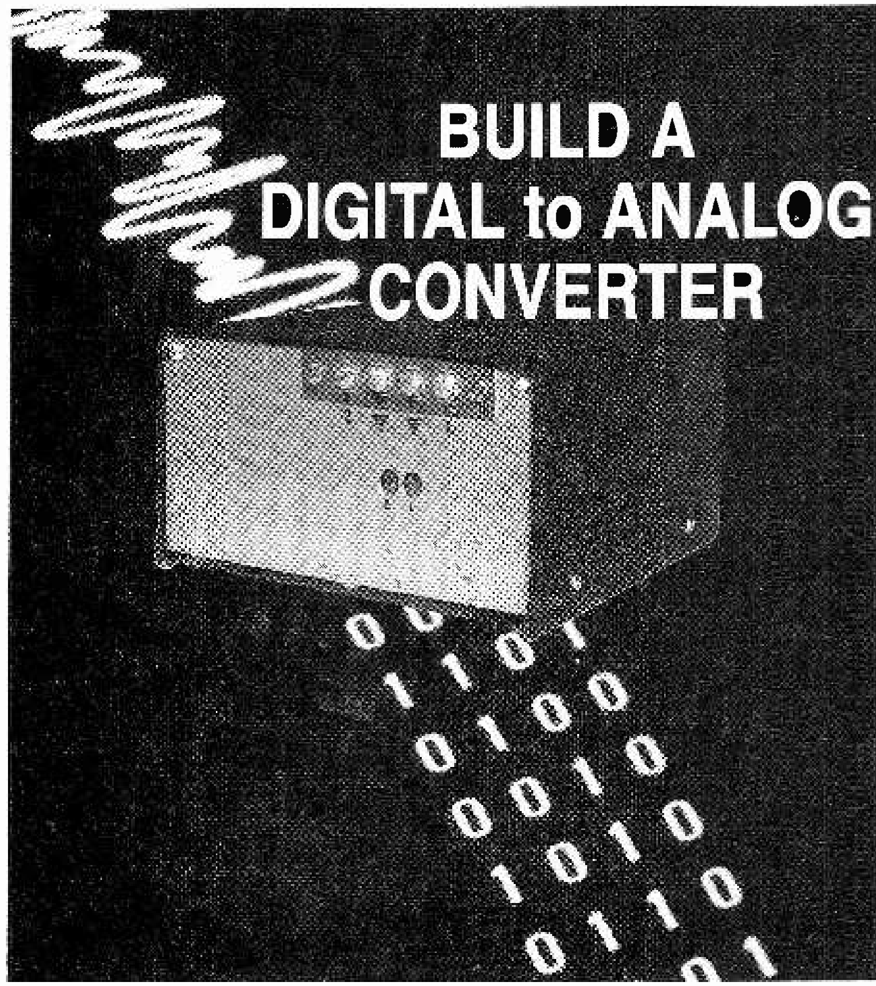
Of course there's more to the code than that description, so you'll have to study it carefully to understand what's going on. But doing so is a worthwhile experience, even if you don't plan on building the clock, since you will come away with a real feel for the instruction set of the 68705.

Construction

To build a clock, first gather all the parts. The next step is to burn the program into the 68705's internal EPROM; that process was described in detail in the first installment (**Radio-Electronics,** September 1989), which also included complete details for building an EPROM burner that's good for the 68705.

Then you can build the clock. Because the circuit is so simple, the author built the prototype using wirewrap and point-to-point wiring techniques, as shown in Fig. 2. Note that for educational purposes, some components were mounted on the outside of the box; in fact, only the power transformer and volume control were mounted inside the box.

continued on page 112



Computers are digital devices. In a computer, all information can ultimately be resolved into bits that are either on or off. The real world, however, is analog. The sun rises gradually, not suddenly. Temperature changes smoothly. Water flows. All human sensory inputs receive data in analog format.

However, it's difficult to represent analog values digitally. When people began to design thinking machines, they quickly discovered that devices that operated on analog principles were complicated, sensitive, and unreliable. The problem needed simplification; what greater simplification than to allow no more than two states, on and off?

The problem, of course, is that operation on digital principles erects a fundamental barrier between the computer and the world outside the box. How can the computer, which is essentially a yes/no device, sense, much less control, analog phenomena in the real world?

Two complementary devices make both sensing and control possible: the *A*nalog-to-*D*igital *C*onverter (ADC) and the *D*igital-to-*A*nalog *C*onverter (DAC), respectively. As the name suggests, an ADC is a device that converts real-world analog quantities into digital terms that the computer can deal with. Conversely, a DAC is a device that converts the computer's digital data to analog form, and it is usually current or voltage.

In this article we'll show what a DAC is, how it works, and how it can be used. To illustrate those ideas, we'll present construction details for building a low-cost ($35), high-speed DAC, with as many as eight independent channels. You can connect the DAC to any standard parallel printer port. We'll also discuss the software that controls the DAC, but space precludes printing full listings. However, the software (DAC.ARC) is available on the R-E BBS (516-293-2283). A special feature of the software is an interactive full-screen editor/compiler that functions much like Borland's Turbo and Microsoft's Quick languages.

DAVID WEBER

DAC basics

The most common technique for making an analog signal from a digital value is the R-2R resistor ladder; an eight-stage ladder is shown in Fig. 1. A precision reference voltage (V_{REF}) is applied to the top of the ladder; current then passes through the R-2R resistor network to ground. The strength of the output current (I_{OUT}) is determined by which of the S1 through S8 switches are open or closed.

The maximum I_{OUT} occurs when all the switches are closed, which places one end of all the 2R resistors at ground potential (disregarding the low resistance of ammeter M1). Solving for the equivalent resistance we get R, so the maximum full-scale current is V_{REF}/R. On the other hand, if only S1 is closed (S2–S8 open), then the maximum current is V_{REF}/2R. The current is now one-half the original full-scale current.

It should be obvious to you now that closing any combination of switches will yield a specific fraction of the full-scale current. By rapidly changing the digital word that closes and opens switches S1 through S8, a changing current will be present at I_{OUT}, and that's digital-to-analog conversion.

EMThe precision of I_{OUT} depends on the precision of V_{REF}, on the precision of the resistors in the ladder, and on the precision with which they are matched. In addition, the number of stages in the ladder determines the fineness with which I_{OUT} can be adjusted. Commercially, eight-bit DAC's are inexpensive and readily available; sixteen-bit DAC's are available at higher cost for high-precision applications.

The DAC0808

The hardware described in this article is built around an eight-

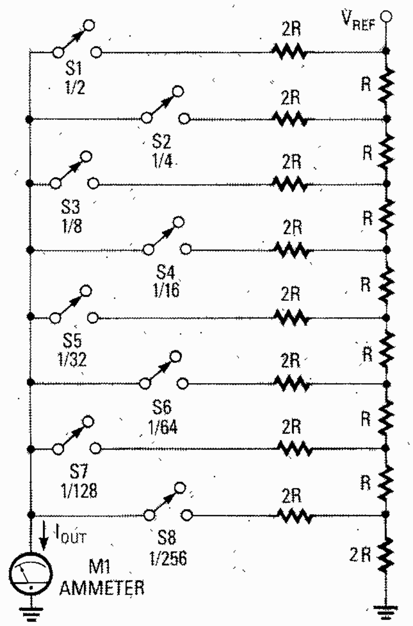


Fig. 1. *THE SIMPLEST DAC: An R/2R resistor ladder. Each switch that is closed increases the amount of current at I_{OUT}.*

bit DAC, the DAC0808 (also known as the LM1408). It has been around for some time, is a stable design, is widely available, and is inexpensive. Eight bits give a precision of 0.39%, which is more than adequate for many uses. The typical settling time for the DAC0808 is 150 ns; that translates to a switching speed better than 5 MHz. In fact, a standard PC cannot come close to driving the converter at that speed. (A 35-kHz square wave was generated using a hand-optimized assembly-language loop on a 4-MHz CPM machine directly driving an 8255 port.)

The internal construction of the DAC0808 differs somewhat from the idealized resistor ladder discussed here. Output is provided on two pins as complementary currents, rather than on a single output as shown in Fig. 1. Also, the lower four stages of the ladder are driven separately from the upper four, because the lower stages are more sensitive to error. The fundamental operating principles, however, are the same.

The circuit

The schematic for the circuit is shown in two parts. The first section (shown in Fig. 2) details the digital interface to the PC's parallel port. One analog section is shown in Fig. 3; bear in mind that the digital section can drive eight analog sections.

An eight-bit parallel printer port is an ideal interface for a DAC, because it is typically the fastest standard interface on a PC. The Centronics parallel port has a 36-pin connector, of which the IBM PC family uses 25; our DAC uses only 16 of those. Eight lines are for data, one is for ground, and the remaining seven are for status and handshaking.

Let's discuss the status lines (PE, BUSY, SELECT, and ERROR) first. When power is applied to the interface, the signal levels on the PE (paper empty) and BUSY lines are low, and the levels on the ERROR and SELECT lines are pulled high by R1 and R2. Those levels prevent the computer from hanging up, thinking that a printer was out of paper, or busy, or in an error condition. We're able to ignore the busy line because the DAC is so much faster than the computer.

When power is off, ERROR and SELECT go low, thereby indicating to the computer that the DAC is in an error state and not selected. In that way the computer can sense whether or not the DAC is powered and ready for data.

There are three handshaking signals: RESET, STROBE, and ACK. RESET is normally used to reset a printer. In our circuit, however, RESET is used to load the value that defines which of the eight converters will receive the data that follows.

The STROBE and the ACK lines handshake data through the parallel port pretty much as they would for a printer. The computer puts a byte of data on D0–D7 and pulses STROBE to tell the parallel device that data is ready. The parallel device reads the data and responds with ACK to signal that everything is fine. To understand what happens in detail, let's walk through a typical data-transfer sequence. Assume that one analog section has already been selected (we'll show how that's done momentarily).

A byte of data enters the circuit and is buffered by IC1, an octal data buffer; IC1 cleans up the signals after their long journey down the cable. The data then proceeds to IC2, an octal data latch; IC2 will latch the data when it gets STROBE from the computer. As for STROBE, it is conditioned by a pair of 74LS14 inverters, IC14-a and IC14-b. It is the rising edge of STROBE that latches the data in IC2.

The output of IC2 is presented to latches IC6–IC13; the latter are

Parts List

Resistors

All resistors are ¼-watt, 5% unless otherwise noted.

R1, R5, R6 ... *10,000 ohms*
R2 ... *2200 ohms*
R3, R7, R8 ... *3300 ohms*
R4 ... *220 ohms*
R9 ... *1000 ohms (for two DAC's; see text)*
R10 ... *5000 ohms, ten-turn potentiometer*
R11 ... *200 ohms*
RP1 ... *3300 ohms, 8 positions, common ground*

Capacitors

C1 ... *0.001 µF ceramic capacitor*
C2 ... *10 pf ceramic capacitor*
C3 ... *100 pf ceramic capacitor*
C4 ... *0.1 µF ceramic capacitor*
C5–C7 ... *2.2 µF, 15 volts, tantalum bypass capacitor*

Semiconductors

IC1 ... *74LS244 octal buffer*
IC2 ... *74LS374 octal latch*
IC3 ... *74LS74 dual D flip-flop*
IC4 ... *74LS221 dual monostable multivibrator*
IC5–IC7 ... *74LS373 octal latch*
IC8–IC13 ... *74LS373 octal latch (optional)*
IC14 ... *74LS14 hex Schmitt trigger*
IC15 ... *DAC0808 8-bit D/A converter*
IC16 ... *LF353 high-speed op-amp*
D1 ... *ECG177 clamping diode*
D2 ... *LM329 6.9-volt precision Zener*

Miscellaneous

Perf board, power supply, IC sockets, wire, solder, etc.

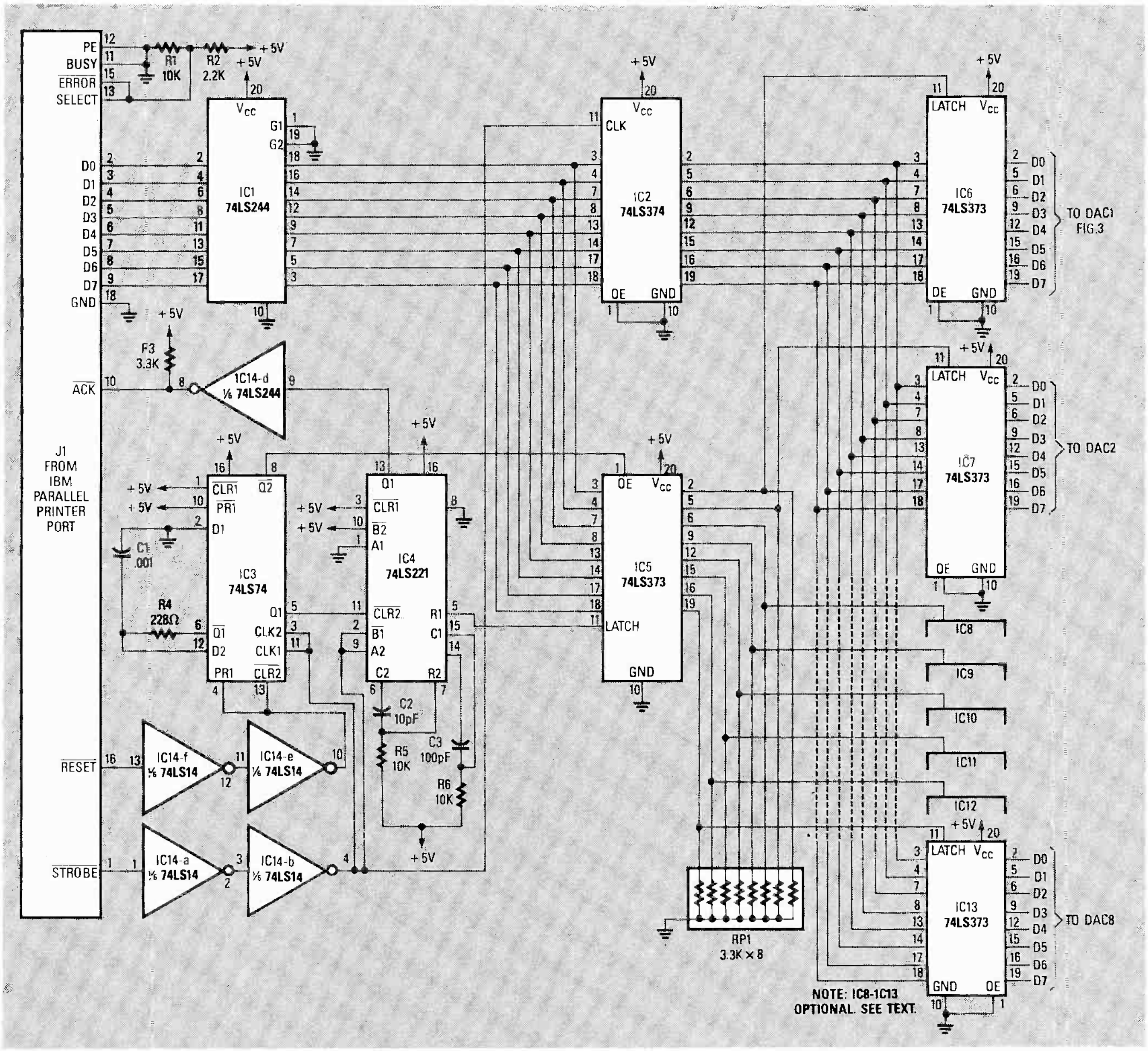


Fig. 2. *DIGITAL SECTION: A standard parallel printer port can control eight digital latches, for a total of 64 bits of digital I/O.*

what drive the eight converters. Which latch picks up the data depends on the mask stored in IC5, but we'll get to that in a moment. For now, let's look a little closer at what STROBE does.

In addition to latching the data into IC2, STROBE drives a dual one-shot multivibrator, IC4, a 74LS221, which generates a pulse of precisely controlled width—1 μs, in this case. After buffering by IC14-d, that pulse becomes the ACK signal that tells the computer the transaction is complete.

Now let's see how the data latches (IC6–IC13) are selected by IC5, also a 74LS373. When one of IC5's outputs is high, the associated latch will be selected and its outputs will follow the data stream presented to the device. When an output is low, the latch ignores the data stream. In addition, the last value sent (when the latch enable signal was high) is retained in IC5's outputs.

Because of that arrangement, the same data may be written to several latches simultaneously. For example, a mask of 0Ch (0000 1100) would enable latches three and four and disable the remaining latches. Subsequently, any data written to the device would put the same data in both latches three and four.

How is the selection mask loaded into IC5? Via the PC's RESET line. When RESET goes low, section two of IC3, a 74LS74 dual flip-flop, is cleared, and that causes IC5's output enable (OE) line to go high. That in turn causes IC5's outputs to go into a high-impedance state, so the latch buffers (IC6–IC13) retain their current contents on their outputs. Also, those latches will ignore the next byte of data (which will be the latch-selection mask) from the PC.

Now the PC sends that selection byte; the STROBE line is pulsed, and that toggles the other half of flip-flop IC3 and also causes IC4 to send a 100-ns pulse to selection register IC5. That pulse latches the selection mask data into the selection register. The selection mask is now where it should be and has been kept out of the places where it was not wanted.

When the next data byte comes, $\overline{\text{STROBE}}$ is toggled again, so IC3 returns control of the selection lines to IC5, which now has a new mask. The data is loaded into the converter(s) specified by the new mask.

The purpose of R4 and C1 (between the two halves of IC3) is to guarantee that the second gate is not flipped until two $\overline{\text{STROBE}}$ pulses have been sensed. The RC combination delays the response to the first $\overline{\text{STROBE}}$ for about 100 ns, leaving it ready to sense the second $\overline{\text{STROBE}}$. Because the time delay is a function of the output drive of $\overline{\text{Q1}}$ and the input impedance of D2, substitutions should not be made for functionally equivalent IC's (74HC74, 74S74, 74F74, etc.) without verifying that the time constant remains the same, or using a different resistor or capacitor to maintain the time constant.

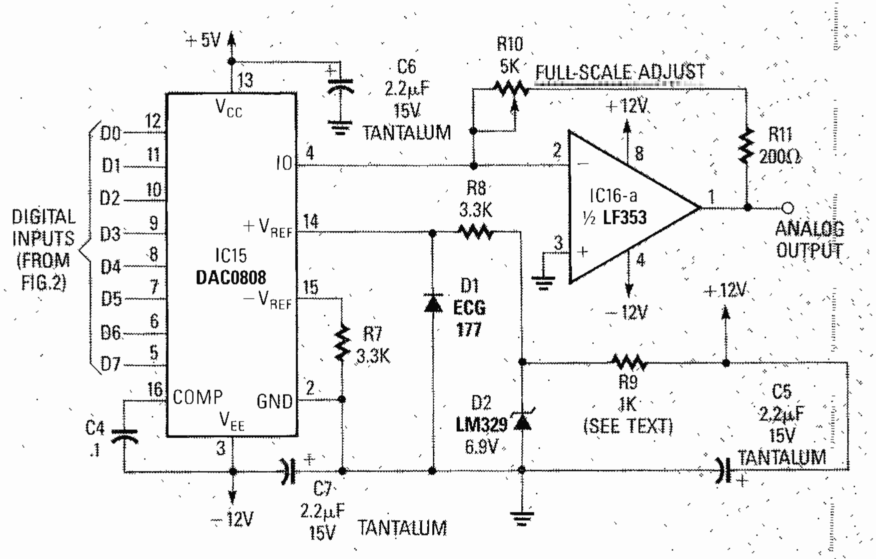


Fig. 3. *ANALOG SECTION: A single channel consists of a DAC0808 (IC15) and half an op-amp (IC16-a). The voltage reference (D2) is common to all channels, but the value of the dropping resistor (R9) varies as the number of DAC's installed in the system.*

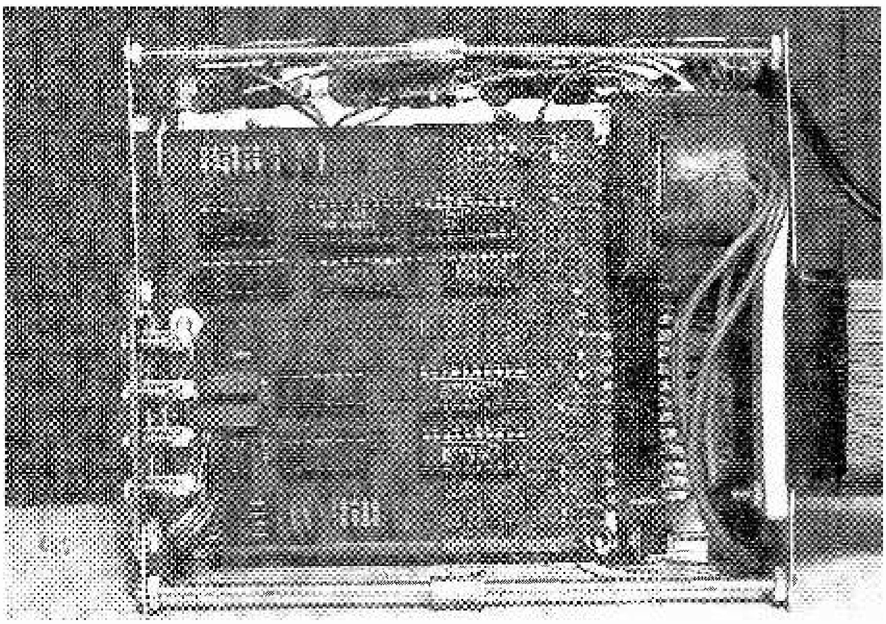


Fig. 4. *SEPARATE THE ANALOG AND DIGITAL SECTIONS of the circuit. The author used point-to-point wiring.*

The analog circuit

Figure 3 shows one DAC channel. The digital circuitry can handle as many as eight DAC channels, but there's no need, of course, to build more channels than you need. However, because the analog amplifiers (IC16, an LF353) contains two amplifiers per package, it makes sense to add DAC's and associated components in pairs.

In the diagram, there are three fundamental components: the DAC, a voltage reference, and an amplifier. The DAC takes the digital number from the latch and the reference voltage from the LM329, and generates a proportional output current that drives the amplifier. Let's look at the job of each individual component in detail.

The LM329 is a precision temperature-compensated Zener voltage reference. It creates a 6.9-volt source with a long-term stability of 0.002% and a temperature sensitivity of 0.01% per degree Centigrade. Only one LM329 is needed, regardless of the number of converters. However, the dropping resistor (R9) between the LM329 and the +12-volt power supply should be adjusted for various loads. With two DAC's it should be 1000 ohms, with four it should be 510 ohms, with six, 330 ohms, and with eight, 240 ohms. In addition, even though only one dropping resistor and LM329 reference are needed for all eight converters, the 3.3K resistor (R8) and clamping diode (D1) must be duplicated in the circuit for each of the converters.

The op-amp is a high-speed, high input-impedance, low power consumption model. It does not have a lot of output drive, but it can produce 10.0 volts across a 2K load. Its strong points are that it is very precise, that it has no offset voltage, and that it can change voltage at the maximum speed of the DAC. The feedback potentiometer (R10) on the amplifier allows you to adjust the full-scale output from 0.5 to 10.0 volts. You'll want to use a 15-turn potentiometer to make fine adjustments easily.

TABLE 1—DACL PROGRAM STATEMENTS

Statement	Meaning
' or ;	The rest of the line is a comment.
use [1pt]p	Use parallel port 'p' for the converter.
reset	Reset the converters on the current port to 0.00
scale, n,val	Use 'val' as a full scale value for converter 'n'
set n,exp	Set value of converter 'n' to expression.
wait t [msec, sec,min,hr]	If no units given, milliseconds assumed
wait until hh [:mm[:ss]]	Wait until 24 hour time.
do index = start, stop, step	Loop on index from start to stop by step.
do forever	Do forever or until user presses ESC
enddo	Close innermost do loop
nop	Do nothing except update display.

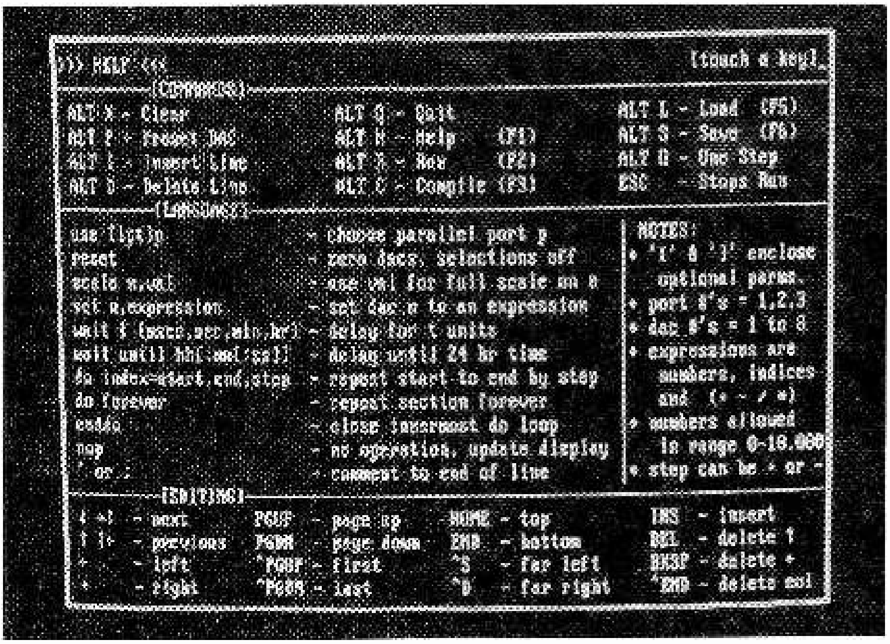


Fig. 5. *THE DACL EDITOR/COMPILER. Compilation is nearly instantaneous; programs may be single-stepped.*

Construction

Unlike some projects, construction details are important. One of the most common failings of mixed analog/digital designs is noisy digital signals corrupting sensitive analog devices. So keep the analog section physically separate from the digital section, as shown in Fig. 4. In addition, keep the analog lead lines short, and make sure that the feedback resistor on the LF353 amplifier is placed close to the IC and far from the digital parts.

Some components can be substituted. A 74LS123 can replace IC4, the 74LS221. Except for IC3, each of the other digital parts can use the corresponding member of another family. For example, 74373, 74C373, 74S373, 74F373, 74HC373, 74HCT373, 74ALS373. Also, an LM1408-8 is a direct replacement for the DAC0808.

The maximum power required when driving eight DAC's into full loads is +5 volts at 250 mA, +12 volts at 100 mA, and −12 volts at 100 mA. Of course, the supply voltages must be regulated too. Power-supply bypassing is also a must. Put a 2.2-µF tantalum capacitor (C5–C7) between ground and each of the three power supplies.

Now calibrate the system. Unplug the device from the computer's parallel port and turn it on. Attach a voltmeter to the output terminals of the first DAC, and adjust it for the desired full-scale value. Repeat the adjustments on the second DAC and continue until all have been set.

Use

It's easy to send data and selection masks to the converter. Loading a selection mask takes three steps: First, pulse the $\overline{\text{RESET}}$ line low, then high. Second, load the selection mask on the data lines. Last, pulse the $\overline{\text{STROBE}}$ line low then high. Sending data to the converter is a two-step process. First, load the data on the lines. Second, pulse the $\overline{\text{STROBE}}$ line low, then high.

Unfortunately, we don't have space to present program listings here. However, sample driver programs are included in DAC.ARC, which is available on the R-E BBS (516-293-2283). Two drivers are provided; DACGEN.ASM and DACPAR.ASM. DACPAR.ASM controls the parallel port directly. It is the fastest method, but requires close compatibility with the IBM standard. The other driver, DACGEN.ASM, uses the BIOS to control the parallel port. DACGEN.ASM should run on any IBM compatible, but it will transfer data at a slower rate.

Functionally, the drivers are identical. Each provides three function calls: one to obtain the status of the DAC; one to send a selection mask to the DAC; and one to send data to the DAC.

In addition, the author has developed a special programming language called DACL (*D*igital to *A*nalog *C*ontrol *L*anguage), and an integrated programming environment that allows you to experiment with programming the hardware. DACL's program statements are listed in Table 1.

The environment is illustrated in Fig. 5. With it, program development is as easy as in an interpreted language like BASIC; but run-time speed rivals that of a compiler. As shown, a full-screen editor is on the left, and current DAC status is shown on the right. The compiler produces plain English error messages, and leaves the editor pointing to the offending line. **R-E**

SERVICING DIGITAL RADIOS

Stop! Don't throw out that radio. We'll show you how to fix the new digitally tuned receivers.

GARY McCLELLAN

REPAIRING SICK AM/FM receivers is generally an easy, straightforward job; that can all change when tackling the newer digitally tuned models. It's bad enough having to work with densely packed circuitry sprouting unfamiliar components, no product documentation, and a matchbook-size schematic; now you have to cope with fixing digitally tuned (synthesized) radios, too.

But don't despair; we'll get you started in servicing those radios. You'll learn about synthesizer circuitry and the most commonly used IC's. We'll also take a look at some troubleshooting techniques that might be new to you.

Synthesizer blues

A lot of technicians have sung the synthesizer blues. Here are some real-life reasons why: One receiver had an annoying whine in the audio on AM. The sound got louder when a station was tuned in. Power-supply problem? Not quite; it turned out to be an open capacitor in the loop filter. Another radio worked on AM but not on FM. Bad FM circuitry? Nope, a dead prescaler IC. And finally a third receiver was dead except for a rushing noise on both AM and FM. Bad power supply or any part in the synthesizer circuitry? You're getting close. That radio had a bad voltage regulator, which powered the synthesizer's controller IC. Let's examine the parts just mentioned a little closer, along with their typical symptoms when they fail.

Actually, the toughest symptom to troubleshoot is the "receives no AM or FM stations," because that fault could be in the synthesizer, the tuner, or even the power supply. Good news! Since the early 1970's, synthesizer radios have gone from PC boards loaded with IC's to a four-IC set. That means that troubleshooting today's circuits will be a lot easier than with the earlier monsters, although the broken-radio symptoms remain the same.

Radio circuitry

Digital tuning offers the advantage of drift-free reception along with such features as station presets and signal-seeking tuning. That makes radios easier for consumers to use, and highly profitable for the manufacturers. Modern car radios are a perfect example of synthesizer radios using presets; that's when you just push a button and the station you preset is automatically tuned in. Of course, the old-fashion pushbutton car radios worked fine, but the manufacturer had the added costs of manually installing the mechanical pushbuttons along with its pulleys and sliding pointer. Quality control then depended on how the assembler felt that day. Now a machine just picks up an IC and solders it in place

Figure 1 shows a typical synthesized AM/FM stereo receiver. Notice that the AM/FM front end uses conventional superhetodyne circuitry—but with a few modifications. Instead of the familiar mechanical tuning capacitor, a set of varactor (variable capacitor) diodes control the tuning frequency. Varactors change their capacitance in direct proportion to the driving voltage. The

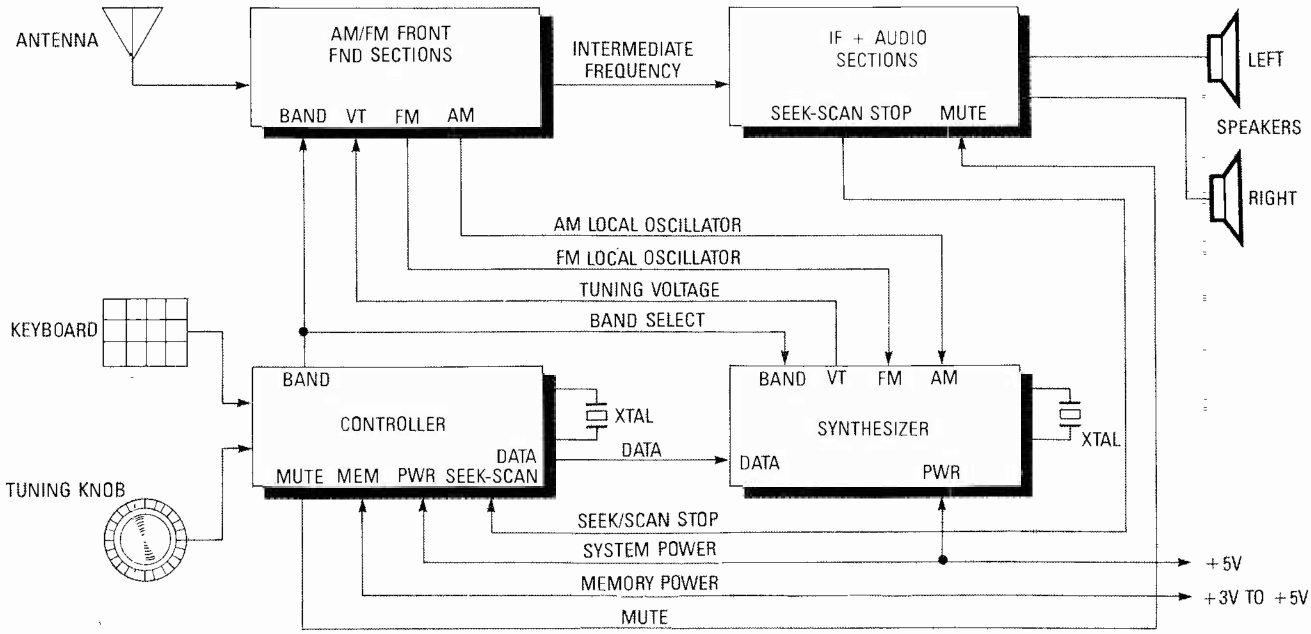


FIG. 1—DIGITALLY TUNED RADIO showing the control lines between the AM/FM front end, controller, prescaler, synthesizer, IF and audio sections, LED display, and keyboard.

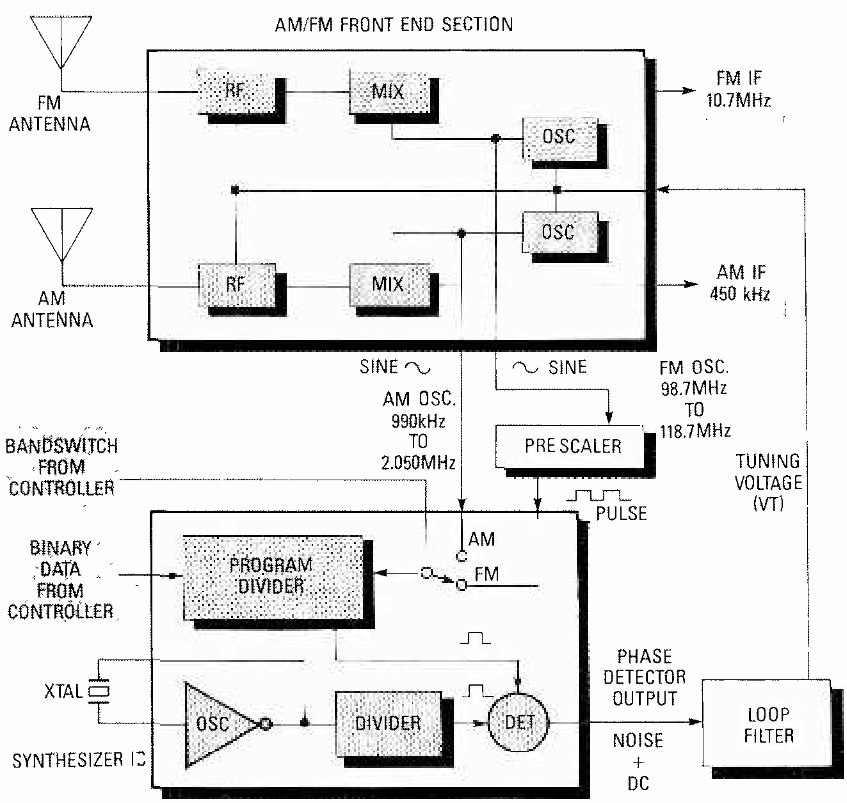


FIG. 2—THE RADIO'S SYNTHESIZER works closely with the AM/FM front end.

synthesizer monitors the AM- or FM-local oscillator and varies V_T, the tuning voltage that drives the varactor diodes, thereby controlling the receiver frequency.

Unique to digitally tuned receivers is the controller, which accepts inputs from the keyboard (presets, AM, FM, Seek, Scan) or the tuner switch. The inputs are converted into a binary code that drives the synthesizer IC via the data lines—essentially, it tells the synthesizer what to do. Notice that the DATA output from the controller drives the synthesizer, and is also decoded for the digital display. Understand that the digital display does *not* read the frequency that the receiver is tuned to; it is the frequency entered into the controller. That's an important fact to know when it comes to radio-tuning problems. The BAND-SELECT output selects AM or FM operation. Incidentally, if the receiver contains a clock, that function is also performed by the controller. Last, the controller also includes a MUTE output, which silences the radio during the tuning interval.

Deluxe receivers may contain an additional pushbutton called seek/scan stop tuning; when depressed, the controller forces the receiver to scan the radio band until a station is found. The radio's IF section then drives the SEEK/SCAN STOP line low, which stops the controller at the received station.

Two power sources are used to run the controller. Memory power is derived from batteries, or a large-value capacitor charged by receiver operation. System power (usually a 5-volt supply) runs the rest of the controller circuitry while the receiver is operating, including the display.

As shown in Fig. 2, the synthesizer IC accepts AM and FM local-oscillator signals from the front end. After receiving a divided-down signal from either local oscillator, a phase detector compares it with a signal derived from a crystal oscillator whose frequency is typically 10 kHz. The phase-detector output is an analog tuning voltage that varies with the difference between local-oscillator and crystal-oscillator frequencies. If the local-oscillator frequency is too low, the tuning voltage rises to a maximum; if the frequency is too high, the tuning voltage drops to zero. When the two frequencies are exactly the same, the voltage reaches an equilibrium and the desired frequency is tuned in. That condition is known as being "in lock."

Although all synthesizers directly accept the AM local oscillator, few work at FM local-oscillator frequencies. So, you'll find a prescaler IC nearby that divides the 98.7-MHz to 118.7-MHz FM local-oscillator frequency down to a frequency that the synthesizer IC can handle.

The analog tuning voltage from the synthesizer output must be filtered, and possibly level shifted (scaled) to suit the AM/FM front end. The filtering is simply a low-pass filter (dubbed a loop filter) that removes noise pulses generated by the phase detector for a clean DC output. Often, several transistors or an op-amp is used to improve filter performance.

Typical tuning voltages for AM reception range from 1.5 volts (540 kHz) to 6.9 volts (1600 kHz) in car radios. Home receivers may increase that range from 3.0 to 21 volts, especially in older models. On the other hand, FM-tuning voltages tend to be a little less than the AM tuning voltages. Note that the received frequency increases with tuning voltage; that information is sometimes useful.

Sought after IC's

Figure 3 is a typical synthesizer radio that features AM/FM digital-tuning along with seek/scan modes, and five station presets per band. There is also a clock feature.

The heart of the radio is the UPD1701 (IC1), manufactured by NEC of Japan. That device sports nearly all of the controller and synthesizer functions in one 28-pin DIP package. It is widely used in both home and car receivers; you'll find it in expensive receivers from Japan and in the "no name" specials from Hong Kong. Another popular IC is the UPD1703, which is like the UPD1701, but without the clock.

A popular FM prescaler is the UPB553 (IC2). It accepts the FM local-oscillator signal on pin 2, divides it by either 15 or 16, and outputs on pin 5 to the synthesizer. One interesting feature is the "divide by" pins 6, 7, and 8, that are controlled by IC1. The division ratio depends upon the frequency programmed by the controller and other factors.

The TD6250 (IC3) drives the display segments, and the UPA53 (IC4) drives the display cathodes. Note that the common-cathode LED display has four digits, plus LED indicators for functions like preset number, AM, FM, and memory. Sometimes you'll find individual transistors replacing the TD6250, and five transistors substituting for the UPA53.

When the keyboard is used, the synthesizer (IC1) internally decodes the key pressed and performs the desired function. Incidentally, the knob-

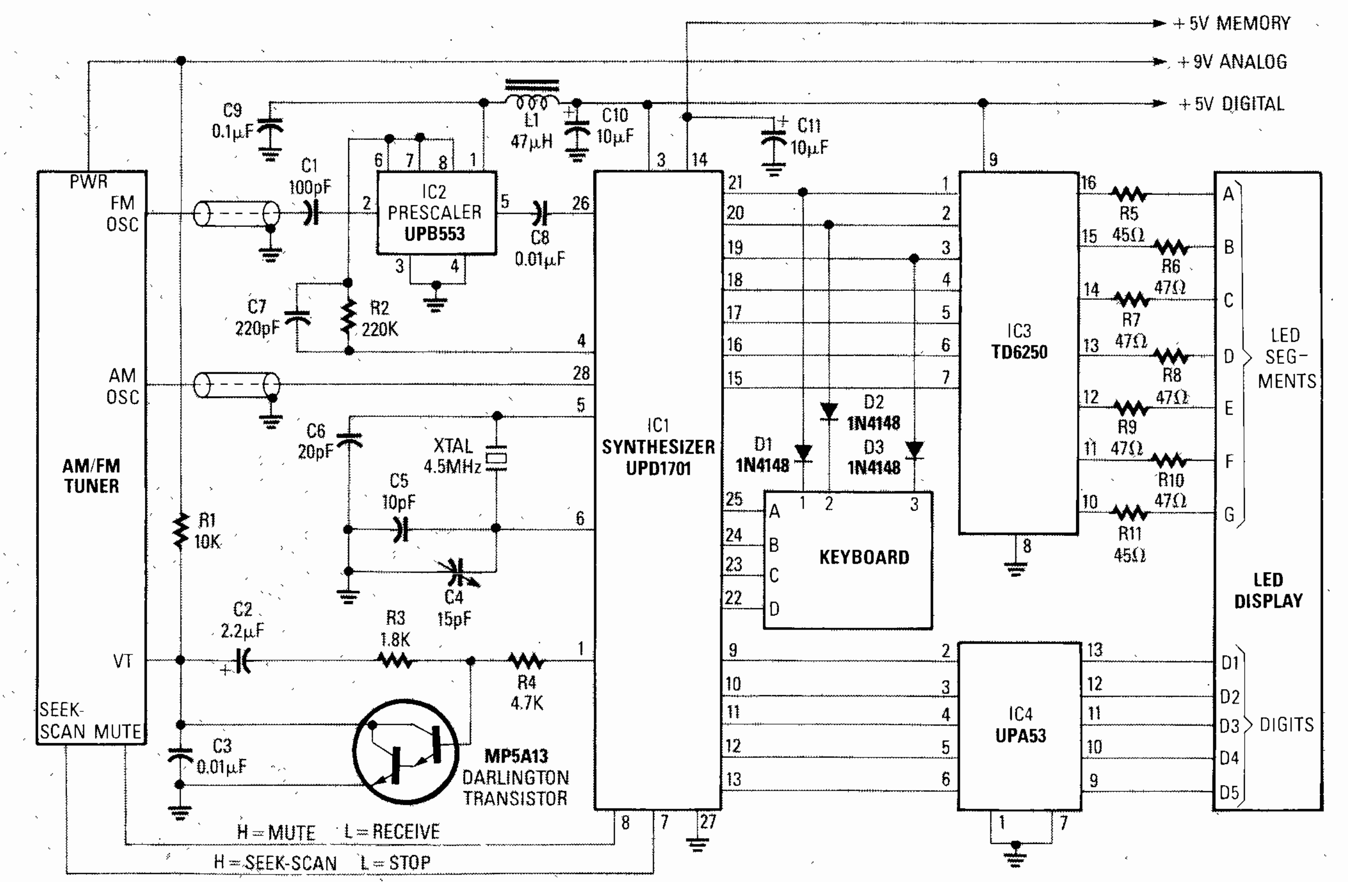


FIG. 3—THIS DIGITALLY TUNED RADIO uses custom IC's that perform complex functions. To fully understand each IC's operation, you really need the manufacturer's service manual.

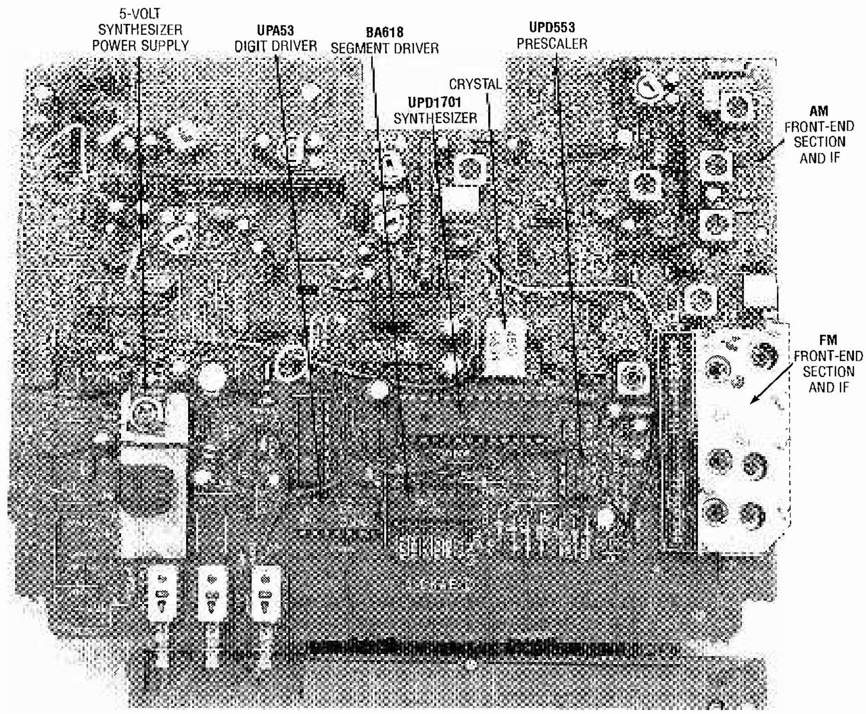


FIG. 4—THIS IS WHAT THE INSIDE of a digitally tuned radio looks like.

tuning feature found in car radios connects exactly like the keyboard. The tuning assembly uses two cam-driven SPST switches. One switch closes momentarily to tune down, and the other closes momentarily to tune up—a simple, but clever device.

The phase-detector output is taken from pin 1 of IC1, through a loop filter consisting of a Darlington transistor, and a few capacitors and resistors. Sometimes you'll find a FET transistor combination used instead. Some high-end receivers substitute op-amps, in their loop filters, for supposedly better results.

The AM/FM tuner may be a collection of discrete components on the board, or more likely a module from Alps or Mitsumi Corporation. It provides buffered local-oscillator outputs on the order of 100–400 mV, and accepts the tuning voltage. Some tuner modules also include IF circuitry; in that case, they can have a seek/scan stop output, and audio-muting provisions.

The increased desire for more presets has forced receiver manufacturers to return to separate controller and synthesizer IC combinations. Chrysler, for example, uses a National COP-series controller and a DS8908 synthesizer-IC set in their recent-model car radios. Headphone portables use a single IC for controller, synthesizer, and display driver functions—available from Sharp or NEC. Should one of those parts fail, you can buy it *only* from the receiver manufacturer, and that often makes repairs uneconomical.

Troubleshooting techniques

Now let's look at some winning troubleshooting procedures. Well, OK, nothing can replace good ol' factory training, full service data, plus five-years experience, but these tips will get you off to a good start. Figure 4 is a typical digitally tuned receiver that you might come across in any repair shop.

Here's the *test* procedure, which is simple enough. Before you do anything else, try all receiver controls and functions to verify and duplicate the customer's complaints. Doing that will help you avoid those problems caused by customers who have trouble using electronic equipment and may simply be confused. Other problems you want to immediately rule out include the obvious: wiring disconnected, blown fuses, and tinkering by Saturday mechanics.

Just trying the controls can uncover digital-tuning defects like stuck keyboards and intermittent switches. Clean or replace the bad part and your work is done. Suffice to say, "Always fix the obvious problems first."

Now let's evaluate receiver problems to isolate a bad power supply or dead amplifier. Only when everything else is working should you turn your attention to the digital tuner. Many times, you'll find fixing the simple problems clears up over half of the "it won't get any stations" problems.

As you might expect, to service the digital tuner, it helps to obtain the radio's service manual from the manufacturer; at least then you'll know what voltages to expect, and can identify the parts on the board.

To troubleshoot down to the component level in a digital tuner, the following tips should be helpful:

- **The AM/FM front-end** is good if you hear a rushing sound with the volume turned up. That can be verified by connecting an antenna, and listening for any stations near 540-kHz AM or 88.1-MHz FM. If you have no local stations, try a signal generator.
- **The controller** is probably good if all keys work, and it stores the frequencies you enter. If you observe one or more bad keys, the keyboard is likely to be at fault—bridging the connections behind the bad key with a screwdriver blade will show that fault.
- **The display** has common problems like missing segments, and are usually caused by an open connection between the display and driver. Look for an unsoldered connection or broken wire.
- **The synthesizer** IC is good if you can tune in AM or FM stations. If you can't get FM, check the prescaler circuit. If you can't get AM, suspect either the local oscillator output from the AM/FM front end, or the synthesizer IC itself.
- **The loop filter** is good if you can tune in AM stations across the entire band, without a whine in the sound.
- **The prescaler** is good if you can tune in FM stations—either it works or it doesn't.
- **The power supply** is a common trouble spot. Typically that defect is obvious because the display is not lit.
- Test or substitute the major components in the area you isolated. Look out for the little things like broken parts and unsoldered connections.

Ok, roll up your sleeves: We're going to put theory and practice together to fix some digitally tuned radios, and find some of those hard-to-find replacement parts.

Digital clock radio

As shown in Fig. 1, Cola on the

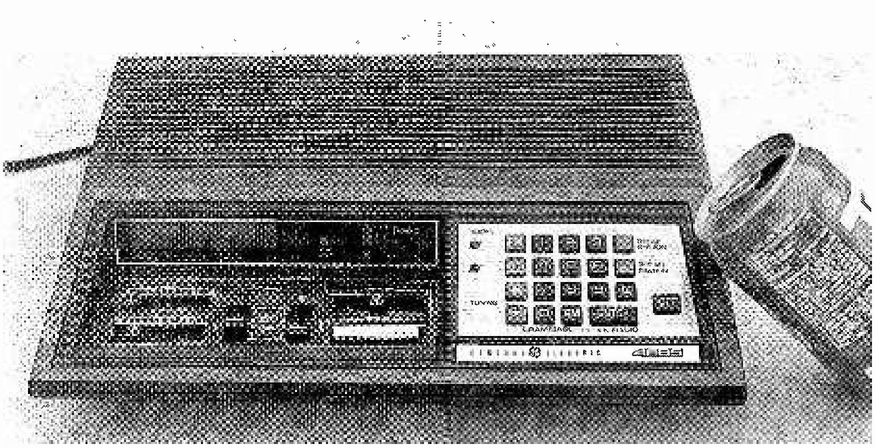


FIG. 1—SPILLED COLA ON A KEYBOARD will ruin any radio.

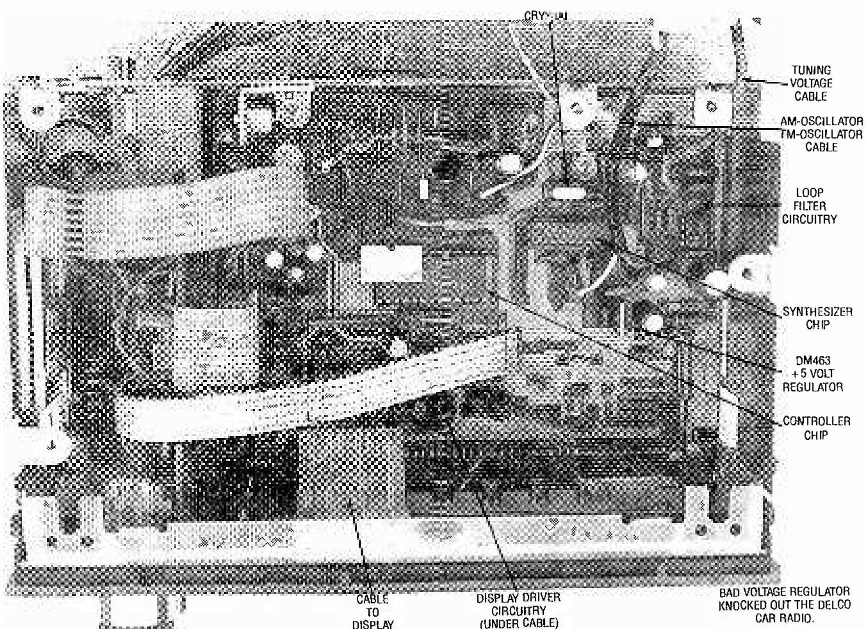


FIG. 2—HERE'S A DELCO CAR-RADIO that doesn't work. Would you know where to look to fix this baby?

keys killed that General Electric model *7-4885A* digital-clock radio. That's right; go ahead, spill cola all over your radio's keyboard and let it leak inside—*your* radio won't work, either. So why should cola kill a radio? Let's take a look inside and check it out. We see dried gook and gunk all over the keyboard. Bridging the FM-key contacts with the screwdriver blade turned the music right on. It doesn't take a genius to know that the keyboard contacts need cleaning. OK, that was an easy fix. While we're on the subject, what's a good way to clean that keyboard, anyway?

Cleaning a keyboard just takes some common sense. Luckily, that radio could be disassembled to access the contacts. Unsolder the cable from the keyboard, scrub out the sticky cola with a toothbrush and a pan of warm water, then let it dry. Shoot each keypad contact with some contact cleaner, rub-a-dub, then re-install the keypad. Success!

Be careful when handling the keyboard wiring, and use *E*lectro*s*tatic *D*ischarge (ESD) precautions. For example, walking across a rug can generate several thousand volts, which (when discharged) can blow a controller IC faster than lightning. Excuse the pun. The cost of a new Texas Instruments TMS-1100 IC can make repairs prohibitive. So please don't say that you weren't warned here first.

Delco car-radio

"I know it's Sunday afternoon, but can you fix my car radio? It doesn't get any stations." Does that sound like your next-door neighbor? The car radio was a Delco model *40JHMAI*, typical of the black-faced digital radios found in recent General-Motors cars.

Figure 2 shows the Delco board. Trying that radio on the bench, the LED display didn't light. Turning up the volume, we heard a rushing noise on both the AM and FM channels; that implied that the audio and RF circuitry were working. Connecting an external antenna verified RF-circuit operation because we heard an 88.1-MHz FM station through the speaker.

At that point, it's best to stop and study the symptoms for a moment. Because the display wasn't lit, that means there's no power, or possibly a open wire somewhere. Measuring the voltages on several IC's revealed zero voltages on every pin of the controller IC. Look at the Delco board a little closer; right next to the controller and synthesizer IC's is a DM463 voltage regulator. Replacing that old IC with an MC7805 from our stock immediately brought the receiver back to life.

Like keyboard problems, power-supply problems are usually repaired quite easily. Here's a tip: If you are working on a car radio, be sure to check the "clock" or "memory" power lead. If that lead gets disconnected, the radio may either play dead or lose time-and-station settings whenever the ignition is turned off.

Toshiba stereo

What about a Toshiba model *KT4066* portable headphone-radio developing an intermittent on FM shortly after purchase? It would go dead at infrequent intervals, but the AM band and cassette player worked fine. Until, finally, the headphone jack went completely bad. Opening up that baby revealed surface-mount circuitry. Think of surface-mount technology like a pizza: the crust is the PC board, while the toppings (tomato sauce, cheese, maybe anchovies) represent the parts.

The headphone-jack problem was fixed first. It was nothing more than a cold solder joint that had broken loose, causing intermittent sound in one channel. But that bad solder connection didn't fix the intermittent FM-reception problem. Unfortunately, the radio wouldn't fail for a long enough time to isolate the problem. In fact, just bringing the radio near the bench was enough to make it work perfectly!

The solution was to inspect the synthesizer board mounted in the lid. Figure 3 shows a bird's eye view of the radio's guts. Under a magnifying glass, several solder connections looked suspicious; one connection next to what appeared to be a pre-scaler IC looked unsoldered! Using a grounded soldering pencil and 0.031-inch solder, each poor connection was resoldered. Jackpot! The receiver works perfectly to this day.

Incidentally, be careful when taking apart and re-assembling headphone stereos. The tiny plastic parts used are easy to break and hard to replace. On some models you must remove the switch knobs first or you'll break them.

Exotic-car radio

An automobile importer had a minor problem with some radios. It seemed that he received a shipment of cars from Europe with radios that would not receive AM stations. Could the problem be a switch? While his mechanics made the cars conform to USA emissions standards, they were stumped when it came to digital radios. The receivers supplied were the Fujitsu-Ten model *EP821*, which has some unusual AM/FM reception capabilities, plus a cassette deck, clock, and equalizer.

The problem with foreign radios is that they are set to tune in the broadcast frequencies of a particular country. For example, the AM-broadcast band (535–1605 kHz) was set to 9-kHz tuning steps, instead of the 10-kHz tuning standard in North America. Because the radio was tuning in 9-kHz steps, it missed most AM stations! The FM reception was unaffected because the *EP821* tuned in 0.05 MHz steps, making it possible to receive either European or USA stations. Understand that Europe uses even-numbered 0.2 MHz steps (100.2, 100.4...), while in the USA we use odd-numbered steps (100.1, 100.3...).

Inspecting the chassis for a switch to select either 9-kHz or 10-kHz tuning steps revealed nothing. So the only alternative was to contact the Fujitsu service department to buy a service manual for the *EP821* model. To our surprise, they didn't know that model number, but they could supply a manual on the *EP820* model, which fit the set's description exactly.

Immediately upon receiving the service manual, we found that the schematic page showed a diode marked "USA" connected across two pins of the MB8851-110 controller IC. After installing the diode, the radio still did not work on AM. The only solution was to obtain the MB8851-101C controller called out in the parts list and try a replacement. Sure enough, the AM section worked fine when a new IC was plugged in.

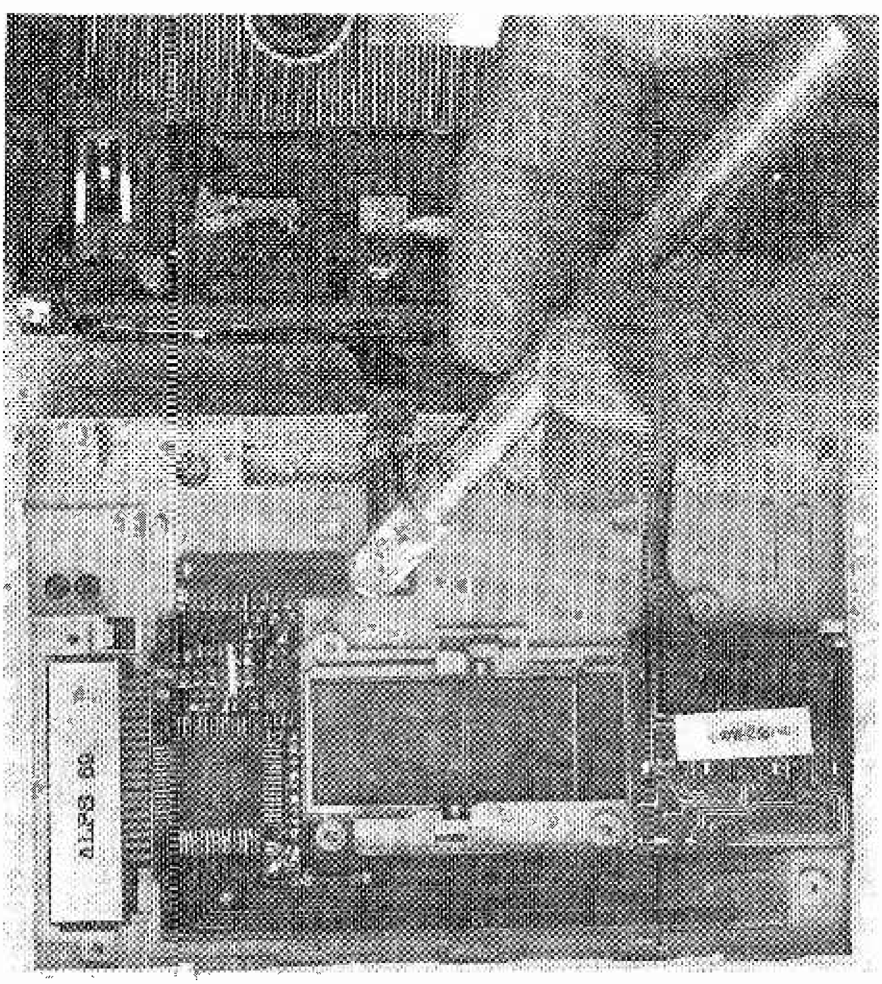


FIG. 3—THIS TOSHIBA PORTABLE HEADPHONE-RADIO uses *Surface Mount Technology* (SMT) components.

Nothing works right

From all appearances the Sansui model *R707* had many problems; yet the cause was a single part that was fixed at no cost. Turning on the power, everything was working except for the AM and FM tuner section. On FM, the display would scan frequencies and it would store ones chosen at random. The only sound was a soft rushing noise. On AM, the display read typical AM frequencies, but the decimal point remained lit and the display said MHz instead of kHz. There was no sound, so it appeared that the AM front end was dead. Unusual symptoms to be sure; but that particular repair project would get stranger as we continued!

Analyzing the problems showed that the controller was basically working because all controls worked and it stored stations. But there was some sort of controller defect that caused the display to read frequencies like 160.0 MHz on AM. So controller troubleshooting was called for. The receiver wouldn't pick up any stations; in fact, it wouldn't respond to the output from a signal generator, either! So, for those reasons, troubleshooting of the AM/FM front end was necessary.

The question was where to start troubleshooting. The controller was a good beginning because of the display faults—but the voltages were good and there was no sign of any problems. Short of substituting the controller IC, there was nothing else to check in that area; therefore, looking at the synthesizer might prove worthwhile. A quick way to check synthesizer operation is to locate the VT (tuning-voltage) line and measure it with a high-impedance voltmeter. For stations around 88 MHz or 540 kHz the voltage will be low, typically a few volts or less. For stations around 108 MHz or 1600 kHz the voltage will be nearing maximum, or roughly 6 to 24 volts, depending upon the model. If the voltage is far below or above that range, the synthesizer is out-of-lock and needs attention or servicing of some kind.

Measuring the tuning voltage showed that it was stuck at maximum; the synthesizer was out-of-lock. From past experience that indicated a failure in the loop filter, synthesizer IC, or local oscillator in the front end. In other words, the bad part could be almost anywhere! After substituting the synthesizer IC, and finding no obvious defects in the loop filter, a scope check of the AM local-oscillator confirmed there was no signal; neither was there any signal from the FM prescaler. So what was going on here?

It looked as if the front-end wasn't getting any power because both local oscillators were out; yet 13 volts was measured to the tuner board earlier. Something on the tuner board was preventing the voltage from getting to the radio's front end. With the receiver still in the FM mode, checking for power on the IF board revealed nothing wrong—12 volts was present at several points. But when we moved to the terminals of the shielded front-end, we struck luck like gold. For the only value above a volt was the (tuning voltage) VT pin. There was no power anywhere else! Tracing the B+ pin from the tuner module to a nearby choke, L1, there was 12 volts on one side of L1, and nothing on the other side. L1 was open, thus disabling the unit!

Inspecting the choke revealed a broken coil-wire. Not the heavier coil-winding itself, but the slender connecting wire extending from the choke body. Soldering a new piece of wire to the choke body repaired that problem. Re-installing the repaired choke restored all functions to the Sansui *R707*.

Getting parts

Let's face it: Obtaining replacement parts can be as difficult as servicing the receivers themselves. That's especially true if you're an individual seeking a single component rather than a factory's authorized-service center receiving weekly scheduled parts deliveries. Here are some insider tips to help you play the parts game and win.

For general troubleshooting, nothing beats a supply of modules and assorted parts. One way to get parts is to collect cast-off radios from owners who have decided that their sets weren't worth fixing. Test each throw-out and determine the radio's general condition, such as no left channel, no FM, and so on. Parts that seem to be good can be pulled as needed for substitution into other radios. If the substitution of a certain part works, an authorized replacement part can be ordered to complete the repair.

Good sources of cast-off electronics components include flea markets, friends, and ham-radio swapmeets; keep your eyes open for local radio clubs that hold swapmeets regularly. Other sources are various auctions. Sometimes you can get current-model receivers dirt cheap at bankruptcy auctions, so don't shy away. Some radios might be new and can be resold below the regular cost; others might be damaged, but can be broken up for parts—an ideal situation. Don't shy away from new-but-damaged goods, which can be scavenged for parts at unbelievable savings. Try it!

Understand that there are limitations to using parts from cast-off receivers and you'll do well. Using those parts is low-cost and sometimes convenient, but you must spend extra time removing and re-installing them. Also, you must be reasonably sure that the part removed is good. It is amazing how much time you can waste troubleshooting a broken radio when you replace one bad part with another!

A better source of parts are the *M*aintenance and *R*epair *O*peration (MRO) suppliers like Phillips-ECG, NuTone Electronics, and others. Check their ads and obtain cross-reference catalogs from each of them. While MRO suppliers offer convenience, they tend to carry only the more popular parts that are found in older equipment. So if you have a sick receiver less than a few years old, which is usually the case for digitally tuned radios, you're out of luck for certain parts.

Another good source for parts are the suppliers who advertise Japanese semiconductors. Typically, they offer exact replacements at reasonable prices. Also, they have other special parts, like flame-proof resistors, VCR belts, and so on. Dig through the ads, call them up and request a catalog. A drawback from ordering from suppliers is the 1–2 week wait for UPS delivery and a minimum-order amount. Many times you'll have to order several more parts than you need, just to attain a $10 to $20 minimum. You can beat minimum-order requirements by combining parts from several repair projects into one order.

One ideal way to obtain parts is directly from the manufacturer. Because most radios are imported, you must contact the radio company's regional office, which is usually on the East or West Coast. Those offices seem to work best for factory-authorized service centers. The service center calls the regional office, orders by part number, and receives it in their weekly (or monthly) scheduled shipment. Billing is done on an account held by the service center; once a month the bill is paid. Simple for service centers. The rub is that many regional offices are warehouses; they have no facilities for walk-in customers who don't have part numbers. To be fair, some regional offices like Sanyo have walk-in centers where you can look up part numbers and get parts, but places like that are extremely rare, so consider yourself lucky if you find such a place.

Dealing with regional offices can be frustrating, but this procedure is typical: First you determine the location of the regional office: Often that information will be printed on the receiver's identification label. Then you dial for Directory Assistance to get the phone number. When you call the regional office, ask for the Parts Department and order a service manual. From the service manual you order the parts you need. Of course, by that time six months have passed. It's therefore best to avoid regional offices altogether if you can get the parts elsewhere—the paperwork is too time-consuming for repairing a single out-of-order unit!

Some regional offices play games: If they find out that you're not one of their dealers, they demand cashier's checks for the manual and parts. A few dealers resort to the letter ploy where they won't take your calls. Instead, you must write to them for a service-manual price and delivery, then again to order parts. Try to avoid outfits like those at all costs when you run into one! **R-E**

VIDEO SCENE SWITCHER

Make your next transition a smooth one!

WILLIAM SHEETS and RUDOLF F. GRAF

IF YOU'RE LIKE MOST VIDEO-CAMERA owners, you've built up an inventory of hours and hours of home video movies. If you like to show your movies to others, you've undoubtedly found that even your best friends won't sit through an hour-long video of your son's first birthday. The solution is to edit your tapes into groups of short scenes. The trick is to do it with professional results.

The problem that arises is how to make the transitions between scenes or sources as smoothly as possible, without visually or a esthetically disturbing transitions. Our Video Scene Switcher is the key to smooth transitions.

In order to switch between video channels with a minimum of disturbance, several technical requirements must be met:

- Sources must be identical in polarity and type (for example, both NTSC with negative sync)

- Sources must have the same levels. That requirement can be met using gain adjustments.

- Color-burst phase must match in order to reduce color shifts between scenes.

- Terminations and impedance matching must be considered in order to reduce reflections and "ghosting."

- The time phases of the sources must be constant and have a fixed relationship. The sync pulses must coincide both in time of occurrence and frequency, both vertical and horizontal.

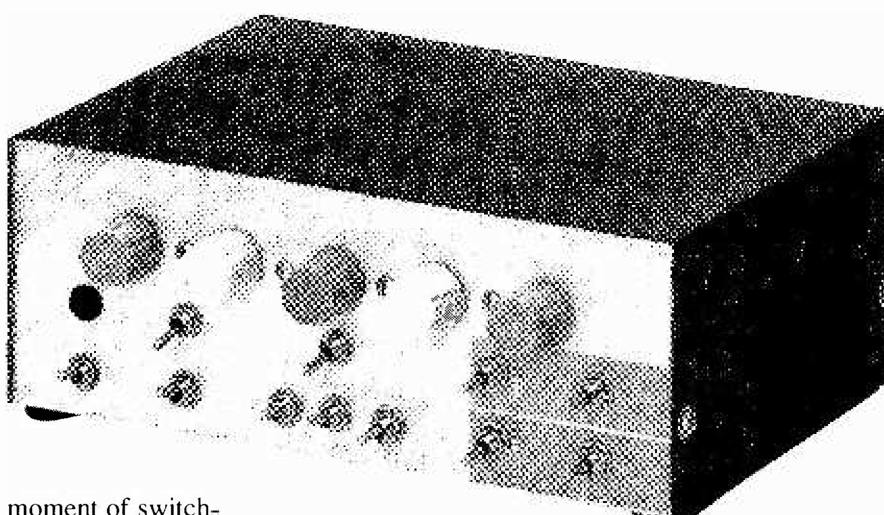
Most of the time there is no problem in meeting the first four requirements, as they are under direct control of the system operator. However, the last requirement, that the video sources have sync pulses in phase, does present a problem. That's because, when using two separate VCR's, a VCR and a camera, or a VCR and an over-the-air source, there is generally no relationship between sync phases.

The term "genlock" is used to describe the act of using a master synchronization source to control the sync phase of other sources. Some video equipment has genlock inputs but, most of the time, the availability of two genlocked sources cannot be relied on.

When the signal source to a video monitor, TV receiver, or VCR is suddenly switched, the synchronizing circuits of the video device experience a discontinuity of input, in frequency, phase, or both, depending on the moment of switching in most instances. If, by chance, the vertical and horizontal sync pulses of both sources are coincident in time (in phase) at the moment of switching, there will be no noticeable disturbance. If, however, they are not (the usual case), a momentary loss of synchronization will occur. Depending on the characteristics of the sync system in the video device in use, a momentary flicker, jump, tear, or roll will occur in the picture—it's objectionable, esthetically unpleasant, gives an "amateur" look to a program, and should be eliminated.

A common way to deal with the problem is to fade to balck, or some other level. During this interval, switching takes place, and since the screen is black, no transient effects are noticed. After a predetermined time, the new video is switched in and then the fade from black to program is performed.

There are other methods that can be used. A black-over can be "keyed" into the picture; for example, a black over can be wiped across the picture, much like a curtain, either horizontally or vertically, or both (diagonally). A black-over can also be broken up like a series of vertical or horizontal strips that gradually enlarge, covering the picture with the effect of a Venetian blind. By doing that vertically and horizontally at the same time, black



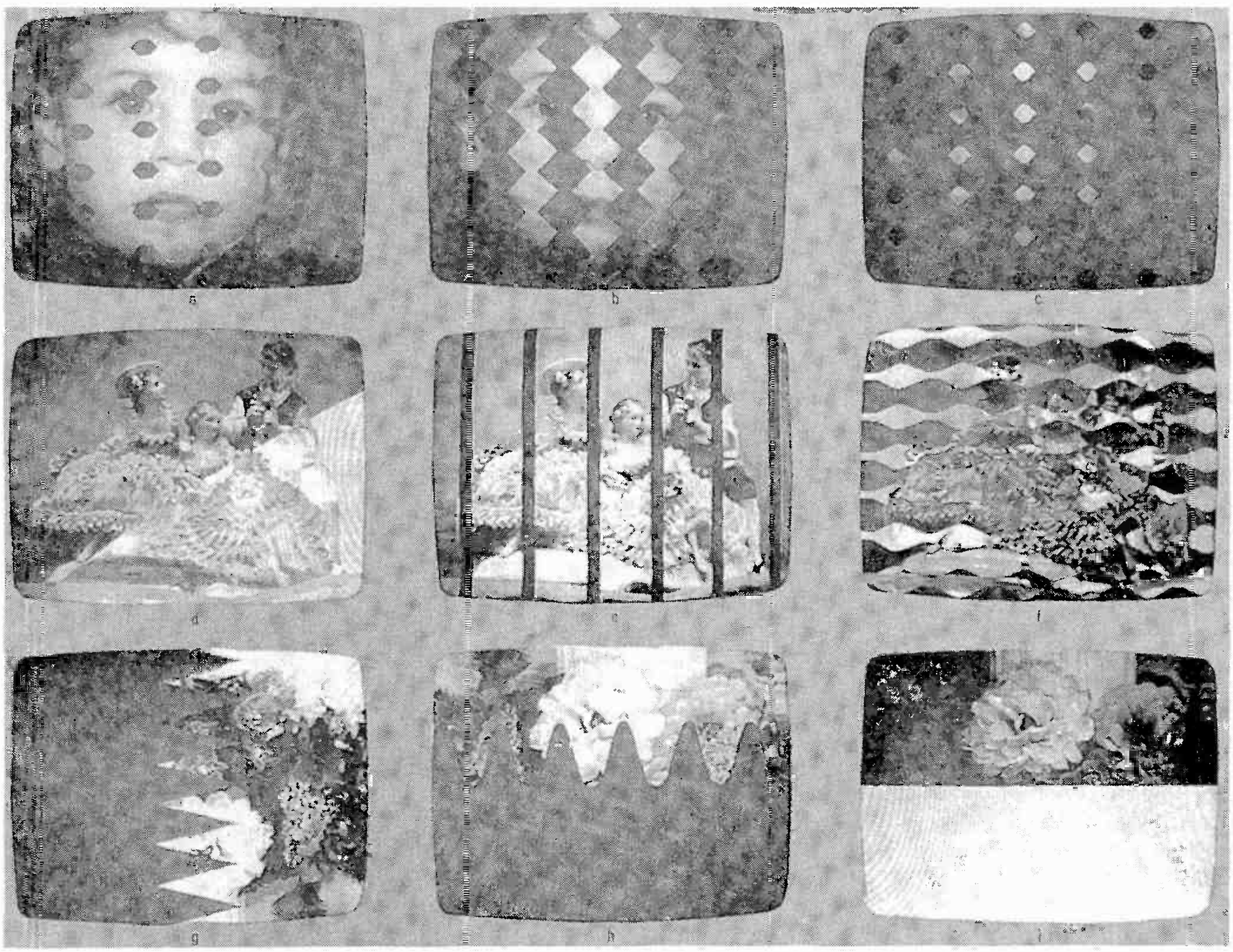


FIG. 1—VARIOUS FADES, WIPES, AND EFFECTS can be keyed into the picture. You don't have to stick to simple horizontal or vertical fades, as complex fades are also possible; see how Danny disappears in *a, b,* and *c*. A diagonal wipe from regular video to effects video is shown in *d*, expanding vertical bars "consume" the picture in *e*, expanding diamond-like patterns in *f*, and *g, h,* and *i* show three additional wipe patterns.

dots appear in the picture that expand in size to first overlap and then completely obscure the picture. Figure 1 shows those patterns.

The act of "keying" is actually video switching using waveforms that are tied to the sync pulses or other picture elements, such as the luminance level (luminance keying) or chroma level (chrominance keying). By producing such waveforms, a great variety of switching and special effects can be produced. Note that the effects are performed steadily on the video, and that the sync pulses must remain unaltered during the switching process.

For wipes, keying, or other switching between two sources without an intermediate fade, the two sources must be genlocked or synchronous. There is no easy way around that, save for a large video buffer memory, or some form of synchronizing storage system. However, that shouldn't be considered a serious limitation, since many fade-to-black techniques have a pleasing effect, and they provide a more defined differentiation between scenes.

Basic operation

The Scene Switcher basically consists of two parts, as shown in the block diagram in Fig. 2. A video switching system is used to switch in various video effects, fade levels, and to select channel 1 (CH1) or channel 2 (CH2), and a waveform generator is used to generate keying waveforms to drive the analog switches at precisely timed intervals.

There are two video channels (CH1 and CH2), but we will describe the operation of only CH1, because the two are identical. Each channel has two switch-selected inputs, main or auxiliary, and each channel is fed to a splitter circuit that separates the video and sync components. That way, the video can be processed separately from the sync. The sync is not processed in any way.

The video from CH1 first passes through an analog switch (NORMAL/EFFECTS) that either passes it or selects CH1 video that has been altered by an external special-effects unit (for example, the Video Palette described in the September and October 1987 issues of **Radio-Electronics**). Since the video from the special-effects unit is inherently synchronous with the CH1 video, direct switching is possible, and you can wipe the altered scene over the original one.

Next, the video is fed to another

analog switch, the FADE SELECTOR. The output of that switch is either unaltered video or a DC background level from the *fade level generator*, which is variable between black (about zero volts) and white (1 to 1.5 volts). That is determined by the setting of the FADE LEVEL control, which gets its switch signals from the control panel and the *keying generator*. During a line-scan internal, several switching actions may take place, causing various pattern configurations to be generated on the monitor screen.

Next, the video goes to a switch network that routes it to either side of the FADER control, or selects CH1 or CH2. Both analog switches are driven by the keying waveform from the keying generator and control panel; switching may take place several times during a line scan, depending on the effects desired. The output from the FADER control is fed to a *summing amplifier*, and mixed with appropriate sync. The system output is composite video.

The keying generator consists of a set of sawtooth-wave generators. Sync from CH1 or CH2 is fed to a phase-locked loop, where constant outputs of 15.74 kHz and 60 Hz are generated, phase locked to the video input waveform. Those outputs are fed to the horizontal and vertical sawtooth generators.

The generators each produce two waveforms; a sawtooth at eight times the input frequency and a sawtooth at the input frequency. The sawtooth waveforms are fed to a comparator, whose "trip" level is adjustable. The sawtooth is compared to the trip level from the keying control, which may be manual, or automatic.

When the sawtooth exceeds the trip level, the comparator switches. Since the sawtooth level varies synchronously with the horizontal, or vertical, or both sweeps, varying the trip level causes the comparator to switch at varying points in either the horizontal or vertical scan. Therefore, since the comparator output is the keying waveform, we can control the position of the switching at any desired point in either the horizontal or vertical scan cycle.

The switching waveform is fed to the control panel and then to the correct analog switches in the video channels. Several switching patterns can be generated, using the ×1 or ×8 vertical, the ×1 or ×8 horizontal, or various combinations.

The circuit features external access capability to the switch signals and sync outputs via emitter followers. That permits using an external computer or microprocessor to generate other switching patterns than we have here, if desired. That is left as a project for the experimenter or computer hobbyist.

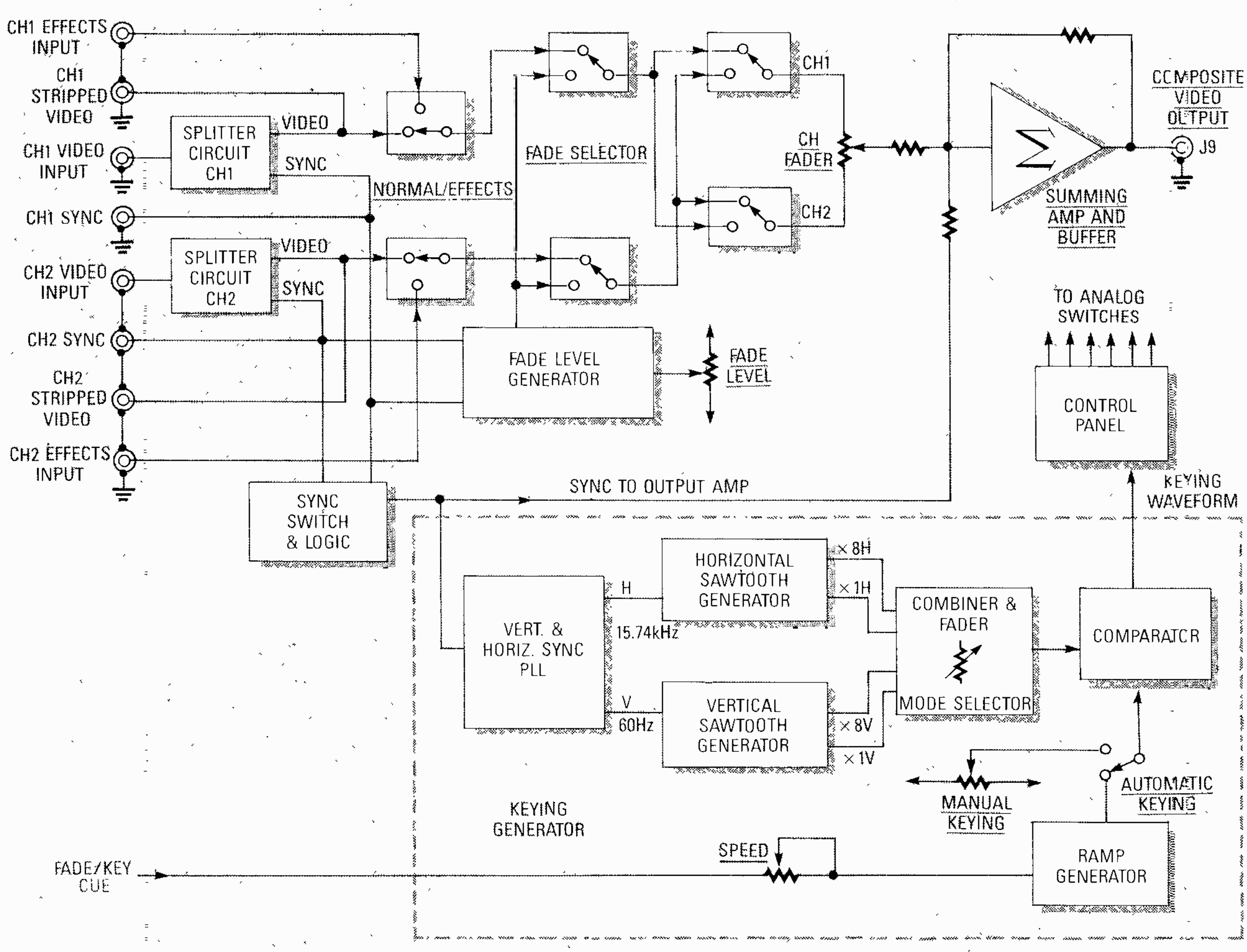


FIG. 2—THE SCENE SWITCHER BASICALLY CONSISTS OF TWO PARTS, as shown in this block diagram. A video switching system is used to switch in various video effects, fade levels, and to select channel 1 (CH1) or channel 2 (CH2). A waveform generator is used to generate keying waveforms to drive the analog switches at precisely timed intervals.

Circuitry

Due to the large amount of circuitry, very detailed descriptions of every circuit will not be given. Only a single example of each essential block will be described in detail, since much of the circuitry is repetitive.

Referring to Fig. 3, video is fed through C1 and filter R1-C2 (to remove excess noise) to sync-separator IC1, an LM1881N; it separates the horizontal and vertical sync from the video. Composite horizontal sync (negative-going pulses) appears at pin 1, and is then fed to IC2-a, the horizontal-delay multivibrator, in which R5, R6 and C6 determine the period.

The multivibrator produces an 8-microsecond pulse triggered by the leading edge of the sync pulse. The 8-microsecond pulse is used to initiate another pulse generated by IC2-b, which is active only during the line-scan portion (the video) of the video waveform. The IC2-b pulse is used to gate the video-only component from the composite video waveform (R7, R8, and C7 set the width of the pulse at 53 microseconds).

IC3-a and IC3-b perform a similar function on the vertical sync pulses from pin 3 of IC1; IC3-a is the delay and IC3-b generates a 16-microsecond pulse which is active during individual fields of the TV signal. During vertical-retrace intervals, it is desirable *not* to gate on the composite video, so horizontal multivibrator IC2-b is locked out during the vertical-blanking interval, when pin 10 is low.

Figure 4 shows the sync selector and PLL block. When SYNC SELECT (pin 2) of IC4 is high SYNC 1 selected, and when it's low SYNC 2 is selected.

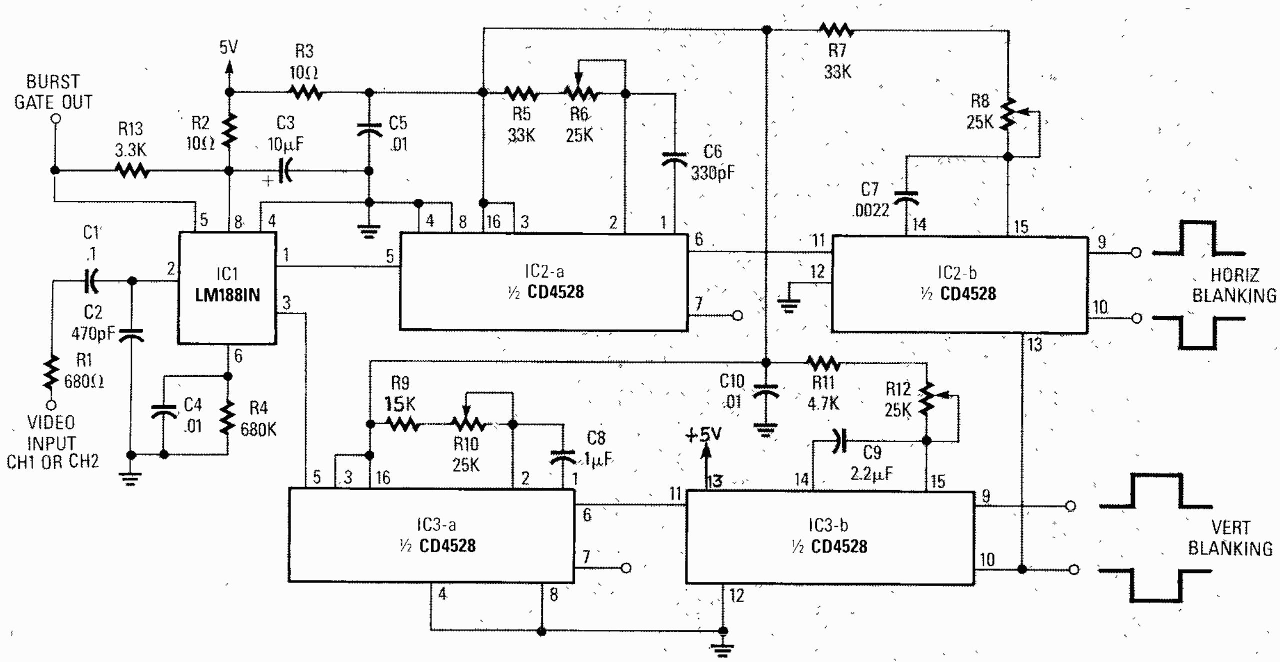


FIG. 3—SHOWN HERE IS A SYNC SPLITTER. Video is fed to pin 1 of sync-separator IC1. Composite horizontal sync appears at pin 1, and composite vertical sync appears at pin 3.

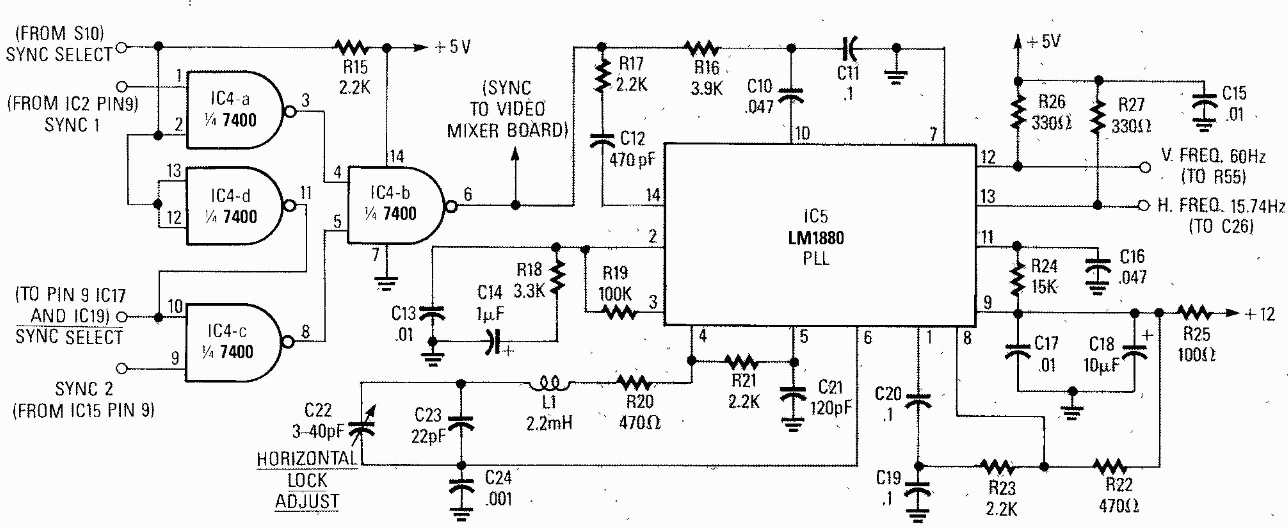


FIG. 4—SYNC SELECTOR AND PLL BLOCK. When pin 2 (SYNC SELECT) of IC4 is high, SYNC 1 selected, and when it's low SYNC 2 is selected.

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise indicated
R1, R201—680 ohms
R2, R3, R29, R62–R64, R134, R135, R127, R128, R140, R141, R143–R150, R202, R203—10 ohms
R4, R204—680,000 ohms
R5, R7, R205, R207—33,000 ohms
R6, R8, R10, R12, R42, R45, R47, R49, R206, R208, R210, R212—25,000 ohms, potentiometer
R11, R32, R33, R36–R40, R52, R53, R58, R59, R130, R209—4700 ohms
R15, R17, R21, R23, R28, R30, R31, R34, R41, R54–R56, R61, R100, R101, R104, R105, R112, R114, R118, R123, R124, R138a–R138f—2200 ohms
R16—3900 ohms
R13, R18, R213—3300 ohms
R19, R102, R103, R106, R111, R120–R122, R136—100,000 ohms
R20, R22—470 ohms
R25—100 ohms
R26, R27, R139a–R139f—330 ohms
R35, R57—5000 ohms, potentiometer
R43, R50, R51—1000 ohms
R44—1 megohm
R46, R48, R113, R116, R119, R126, R129, R131, R142—10,000 ohms
R60—47,000 ohms
R132—68 ohms
R108, R133—82 ohms
R115, R125—2000 ohms, potentiometer
R110, R117, R137—22,000 ohms
R9, R24—15,000 ohms

Capacitors
C1, C8, C11, C19, C20, C33, C34, C40, C101, C208—0.1 µF, Mylar
C2, C12, C202—470 pF, ceramic disc
C3, C18, C27, C30, C35, C36, C37, C38, C41, C47, C50, C203, C307, C309, C311—10 µF, 16 volts, electrolytic
C4, C5, C13, C15, C17, C32, C43–C45, C48, C49, C101, C102, C105, C106, C109–C116, C204, C205, C302, C303, C305, C306, C308, C310—0.01 µF, ceramic disc
C6, C206—330 pF, NPO
C7, C207—0.0022 µF, Mylar
C9, C209—2.2 µF, tantalum
C10, C16, C26, C28—0.047 µF, Mylar
C14, C42—1 µF, 35 volts, electrolytic
C21—120 pF, ±5%, NPO
C22—3–40 pF, trimmer
C23—22 pF, NPO
C24, C25, C29, C39—0.001 µF, Mylar
C31—470 pF, NPO
C103—5 pF, NPO
C104, C107—2–18 pF, trimmer
C301—4700 µF, 25 volts, electrolytic
C304—2200 µF, 25 volts, electrolytic

Semiconductors
IC1, IC14—LM1881N video sync separator
IC2, IC3, IC15, IC16—CD4528B dual monostable multivibrator
IC4—7400N quad 2-input NAND gate
IC5—LM1800N PLL FM stereo demodulator
IC6, IC9—LM565N PLL IC
IC7, IC10—74C93 4-bit binary counter
IC8, IC11, IC12—TL081 wide-bandwidth JFET-input op-amp
IC13, IC21, IC22—LM318N op-amp
IC17–IC20—CD4053B analog multiplexer/demultiplexer
IC301—LM7812 12-volt regulator
IC302—LM7805 5-volt regulator
IC303—LM7905 −5-volt regulator
D1, D100—1N914B diode
D301–D303—1N4007 rectifier diode
Q1–Q3, Q5, Q6, Q101, Q103a–f, Q105—2N3904 NPN transistor
Q4, Q102, Q104a–f—2N3906 PNP transistor

Other components
L1—2.2 mH coil
T1—120VAC/24VAC, 500 mA transformer
J1–J10—RCA jack
S1–S3—SPDT switch
S4, S10, S11—SPST switch
S5–S9—SPDT with center off
Miscellaneous: project case, wire, line cord, solder, etc.

Note: A kit consisting of the two PC boards, the parts that mount on them, and the front-panel potentiometers is available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804, for $137.50. The kit does *not* contain other parts that mount off the board, such as the switches, RCA jacks, power supply components, project case, etc. A set of two PC boards is available separately for $27.50. Add $2.50 to either order for postage and handling. New York residents must include sales tax.

Sync from pin 4 of IC4 is fed to a filter network (R16, R17, C10, C11, C12) and then to IC5, an LM1880 PLL. Components C13, C14, R18, and R19 help determine loop parameters; R20, R21, C22–C24, and L1 are for the internal oscillator of IC5 operating at 503 kHz; and C19, C20, R22, and R23 are feedback components.

R24 and C16 are vertical-timing components necessary for correct operation of IC5, and R25, C17, and C18 are supply decoupling components. A signal at the horizontal frequency appears across R26. Capacitor C22 is adjusted for lockup with the SYNC 1 or SYNC 2 input. The outputs (pins 12 and 13) are fed to sawtooth generator circuits for vertical and horizontal frequencies, respectively.

The keying circuits are shown in Fig. 5. There are four circuits—two for horizontal and two for vertical. Horizontal square-wave pulses at the junction of C25 and C26 are differentiated by C25 and R28. Therefore, Q1 is momentarily forward biased during sync intervals, and C33 is thus discharged through R29. When Q1 is cut off, C33 charges toward +5 volts through R30 until discharging again at the next sync pulse. Q2 and R31 form an emitter follower to interface the waveform, which is a sawtooth of about 1–2 volts at the horizontal frequency, to HORIZONTAL PATTERN SELECT switch, S1.

Vertical sync pulses (very short and negative-going) are directly integrated by R60 and C42, and D1 provides a discharge path. Emitter-follower Q6 and R61 feed S2, the VERTICAL PATTERN SELECT switch.

The triangle waves needed to produce keying waveforms are obtained from PLL circuits IC6, IC7, and IC8 for horizontal, and IC9, IC10, and IC11 for vertical. Only the horizontal circuitry will be discussed, as the two are similar except for component values, and their operation is identical.

Horizontal sync is fed through C26 to an LM565 PLL, which is biased by R32 and R33, and supply bypassed by C27 and C30 for the ±5V lines. C28 is a loop filter capacitor and C29 suppresses spurious responses. The VCO frequency at pin 8 is nominally 126 kHz (480 Hz for the vertical circuit). It is set by R34, R35, and C31. The VCO output at pin 4 of IC6 is fed to the pin-8 input of IC7, a 74C93 four-stage counter. Only three stages

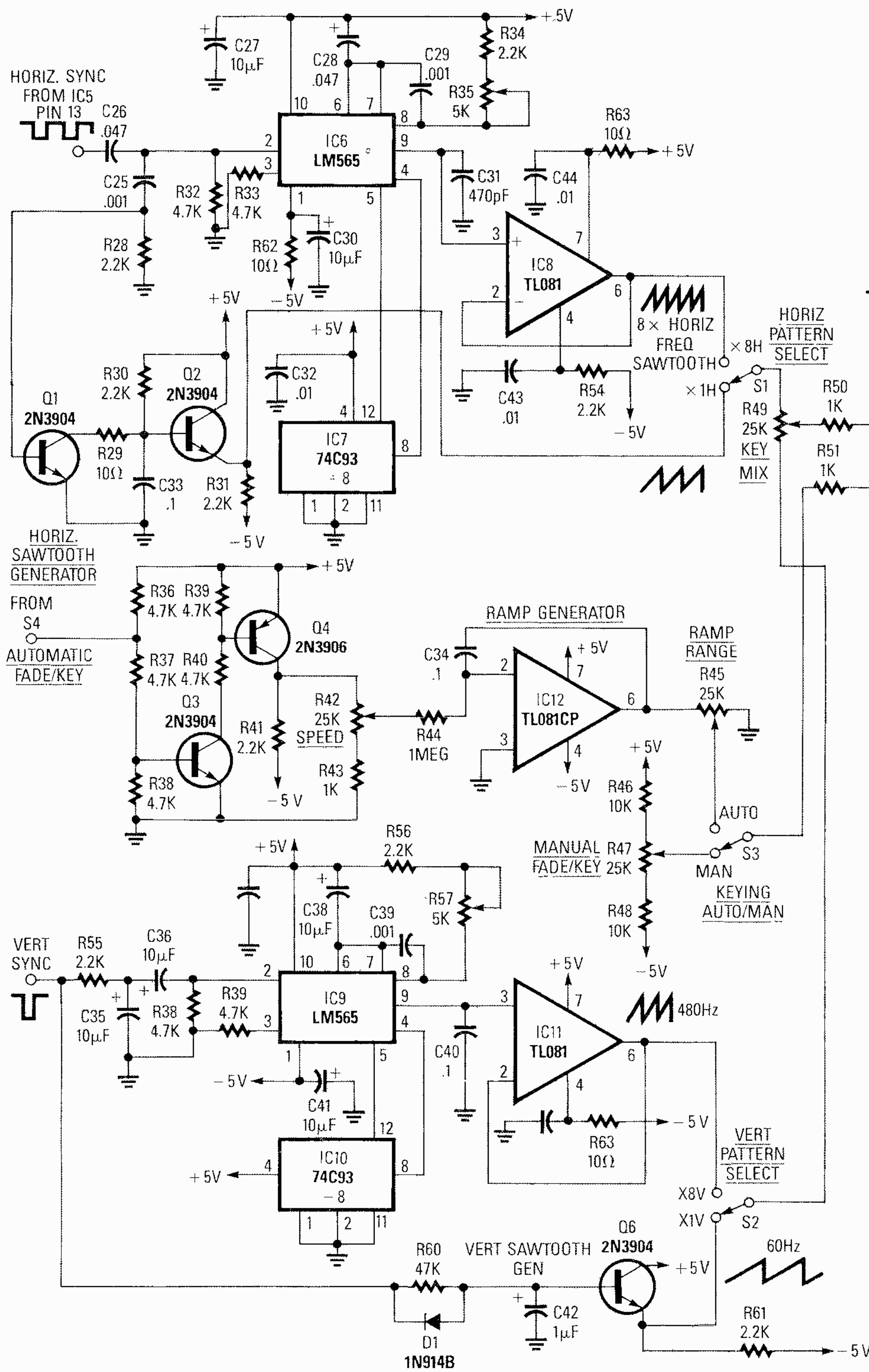


FIG. 5—THERE ARE FOUR KEYING CIRCUITS; two for horizontal and two for vertical.

are used to get a divide-by-8. The divide-by-8 output (IC7 pin 12) is fed back to IC6 pin 5, the phase detector input. Therefore, under lock conditions, the VCO frequency at pin 9 will be 126 kHz (8 × 15.74) and will be a triangle wave. IC8 is a buffer amplifier and delivers the triangle wave to S1.

Potentiometer R49 is a mixer control that taps any combination of two out of the four available waveforms (V, 8V, H, and 8H). The resultant proportion can be varied to achieve various key patterns. The resulting waveforms are fed to comparator IC13 via R50.

IC13 is biased to a threshold by a DC voltage from S3 and voltage divider R46–RR48, or by a slowly varying DC voltage from pin 6 of IC12, as selected by S3. The output of IC13 feeds Q5 via R52 and R53. The output Q5 is a square wave whose duty cycle depends on the signals for S3 and R49. It is used to drive the keying switches in the video mixer circuit.

Ramp-generator IC12 is used to generate a slowly varying DC voltage for slow fades, wipes, or key-ins. It is fed either positive or negative signals through R44. The speed (rate) of the ramp depends on the setting of the speed control R42. By varying R42, either a slow or fast key transition can be obtained. R47 is used where manual control of key transition is desired. Q3 or Q4 feed either +5 or −5V DC to R42, depending on the logic level at the junction of R37 and R36.

Figure 6 shows the video switching circuits; IC17-IC120 are CMOS analog SPDT switches. Each has three sections that can be switched at over 1-MHz and can handle signals up to 5 MHz with 50 dB isolation. They are controlled by a logic level at the input. All switches are in "up" positions (N.C.) when logic level is zero, and "down" (N.O.) when logic level is high.

Channel-1 video is input to pin 15 of IC17 (IC1 is fed from that point as well), where it is split into video and sync. IC17 is driven by IC2 in the keying section. Sync and video are available separately at J2 and J7. In Fig. 6, an "EF" followed by a letter represents an emitter-follower circuit; one is shown in detail inside dashed lines in Fig. 6. IC18-a selects either input video or effects video (derived externally from video 1). IC18 selects either CH1 or a DC level between −0.5 and +1.5 volts from R115 used in a fadeout; it is blanked during sync

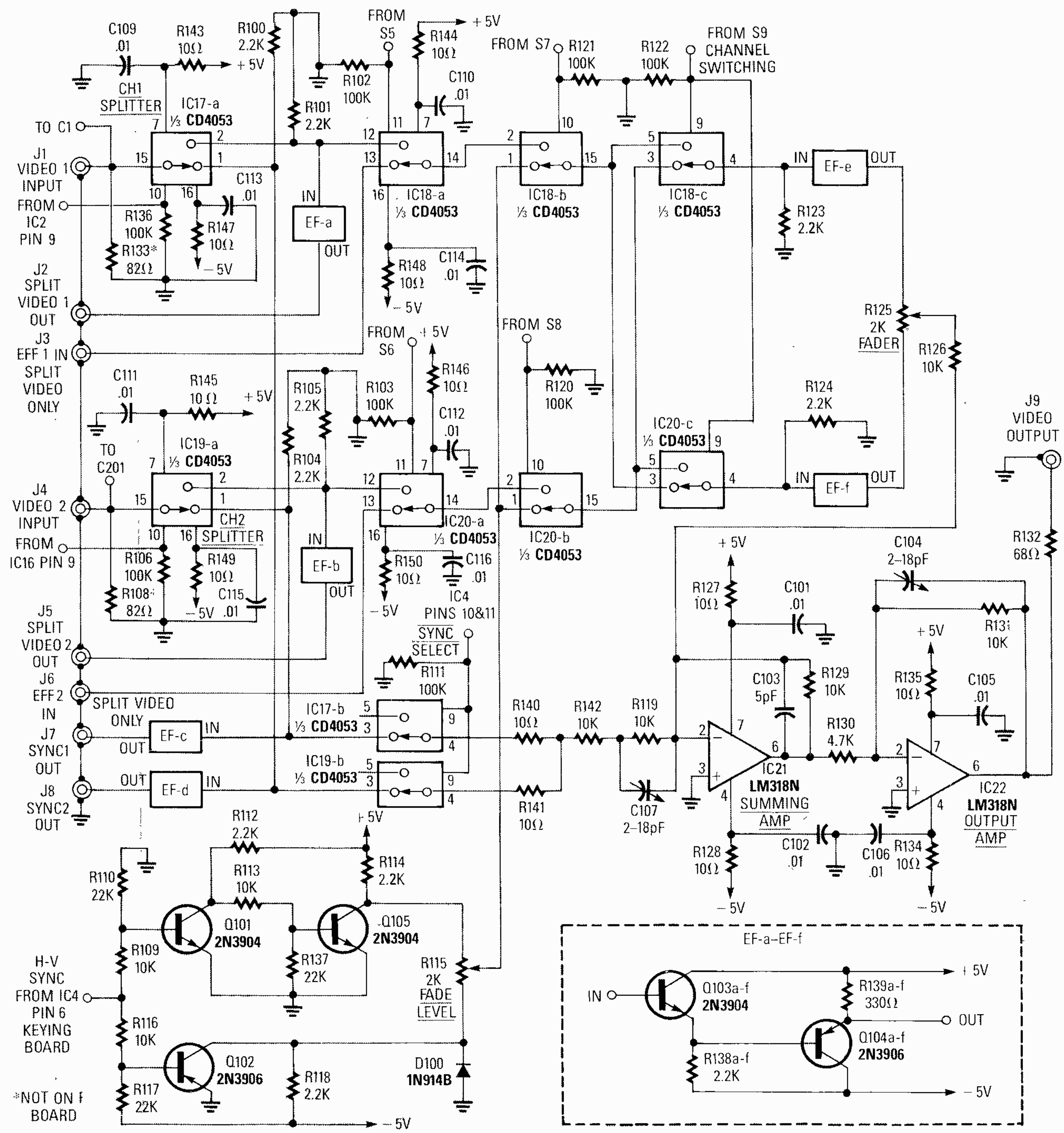
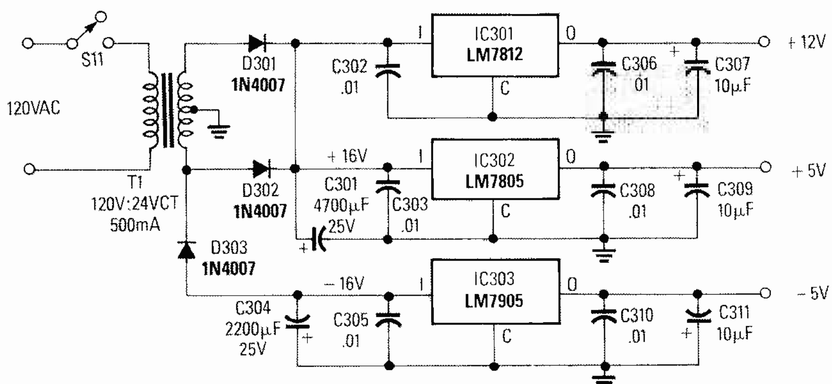


FIG. 6—THE VIDEO SWITCHING CIRCUITS. Each analog switch (a CD4053) has three sections that can be switched at over a 1-MHz rate, controlled by a logic level at the input. An "EF" followed by a letter represents an emitter follower circuit; one is shown in detail inside the dashed lines.

intervals so as to not upset sync levels. Transistors Q100-Q102, D100, and R112-R118 generate the required waveform.

IC18-c and IC20-c are configured as a DPDT switch to switch between CH1 and CH2 for direct fades, wipes, or key-ins (genlock sources are required). Switched video from both channels is fed to fader R125. The output of R125 is taken to summing amplifier IC21, together with sync from IC17-b and IC19-b (sync is selected for the channel in use). Frequency-compensation components R119 and C107 maintain correct burst phase. The output of IC21 is a complete inverted video signal. It's fed to IC22 for re-inversion and then to J9 via termination-resistor R132.

The unit requires ±5, and +12-volts DC. The ±5-volt supplies must be at least 500 mA. Two IC regulators, an LM7805 for +5 and an LM7905 for −5, together with a 12-volt AC transformer and bridge rectifier can be used. The +12 volts for the PLL on the keyer board (IC5) need be only 50 mA, but it should be well filtered. A suitable power-supply is



Note: A kit consisting of the two PC boards, the parts that mount on them, and the front-panel potentiometers is available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804, for $137.50. The kit does *not* contain other parts that mount off the board, such as the switches, RCA jacks, power supply components, project case, etc. A set of two PC boards is available separately for $27.50. Add $2.50 to either order for postage and handling. New York residents must include sales tax.

FIG. 7—THE SCENE SWITCHER REQUIRES ±5 AND +12-VOLTS DC. The prototype's power supply is shown here.

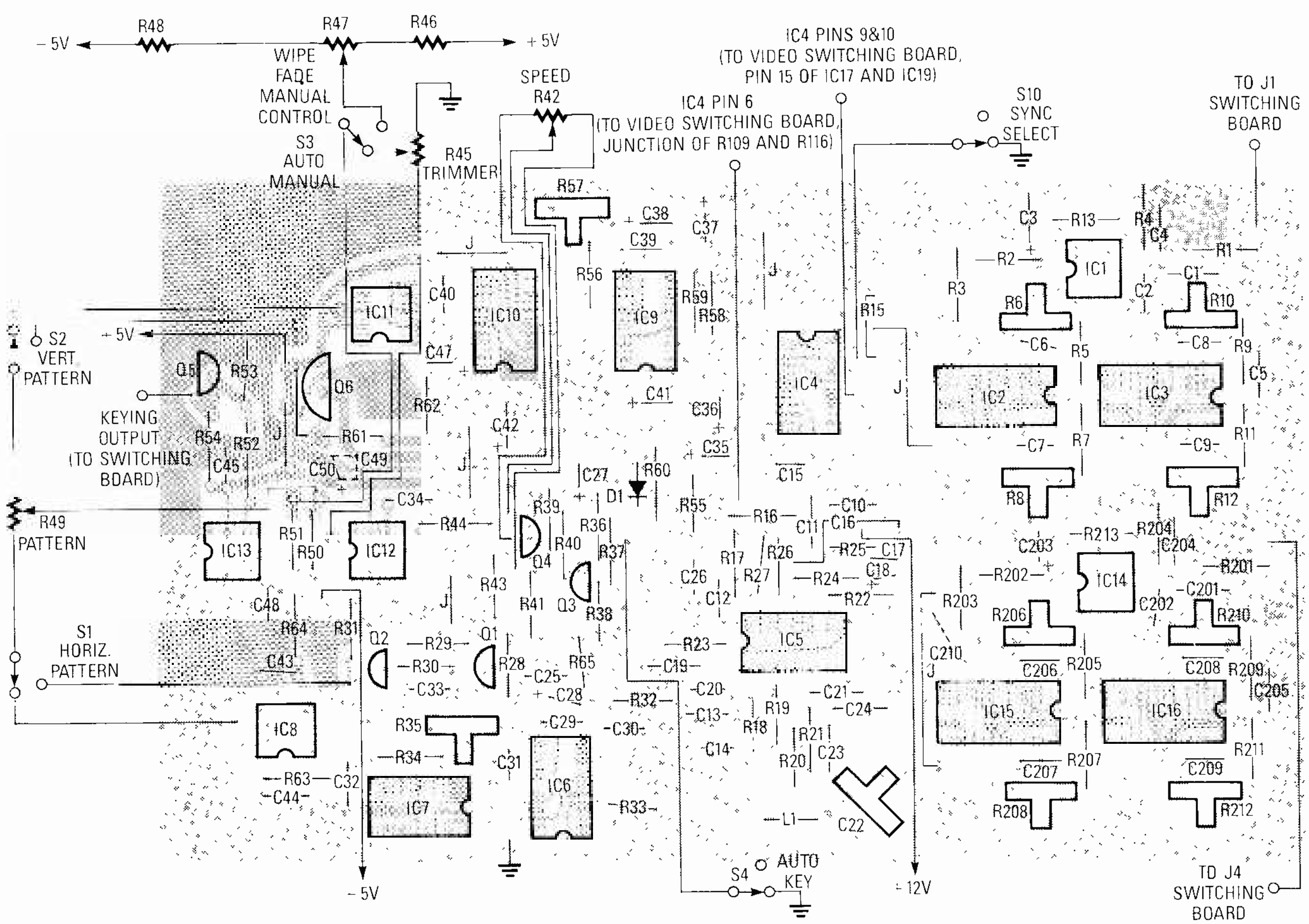


FIG. 8—VIDEO-KEYING BOARD parts-placement diagram. Solder the resistors and capacitors first, and then the IC's.

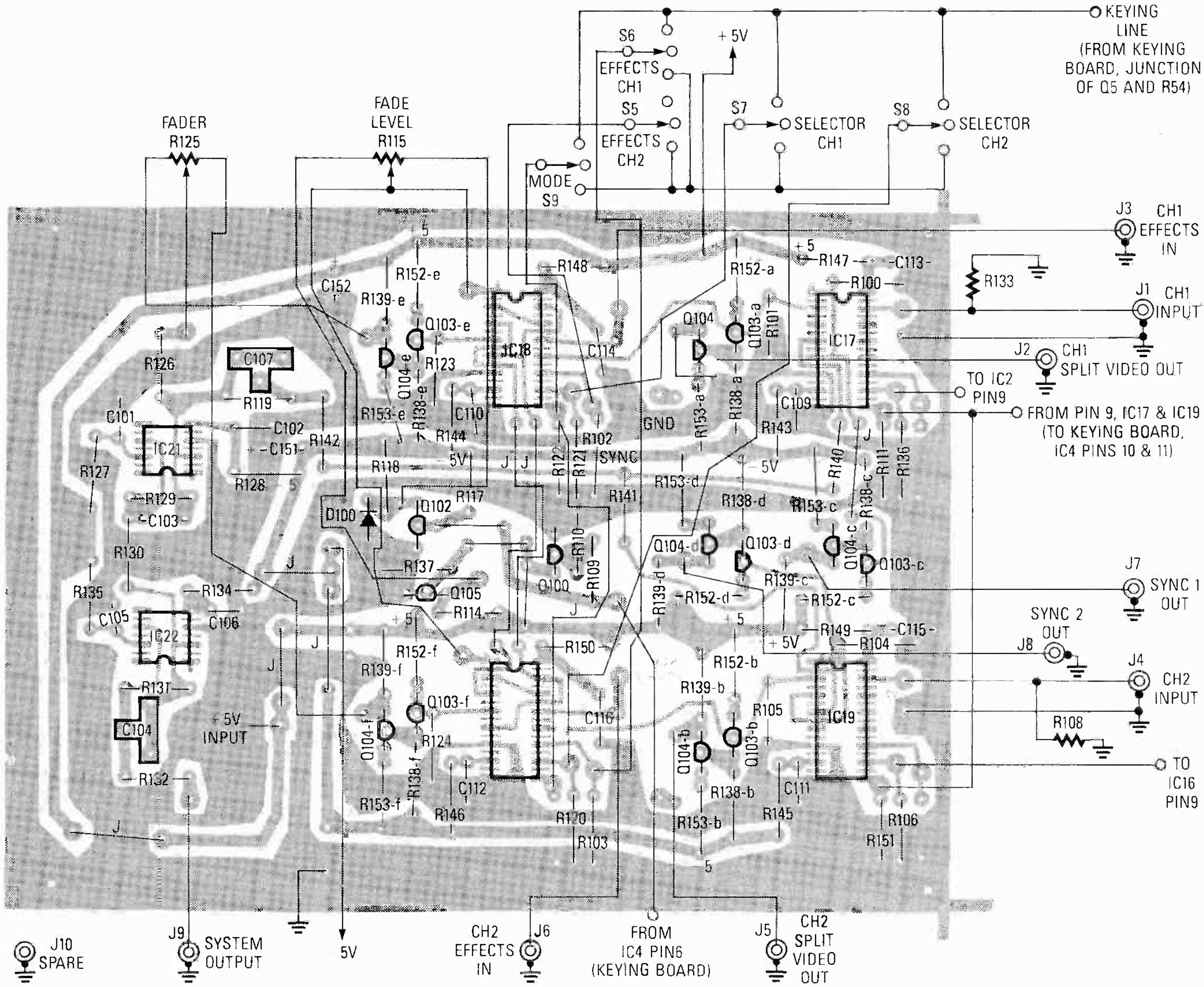


FIG. 9—VIDEO-SWITCHING BOARD parts-placement diagram. Check your work as you go along, to lessen the likelihood of any problems.

shown in Fig. 7.

The two PC boards can be constructed using the Parts-Placement diagrams of Figs. 8 and 9. Foil patterns for the two PC boards are provided in PC Service. Just be very careful when soldering, so that you don't create any problems for yourself when you go to calibrate the unit. Check off each part as you install it, and inspect your work as you go along to minimize headaches later on.

After you've assembled and checked out the two boards, you must wire them along with the switches, RCA jacks, control potentiometers, and power supply as shown in Fig. 10. There are a lot of connections to be made, so be patient, take your time, and do a careful job.

Any suitable control-panel layout can be used. Just make sure that leads are kept as short as possible and separated from each other to minimize crosstalk. The prototype that you see pictured in this article is mounted inside a metal cabinet. While a metal cabinet is preferred for its shielding, any other kind will do, as long as everything fits inside.

Checkout and alignment

After the unit is all together, and you've inspected the boards for soldering defects, turn the unit on and make sure that none of the IC's get hot. Then check all points for proper voltages—+5, −5, and +12. You will need an oscilloscope for the following checks, and we will go over the procedures for CH1 only, but the procedures are identical for CH1 and CH2.

Apply a 1-volt p-p negative-sync NTSC video signal to J1, and verify negative sync pulses at about 5-volts p-p at IC1 pin 1. Adjust R6 so that IC2 pin 6 (IC2-a) shows an 8-μs pulse and adjust R8 so that pin 9 (IC2-b) shows a 53 μs-pulse. Check for a 60-Hz vertical-sync pulse at IC1 pin 3. Adjust R10 for 0.5–0.6-ms pulses at IC3-a pin 6, and adjust R12 for a 16-ms pulse at IC3-b pin 9. (Start out with R12 at its minimum-resistance setting). Make sure that S10 (SYNC SELECTING) is in the CH1 position, and then check for sync pulses at pin 6 of IC4. Connect the scope to IC5 pin 13 and, using a non-metallic tool, adjust C22 so that the pulses are synchronized to the video signal. Check for 60-Hz pulses at IC5 pin 12.

Connect the scope to IC8 pin 4, and adjust R35 for a 126-kHz sawtooth wave. Now connect the scope to IC11 pin 6, and adjust R57 for a 480-Hz sawtooth. Verify a 15.7-kHz horizontal sawtooth at the junction of R31 and the emitter of Q2, and a 60-Hz vertical sawtooth across C42. Now check the waveform at the wiper of R49; it should be a mixture of two of the four previous waveforms, depending on the settings of S1, S2, and R49.

Check for ±2.5 volts at the wiper of R47, and also for between +4 and −4 volts at IC12 pin 6. When you activate S4, the voltage should slowly change, and R42 should vary the rate of change. Set R45 at the center of its range, and set S3 to manual.

Place the scope at the collector of Q5; you should see the keying waveform. The waveform will disappear if you rotate R49 to its extremes, and you will see either 0 or +5 volts at either extreme.

Place S5–S9 in the "normal" position; you should get video at J9 that you can check with a monitor. Adjust C104 for optimum sharpness. Adjust C107 for correct burst phase, as indicated by proper flesh tones on a video image. Place S8 in the "fixed" position, and vary R125. You should be able to fade to a level set by R115.

Using the switcher

Switches S5–S9 determine exactly what signal is applied to each side of the fader control. For example, suppose a fade to black is desired. In that case, FADE SELECT (S7) would be set so that CH1 video passes directly to one side of FADER CONTROL (R125). S8 would be placed in the fixed position, which applies a fixed DC level (set via the FADE LEVEL CONTROL) to the opposite side of the FADER CONTROL. By rotating the FADER CONTROL, a mix of CH1 video and the DC fade level is sent to the output amplifier, and manual fading is performed.

If a fade from CH1 to CH2 is desired, both CH1 and CH2 fade selectors must be placed in the normal position. If a fade from CH2 to CH1 is desired, S7 and S8 must be placed in the fixed and normal position. S9 swaps CH1 and CH2, reversing the connections to each side of the fader control. If the fader control is set at one extreme, and CH1 is coming through, then moving S9 to the "reverse" position instantly routes CH2 into the output amplifier.

In the "keyed" positions, S5–S9 apply a waveform to electronically switch the video for wipes, transitions, and fades. Switches S1 and S2, in combination with R49 determine the particular pattern. Switch S3 selects the manual fade/key mode where R47 manually controls the effect, or the auto-key mode where the ramp generator produces the effect; S4 initiates the transition or effect, but has no effect in the manual position of S3. Switches S5 and S6 select the effects channel or other video inputs that are synchronized to CH1 or CH2. **R-E**

AUDIO MUTE

continued from page 10

the grounds of J2 and J4, but leave both pairs separate.

That isolates the two channels, but make certain that there's no accidental short between the two channels, like a solder splash. Thus, only in the case of two mono sources, should there be three separate grounds; the main one for the audio-muting circuit, the one for the J1-J3 channel, and a separate one for the J2-J4 channel. (Figs. 1–3 show the two grounds that would normally be present for stereo audio.)

Construction

This is a very simple project to build. The parts-placement diagram is shown in Fig. 2, and the foil pattern is shown below. You might, however, want to build the circuit on either breadboard or perfboard. You can stuff the PC board in any order, and you might want to use sockets for Q1, Q2, and IC2, even though they weren't used in the prototype. When you're finished building the circuit, check for mistakes like solder splashes, or diodes, transistors, or IC's inserted backwards. The completed board can be installed in any suitable case. **R-E**

MICROCONTROLLER

continued from page 90

After connecting everything, check for wiring errors, clipped wires, shorts, and opens. If everything seems OK, apply power. You should see the "HELP" message on the display. Turn S6 on and R30 (VOLUME) to maximum, and you should hear the alarm. If not, remove power and check your work again.

Other ideas

Now that you've gotten your feet wet with the 68705, you might want to consider other projects that can exploit its power. Here are a few suggestions.

Astronomers use a clock that keeps track of "sidereal time," which is related to the apparent motion of the stars, rather than the sun. A sidereal day is 23 hours, 56 minutes and 4 seconds long. Can you modify the clock as presented to keep track of sidereal time?

Another astronomical application is telescope control. A telescope mounting has two axes; can you figure out a way for servo motors to control the rotation of those axes under control of the 68705?

How about a programmable light show? With suitable opto-isolators (for electrical safety) and high-current semiconductor relays, that should be a straightforward task. What about designing a scanning keyboard using the 68705?

Another project is a frequency counter. You could use the multiplexed display in the alarm clock as is, and likewise derive the time base from the power-supply's AC source. Then, determining the frequency of an input signal is no harder than counting how many zero crossings occur per time-base period. The alarm clock's software and hardware are a good starting point.

As you can see, designing with the 68705 is quite simple—and fun! So consider designing your next project around the 68705 and reap the rewards that the microcomputer revolution makes possible! **R-E**

ACOUSTIC FIELD GENERATOR

Our AFG will turn any livingroom into a full-sized movie theater or concert hall.

TOD T. TEMPLIN

IF YOU'VE SEEN A RECENTLY PRODUCED motion picture presented in a modern theater, then you are undoubtedly aware of the stunning realism and dramatic impact created by the use of the Dolby-stereo surround-sound audio process. The system was developed by Dolby Laboratories for the motion-picture industry to literally surround viewers with sound and place them in the very midst of the action.

For anyone unfamiliar with the concept, the Dolby-stereo surround-sound process works to increase the sensation of "being there" by reproducing distinct sounds toward the front, sides, and rear of the viewer. In practice, it is accomplished by feeding the primary stereo soundtrack to speakers located behind the screen on the left, the center, and the right side of the theater.

Simultaneously, an additional audio channel, decoded from within the primary channels, is sent to a system of smaller speakers located to the sides and to the rear of the audience. That additional surround channel is used to re-create ambient sounds like wind noise or "on location" street sounds as well as special sound effects intended to travel past the audience from front to rear, or even to seem to circle overhead.

Since the mid 1970's, over 1100 motion pictures have been produced with surround-sound tracks. Because the process encodes the surround information into a 2-channel stereo signal, when the movies are transferred to video tapes and laser discs, the encoded information remains intact. However, in order to enjoy surround sound at home, at the very minimum, a stereo VCR; some type of decoder, and additional surround speakers are required.

The basic principle of all surround-sound decoders, from the simplest to the most expensive, is the same. They all reproduce the surround information by recovering the (L − R) difference signal which is encoded into the left and right channels of the movie soundtrack. The decoder presented here goes beyond the capabilities of a simple surround-sound decoder. Besides the surround decoder circuit, additional circuitry is

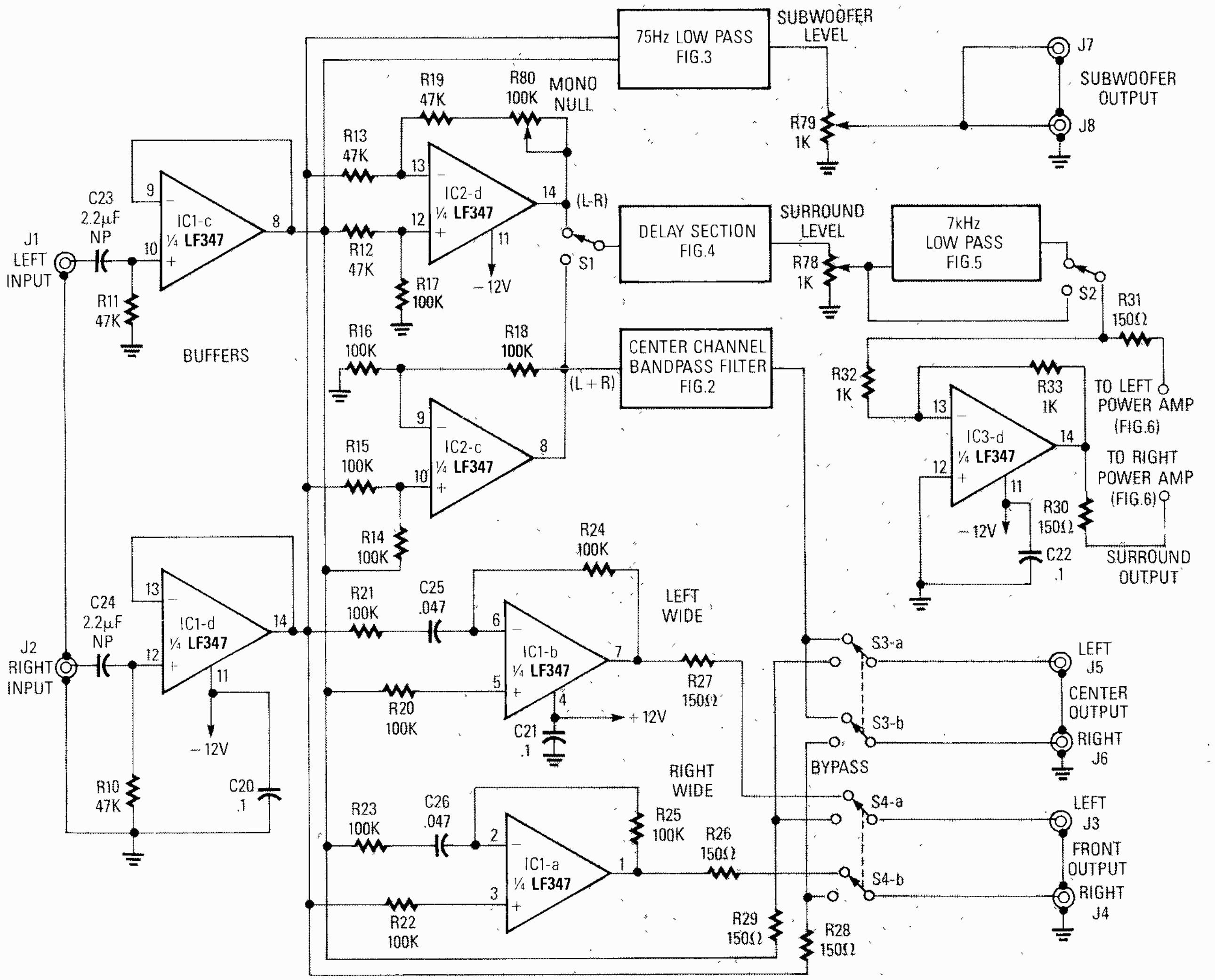


FIG. 1—THE AFG IS MADE UP OF 10 relatively simple circuit elements.

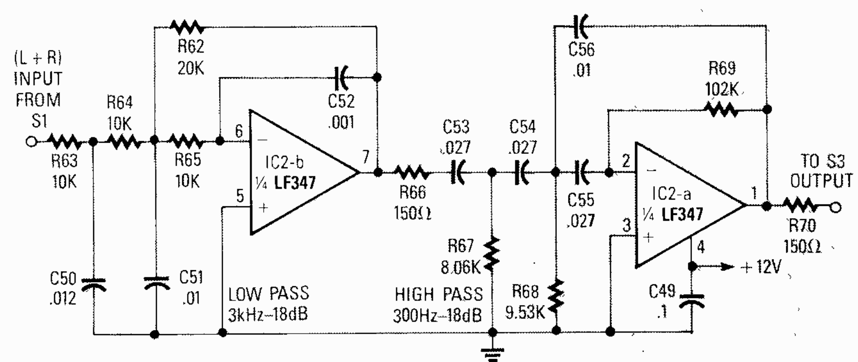


FIG. 2—THE CENTER-CHANNEL SPEECH FILTER is built by cascading a 3-kHz low-pass filter with a 300-Hz high-pass filter to form a band-pass filter.

used to create wide-left, center-dialogue, wide-right, and subwoofer signals. Presenting those signals through six properly arranged speakers results in the acoustical illusion of a large, almost boundless, three-dimensional listening environment, even in a small room; hence the name, "*A*coustic *F*ield *G*enerator," but we'll call it the AFG for short. This article is not intended to provide an in-depth tutorial or technical description of the surround-sound system. Rather, it is intended to show you how to construct and install a high-quality, multichannel sound decoder for use in your home.

The AFG offers two different modes of operation; "matrix" and "concert." In the matrix mode, the (L − R) difference signal is recovered from surround-encoded source material and is then passed through a 2048-stage bucket-brigade delay line. The delay is continuously adjustable from about 5 to 35 milliseconds, and has a bandpass of 50 Hz to 15 kHz. That enables the accurate decoding and presentation of the surround-channel information present within the source material. The (L + R) sum signal is also recovered to be sent through the delay section of the AFG when the concert mode is selected. That imparts the ambience and realism of a live concert-hall performance to musical material played through the AFG. In either mode, the output of the decoder/delay section is sent to a pair of 10-watt-per-channel power amplifiers, included on the main circuit board, for driving a pair of surround-channel speakers.

The AFG also provides a means of greatly increasing the apparent separation or "width" of the stereo image presented by the front speakers. In an ordinary decoder, the left- and right-channel signals are sent to the front speakers unaltered, and the center channel, if present at all, is fed a simple sum of the left and right signals. Although that technique provides a very solid front soundstage, it severely limits the system's ability to convincingly present extreme-left or -right sound effects. And, because the screen in most home-video systems is relatively small, especially when compared to the screen in a movie theater, dialogue which should be confined to the screen, tends to appear off screen in the left and right speakers—particularly for viewers seated off center.

The AFG uses frequency-selective circuitry to cancel some of the dialogue from the left and right channels, but that creates a phantom "hole" in the center of the soundstage. So, the AFG also creates a center dialogue channel to fill that hole by summing the left and right channels and passing them through a band-pass filter with a response curve which favors the range of frequencies covered by the human voice. Feeding the voice-only "dialogue" signal directly to the speakers in the video monitor locates the dialogue firmly on the screen without destroying the spatial effects of the front soundstage.

Finally, the AFG includes a 75-Hz active low-pass filter for driving a subwoofer setup. If you are not currently using a subwoofer as part of your system, you are missing out on the dynamic impact and heightened level of excitement which is imparted by the extreme low-frequency sounds used in motion pictures, primarily as a special audio effect. The subwoofer output of the AFG has that sonic information isolated and ready to feed to a power amplifier and speaker of your choice. You may wish to consult with a local audio dealer for advice on selecting a proper subwoofer and power amplifier. Suffice it to say, that a relatively high-power amplifier and large subwoofer will be required if you intend to fill your room with earth-shaking bass that goes far beyond the capabilities of most "full-range" speakers. It is preferable to place the subwoofer toward the front of the soundstage, although the exact position is not critical, due to the ear's inability to accurately locate very low-frequency sound. Thus, many subwoofers are designed to physically resemble an end table or other piece of furniture, so that they can aesthetically blend into the other room decor.

The AFG was designed to be connected into the pre-amp/power-amp loop of your regular home entertainment system. Consequently, all the functions of the AFG may be switched to bypass and unity gain to effectively remove it from the system, if required. We believe, however, that once you experience the added sonic dimension that the AFG adds to music as well as movies, you'll never want to switch it off.

PARTS LIST

All resistors ¼-watt, 5%, except as noted.

R1—1500 ohms
R2, R3, R54—22,000 ohms
R4, R5, R32, R33—1000 ohms
R6, R7, R61, R62, R74—20,000 ohms
R8, R9—1 ohm, ½-watt, 5%
R10–R13, R19, R34, R35—47,000 ohms
R14–R18, R20–R25, R47–R49, R55, R56—100,000 ohms
R57—330,000 ohms
R26–R31, R66, R70—150 ohms
R36–R43, R67—8060 ohms, 1%
R44–R46—16,000 ohms
R50, R51—5600 ohms
R52—2400 ohms
R53—8200 ohms
R58–R60, R63–R65, R71–R73—10,000 ohms
R68—9530 ohms, ¼-watt, 1%
R69—102,000 ohms, ¼-watt, 1%
R75, R80—100,000 ohms, potentiometer
R76—10,000 ohms, potentiometer
R77—50,000 ohms, PC-mount potentiometer
R78, R79—1000 ohms, PC-mount potentiometer

Capacitors

C1–C4—2200 µF, 25 volts, electrolytic
C5, C6—10 µF, 35 volts, radial electrolytic
C7–C12, C19–C22, C27, C28, C30, C31, C45, C49—0.1 µF, 50 volts, metal film
C13, C14, C23, C24, C43—2.2 µF, 50 volts, bi-polar radial electrolytic
C15, C16—22 µF, 16 volts, bi-polar radial electrolytic
C17, C18—0.22 µF, metal film
C25, C26—0.047 µF, metal film
C32–C34—3300 pF, polyester
C35–C37—2700 pF, polyester
C38–C41—270 pF, 5% ceramic disc
C42, C47—0.47 µF, metal film
C44—120 pF, 5% ceramic disc
C46—0.56 µF, metal film
C48—0.039 µF, metal film
C50—0.012 µF, metal film
C51, C56—0.01 µF, metal film
C52—1000 pF, 5% polyester
C53–C55—0.027 µF, metal film
C57—5600 pF, 5% polyester
C58—4700 pF, 5% polyester
C59—470 pF, 5% ceramic disc

Semiconductors

D1, D2—1N5400 50 PIV 3-amp diode
IC1–IC4—LF347 quad JFET
IC5—MN3008 2048-stage bucket brigade device
IC6—MN3101 2-phase clock
IC7—7812T +12-volt regulator
IC8—7912T −12-volt regulator
IC9, IC10—LM1875T audio amp
LED1—light emitting diode pilot lamp

Other components

T1—Power Transformer 25.2 Volt Center Tapped 2 Amp.
F1–F3—1-amp fuse
J1–J8—8-pin RCA-style jack panel
J9–J12—4-position pushbutton speaker-terminal panel
S1, S2, S5—SPDT switch
S3, S4—DPDT switch

Miscellaneous: speakers of your choice, 5 14-pin IC sockets, 1 8-pin IC socket, 1 heat sink (2×2×5¼-inch aluminum angle stock), 2 T0-220 mica insulators with mounting hardware, silicone grease, 3 in-line fuse holders, 3 knobs, chassis, linecord, solder, etc.

Note: The following items are available from T3 Research, Inc., 5329 N. Navajo Ave., Glendale, Wisconsin 53217-5036: An etched, drilled, and plated PC board, $15.00; a basic parts kit consisting of all semiconductors, resistors, and capacitors, $60.00; a piece of aluminum stock for the heat sink, $3.00. Please include $2.50 for postage and handling with your order. Wisconsin residents please include appropriate sales tax.

About the circuit

When viewed as a whole, the AFG circuitry is quite complex. However, referring to the simplified schematic in Fig. 1, you can see that the AFG is really made up of 10 relatively simple circuit elements. IC1-c and IC1-d are configured as unity-gain non-inverting buffer amplifiers. They transform the 47-kilohm input impedance, which is set by R10 and R11, to a low-impedance source which drives all of the AFG amplifiers, filters, and bypass outputs.

The summing (L+R) amplifier, IC2-c, combines equal amounts of the left and right signals, via R14 and R15, to develop a total composite signal. Left- and right-channel signals are applied equally through R13 and R12 to IC2-d, the difference (L−R) decoder. Any signal that's common to both channels is canceled by IC2-d, thus forming one signal which contains none of the common "mono" information present in the original stereo signal. Potentiometer R80 provides a means of exactly balancing the inverting and non-inverting gains of the amplifier for a perfect null.

The stereo width-enhancement circuit is made up from IC1-a and IC1-b. It works similarly to the (L−R) decoder, except that C25 and C26 have been added in the inverting inputs of each op-amp. Consider, for the moment, just the "right wide" circuit of IC1-a; C26 and R23 form a gently sloping high-pass filter for the left-channel signal only. Thus, the amount of signal cancellation is dependent on frequency and the relative amplitude between the two channels. In other words, the more a signal is the *same* in both channels, the more it is removed from the output of the circuit; the effect increases as the signal's frequency rises. If, however, the input signal appears only in the right channel, no matter what its frequency or amplitude, it does not cancel in the difference amplifier and appears at the output unaffected.

IC1-b functions in the same way to develop the "left wide" signal because its inverting and non-inverting inputs are connected to the left and right channels in a manner opposite that of IC1-a. The net effect of all that is to increase the apparent separation between the left and right channels by eliminating some of the material common between them. The output of the width-enhancement circuit is routed to S4, which selects either the "wide" or the bypass signal for feeding the front-channel amplifier.

The center-channel dialogue filter, or speech filter if you prefer (see Fig. 2), is built by cascading a 3-kHz low-pass filter with a 300-Hz high-pass filter to form a band-pass filter. The frequency characteristics of the human voice fall predominantly within that range. As with all of the other filters used in the AFG, those are of the 3rd order Butterworth design. That design was chosen because it offers minimum peaking within the passband. It has a sharp −18 dB/octave cutoff, a flat voltage and power frequency response, and minimum phase change within the passband. The output of the bandpass filter is routed to the high side of S3. That switch allows the center-channel output of the AFG to be switched between the dialogue filter and the bypass mode.

As shown in Fig. 3, IC3-a and IC3-b form an active crossover network for driving a subwoofer. IC3-a sums signals from the left- and right-channel buffer amps, it inverts the summed signal 180 degrees, and it provides a low driving impedance for the following filter stage. IC3-b and its associated RC network form a 75-Hz, 3rd-order low-pass filter. Because the filter inverts the signal another 180 degrees, the signal that appears across R79 (which is the output-level control) is back in phase with the original input signal.

The delay section of the AFG, shown in Fig. 4, is built around the MN3008 *B*ucket *B*rigade *D*evice (BBD), made by Matsushita (Panasonic), and the MN3101 two-phase variable-frequency clock generator. The BBD is a P-channel silicon-gate MOS LSI circuit comprised of 2048 bucket-brigade stages fabricated on a single chip. Each stage consists of a small capacitor that stores an electric charge and a tetrode transistor for switching purposes. Electrical charges corresponding to analog signals are transferred from one stage to the next by a two-phase clock drive, in the same manner that a fireman's bucket brigade transfers a pail of water from one man to the next. A signal presented at the input is transferred down the line of buckets toward the output at a speed controlled by the clock frequency. The more slowly the clock runs, the longer it takes for the signal to travel through the circuit. (See discussion of BBD theory in the October 1986 **Radio-Electronics**.)

The amount of delay required in our system varies between approximately 5 and 35 milliseconds, so our first consideration must be to select the proper range of clock frequency. The delay time of a BBD is equal to the number of stages divided by twice the clock frequency. So, based on manufacturer's data for the MN3101 clock-generator IC, values were chosen for R53, R54, R77, and C44, to produce a clock frequency, adjustable via R77, which varies from about 30 kHz to 130 kHz.

Our next consideration deals with the property of delay lines known as aliasing. If the frequency of the signal applied to the input of a delay line becomes higher than one half of the clock frequency, the time available to store the sample of that signal in the capacitor becomes too short. The amplitude of that signal's frequency has a value which changes during the time of the sample, so the charge stored in the capacitor is not an accurate representation of that instant of time. To avoid the problem and the resulting distortion, a filter is placed ahead of the BBD which limits the input frequency to one half of the lowest clock frequency used. Given that we'd like to run the clock at speeds as slow as 30 kHz, we must limit the maximum fre-

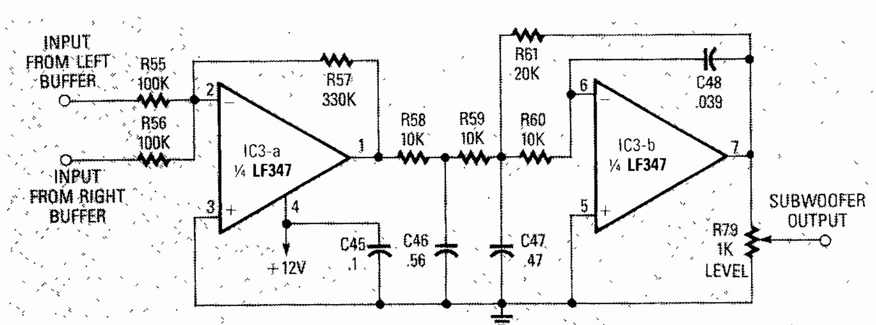


FIG. 3—AN ACTIVE CROSSOVER NETWORK for driving a high-power subwoofer system is made from IC3-a and IC3-b.

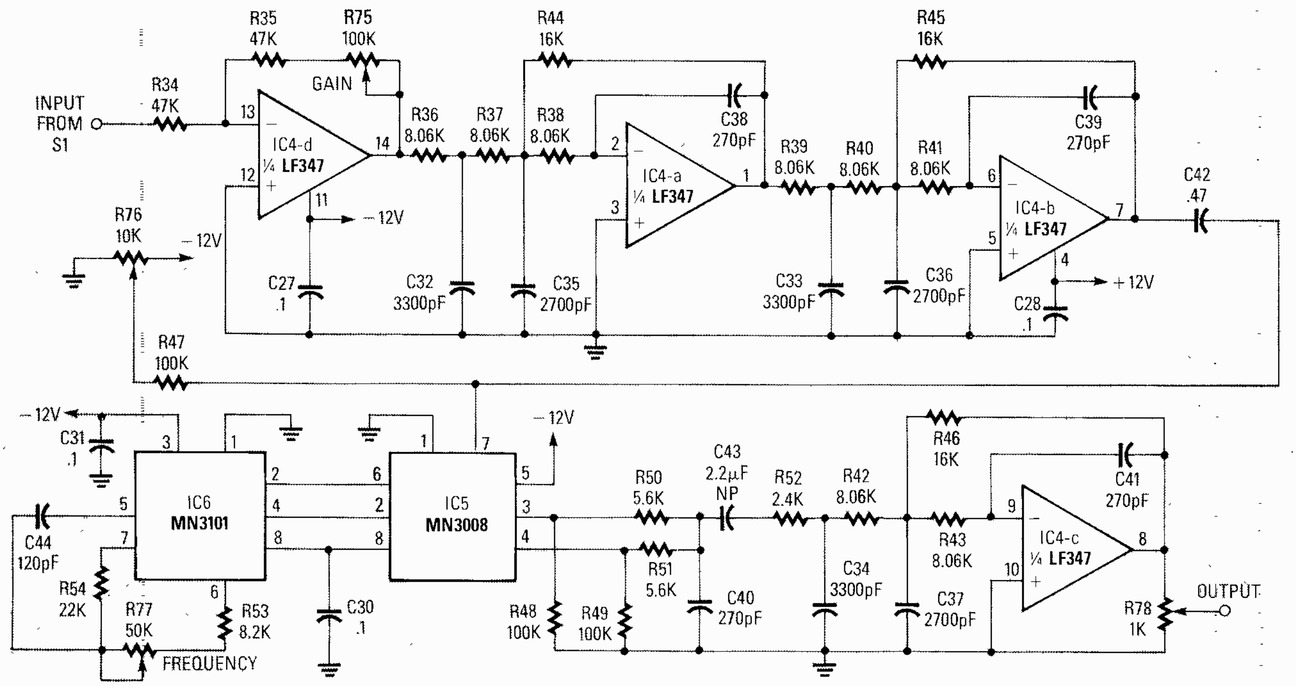


FIG. 4—THE DELAY SECTION OF THE AFG is built around the MN3008 bucket-brigade device and the MN3101 two-phase variable-frequency clock generator.

quency that we apply to the BBD to 15 kHz.

If you refer back to Fig. 1, S1 selects the signal to be delayed; either the difference signal (L − R) from IC2-d in the matrix mode or the sum signal (L + R) from IC2-c in the concert mode. The selected signal is fed from S1 to the delay section (Fig. 4) where IC4-d is configured as an inverting amplifier; R75 adjusts the gain between unity and × 3. Integrated circuits IC4-a and IC4-b, along with their associated RC networks, are identical 3rd-order 15-kHz low-pass filters. Cascading two filters produces a very sharp cut off (−36 dB per octave), which is convenient, as it eliminates any problems that may arise with aliasing, while maintaining a respectable 15-kHz bandwidth for the section. Potentiometer R76 is used to adjust the bias voltage required by the BBD to exactly one half the supply voltage; a requirement of the device. Notice that both the BBD and the clock IC run off of the negative power-supply rail.

Another property of a BBD is that clock phase 1 drives all the odd-number stages of the device and clock phase 2 drives all the even stages. When the signal reaches the end of the line, the output of the last odd stage must be combined with the output of

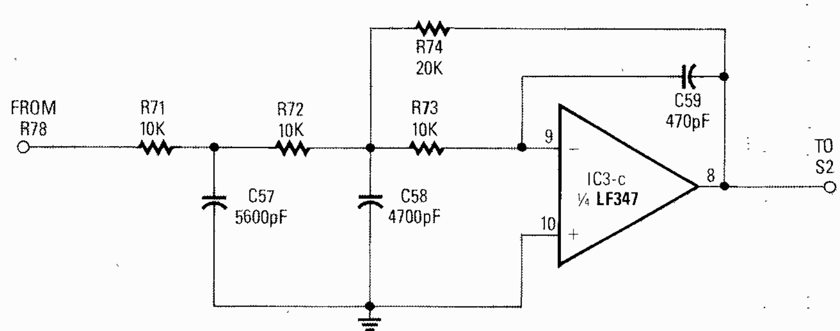


FIG. 5—A 3rd-ORDER 7-kHz LOW-PASS FILTER is made from IC3-c and its associated RC network.

the last even stage to reconstruct an exact replica of the input signal. The purpose for doing that is to self-cancel any of the clock signal from the output of the device; R48 and R49 are the source-load resistors for the last two BBD stages and R50 and R51 sum the two outputs. The delayed signal is next applied to another 3rd-order 15-kHz low-pass filter comprising IC4-c and its associated RC network. That last filter is required to stop any remaining clock signal from reaching the output of the circuit. Potentiometer R78 is there to serve as the volume control for the surround channels by controlling the amount of delayed signal that is applied to the power amplifiers.

To provide for increased high-frequency noise reduction in the surround channel and to more closely comply with the Dolby Laboratories standards for surround sound, a 3rd-order 7-kHz low-pass filter is included in the AFG design. As shown in Fig. 5, IC3-c and its associated RC network forms the filter; S2 then selects between the output of that filter and the bypass mode. If you refer back to Fig. 1, notice that the wiper of S2 is connected to two circuits; it goes directly to the left surround power amplifier via R31, and to IC3-d, a unity-gain inverting amplifier, via R32. The output of IC3-d drives the right surround power amplifier via R30. The reason for driving the power amplifiers out of phase will be explained shortly.

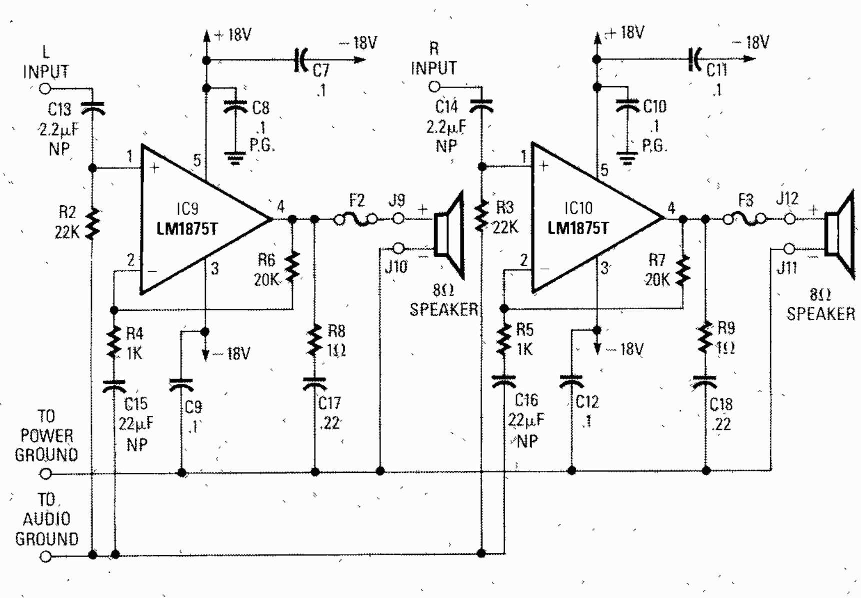


FIG. 6—THE SURROUND CHANNEL POWER AMPLIFIERS are designed around a pair of LM1875 monolithic power-amplifier IC's.

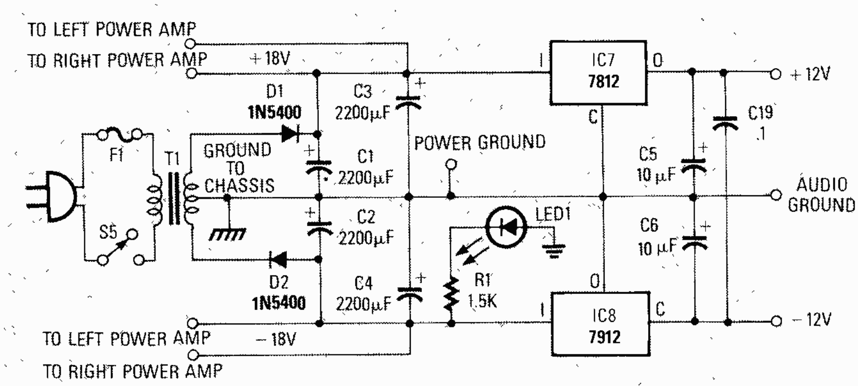


FIG. 7—THE POWER SUPPLY produces about ±18-volts unregulated DC.

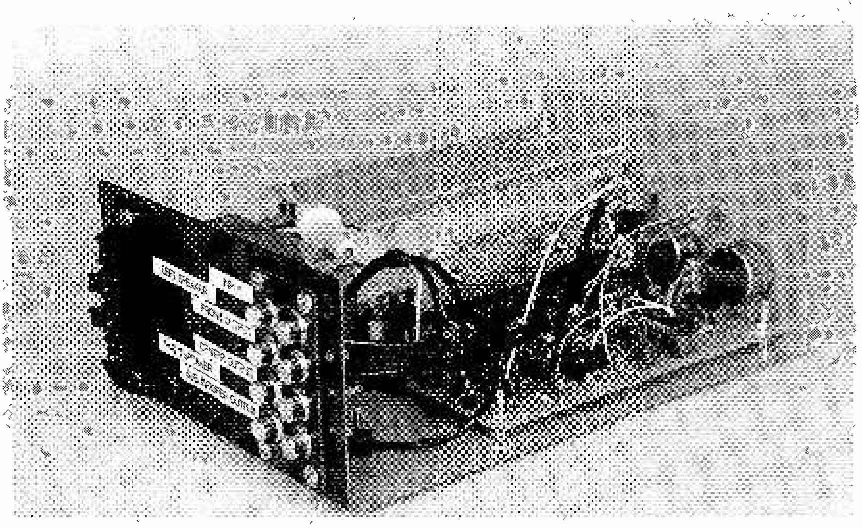


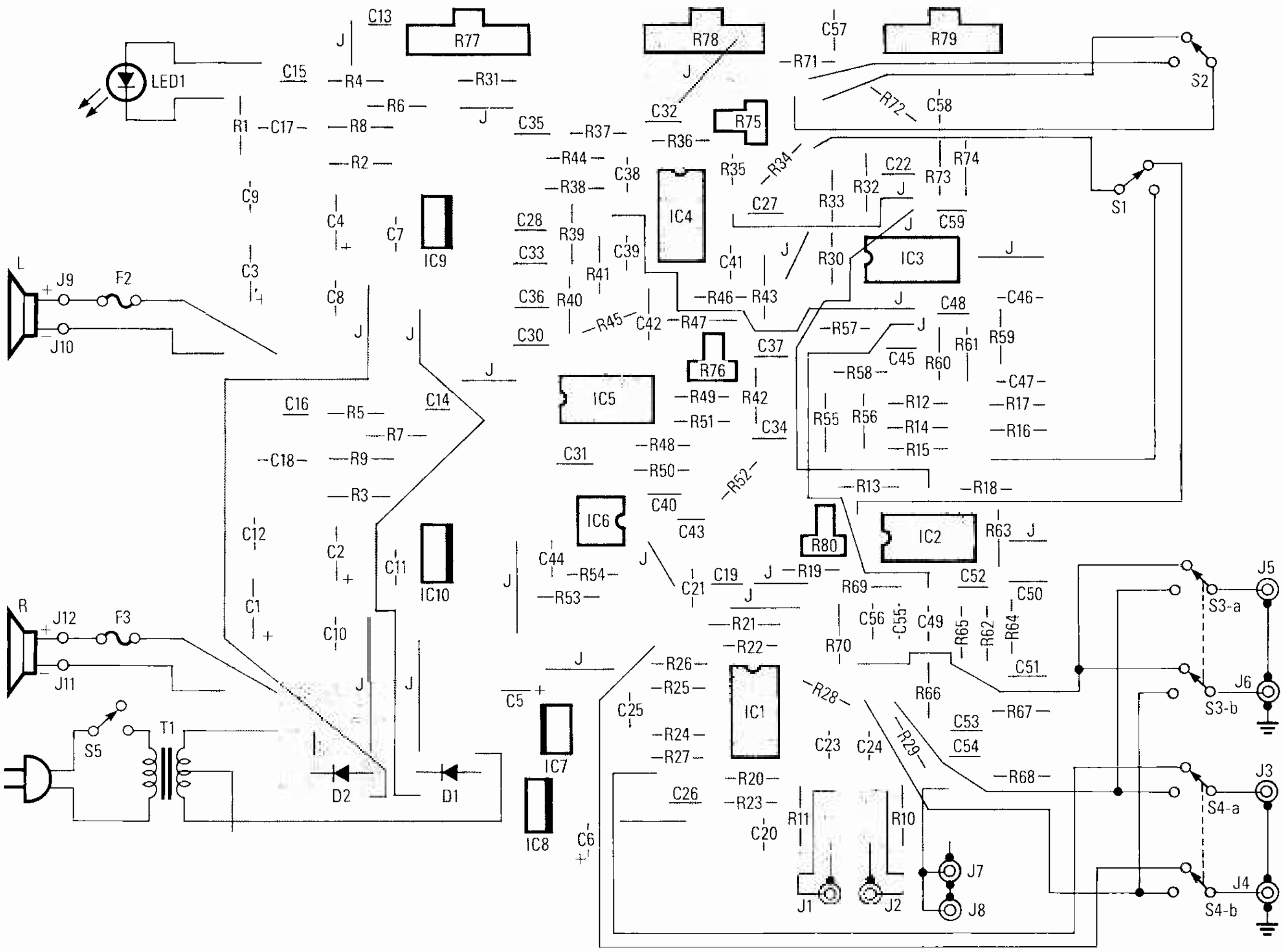
FIG. 8—THE PROTOTYPE ACOUSTIC FIELD GENERATOR. It's a tight fit in this cabinet, but it makes for a neater finished unit.

The surround channel power amplifiers of the AFG, shown in Fig. 6, are designed around a pair of LM1875 monolithic power-amplifier IC's. Chosen primarily because they require very few external parts to implement, and they also offer very low distortion, fast slew rate, wide power bandwidth, and the ability to deliver up to 20 watts into an 8-ohm load; all in a 5-pin TO-220 package. Because of limited heat-sink space in the AFG, we are running the LM1875 at about half of its power capability. The circuit configuration of the power amp is essentially the same as that of any ordinary op-amp operating in the inverting mode. Notice however, that there are two separate ground-return lines to the power supply. That is necessary because high currents flow through the output ground-return line. If a common ground-return line were used for both the input and output signal, those currents could develop enough voltage across the resistance of the return line itself to effectively act as an input signal to the amplifier, thus causing problems such as high-frequency oscillations or distortion.

The power supply of the AFG, shown in Fig. 7, is of conventional design. A 25 volt center-tapped transformer, along with diodes D1 and D2, produces about ±18-volts unregulated DC. Two 2200-μF filter capacitors are used in each leg of the supply to provide ample energy storage to meet the high-current demands of the audio output amplifier IC's during high output peaks. Integrated circuits IC7 and IC8 regulate the positive and negative supply rails to plus and minus 12 volts for use in the low signal level circuits. The plus and minus 12 and 18 volt rails are bypassed to ground by 0.1 μF capacitors distributed throughout the entire AFG circuitry. That keeps the impedance of the supply rails at audio frequencies as low as possible, thus reducing the interaction between circuits.

Construction

All of the electronic components are mounted on a single PC board as shown in Fig. 9. The board can be made using the foil pattern provided in PC Service or purchased from the source mentioned in the parts list. Only the power transformer, the input and output jacks, and the function switches are mounted off-board.



9—ALL OF THE COMPONENTS mount on a single PC board as shown.

The chassis shown is readily available, but it makes for a rather tight fit. If you plan to use a similar chassis, study the pictures of the prototype carefully before drilling. If you choose a different chassis, keep all the leads between jacks, switches, and the circuit board as short as possible. Locate the power transformer as far away from the circuit board as possible to avoid 60-Hz hum. If you must mount the transformer near the circuit board, wait until your unit is operational before you choose a final position for the transformer. Then, while listening, you can try the transformer in different positions until you find a location where there's no hum.

Begin stuffing the board by mounting all of the fixed resistors and the small potentiometers. Note that R35 and R69 are mounted upright. Next mount the IC sockets. Position each socket's pin 1 identifier so that it matches the small dot indicating pin 1 on the circuit board (do not insert the IC's into their sockets at this time). Next mount the capacitors. Please note where polyester and metal-film capacitors are called for in the parts list. *Do not* substitute ceramic capacitors; they perform poorly in audio circuits and their use will destroy the performance of the AFG. Also, don't substitute polarized electrolytic capacitors where bi-polar units are specified in the parts list.

Using some of the excess leads clipped from the capacitors, install bare jumpers where indicated, except for the six long jumpers. The two long jumpers in the audio power amplifier should be made from insulated heavy-gauge wire, as they carry relatively high current—no. 18 will do. The other four long jumpers in the decoder section should be made from lighter gauge insulated hookup wire.

Finish stuffing the circuit board by installing D1, D2, IC7–IC10, and the three large potentiometers, R77, R78, and R79. You can plug in the IC's now, but you should take static-electricity precautions with them.

Finish up the wiring between the PC-board pads and the switches, the input/output jack panel, the speaker terminal jacks, the power transformer, and the pilot LED. Use shielded cables for the leads to the input/output jacks. Try to keep all wiring as short and direct as possible to avoid crosstalk and hum. Use no. 18 or heavier wire for the speaker connections. To simplify construction, the prototype used inline fuse holders in the positive speaker leads and the power transformer primary circuit, as indicated in the schematics.

The power-supply regulator IC's are being operated very conservatively and thus do not require heat sinks. However, the LM1875T audio power amplifiers must *always* be operated with a heat sink. Failure to use a proper heat sink will cause the IC's to quickly overheat and possibly destroy themselves. Although they contain on-board circuitry to shut them down in case of overheating under normal operating conditions, it is best to leave fate untempted and refrain from operating the AFG until after the heat sink has been installed.

The heat sink used on the prototype was homemade from a 2- × 2- × 1/16-inch thick piece of aluminum angle stock cut 5¼-inches long and notched out in the front to fit over R77. If you use a commercially made heat sink, be sure that it provides about 8 to 10 square inches of surface area for each IC. Assuming that you are using a homemade heat sink like the one shown, temporarily position it so that the bottom edge is even with the bottom of the IC cases, or about 3/8" above the circuit board. Be sure that it does not touch D1. Mark the heat sink where the holes in the IC tabs fall and drill mounting holes at those points. In order to provide additional support, holes were also added at the top corners of the heat sink in line with the PC-board mounting holes. 3-inch screws with double sets of nuts were then used to mount the PC board as well as to hold the heat sink in place. Carefully examine the photographs that are shown in Fig. 10 to see how that was accomplished.

Because the metal tab of the LM1875T is not at ground potential, mica insulators and plastic shoulder washers must be used between the cases of the IC's and the heat sink. Use a small amount of silicone grease between the IC's and the heat sink to increase thermal conductivity. Make sure that the tabs of the IC's are actually insulated from the heat sink before operating the unit. Although adequate, the heat sink becomes moderately warm during operation, so be sure to provide good ventilation in your chassis.

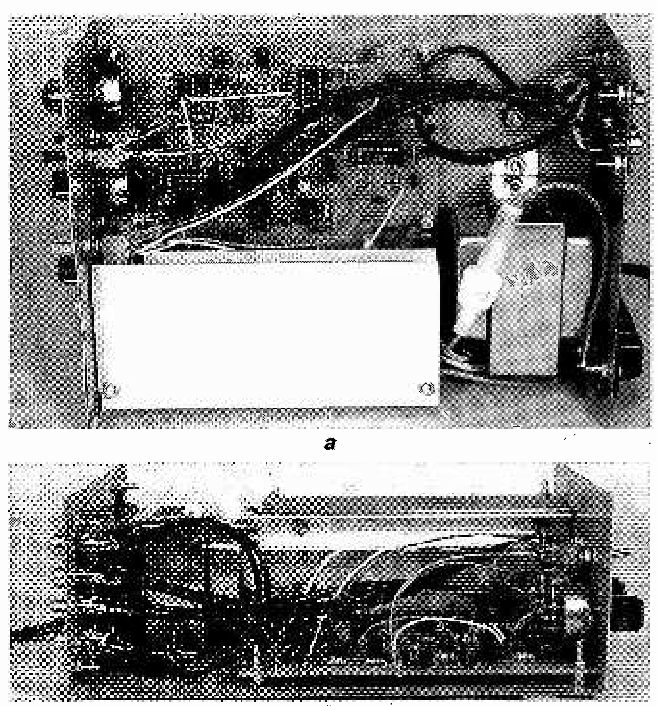
Setup and operation

Figure 11 shows one method of integrating the AFG into a home audio-video system. As mentioned earlier, a separate power amplifier is required for the subwoofer channel, in addition to the subwoofer speaker itself. In the setup in Fig. 11, the center channel is connected to the audio inputs of a monitor-style television receiver which has provisions for amplifying external line-level audio signals. If your TV set doesn't have audio inputs, or if you use the AFG in a music-only system, you'll have to provide a separate amplifier and speaker for the center channel as well. Please note that although the subwoofer-channel and center-channel speakers are a desirable part of any audio system, they are not absolutely necessary. The AFG may still be used as an excellent surround-channel decoder simply by adding a pair of small speakers for the surround channels.

The best place to patch the AFG into your system is between the preamplifier outputs and the power-amplifier inputs of your receiver or amplifier. Most component receiver/amplifiers allow for that connection by providing removable jumpers between the appropriate phono jacks on their rear panels. By placing the AFG in that loop, all the audio signals selected by the amplifier will also pass through the AFG. Furthermore, the volume and tone controls of the main amplifier will have control over all the levels in the system simultaneously; i.e. the subwoofer, surround speakers, and the center channel, as well as the regular left and right speakers. If your amplifier doesn't provide preamp out/main input jacks, you may still use the AFG by connecting it into a tape-monitor loop, or even more simply, to the audio output of a stereo VCR; but then you will have to adjust the levels of the subwoofer and surround channels independently of the main amplifier via the level controls on the AFG.

Calibration of the AFG is easy. Begin by setting, R75, R76, and R80 to their center positions. Now feed a mono signal into the AFG from some source in your system (an FM tuner switched to mono operation is a good choice). Set the balance control on your amplifier to its exact center mark. With the AFG switched to the matrix position (L − R), adjust R80 for the minimum output from the surround speakers. Now switch the receiver back to stereo and the AFG to concert (L + R). Adjust R76 for minimum distortion. R75 provides a means for matching the drive level of the AFG delay section to your system's normal audio levels. The BBD delay line has a maximum recommended input-signal level of 1.5 volts. To maximize the signal-to-noise ratio of the delay amplifier, the signal going into the delay line should be as high as possible without driving it into distortion. While using the highest normal level you are likely to feed the AFG, adjust R75 to obtain the maximum level that does not cause distortion.

The speakers you choose for the surround channels don't have to match your front-channel speakers in sonic characteristics. The frequency response of the surround channel is limited at the time of encoding to a bandwidth from approximately 100 Hz to 7 kHz by the Dolby process. Small bookshelf-style speakers



a

b

FIG. 10—THE HEAT SINK AND PC BOARD are installed as shown. Two 3-inch screws with double sets of nuts are used to mount the PC board on one side and hold the top of the heat sink in place (*a*). Two shorter screws hold down the other side of the board (*b*). Be sure to use spacers to prevent the board from touching the metal cabinet.

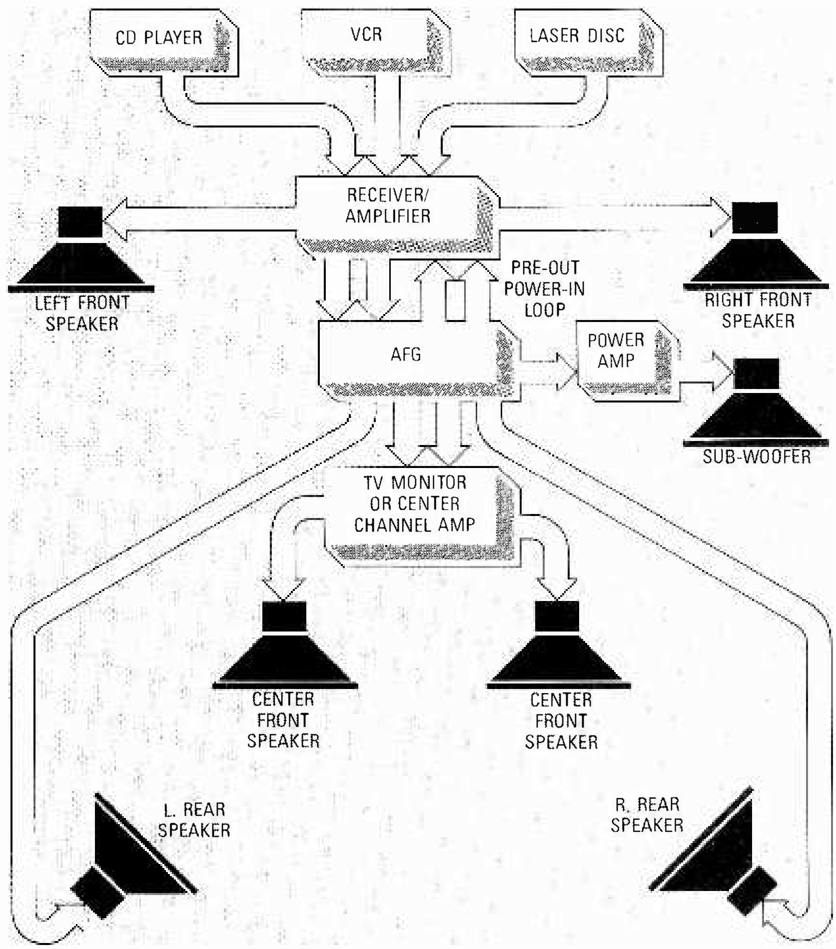


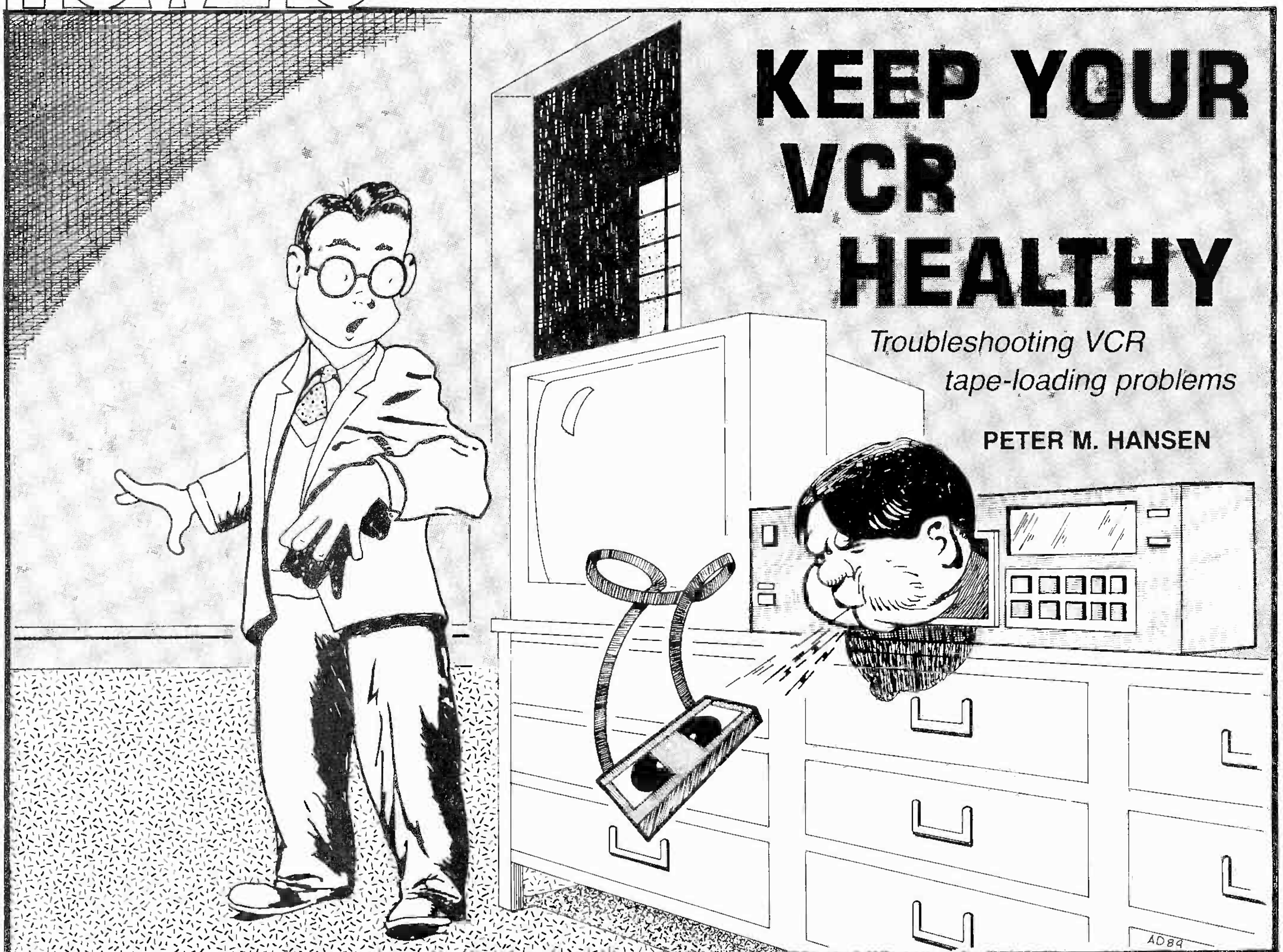
FIG. 11—HERE'S ONE METHOD OF INTEGRATING THE AFG into a home audio-video system. A separate power amplifier is required for the subwoofer channel, in addition to the subwoofer speaker itself.

mounted toward the rear of the room at ear level or slightly above are adequate. Although it is customary to use two speakers for the surround channel, one placed to the right rear and one to the left rear of the listening position, the surround channel signal that feeds those speakers is really monaural. The internal power amplifiers in the AFG drive the signal to the two rear speakers 180 degrees out of phase. That tends to spread apart the sound field created between the rear speakers. However, that may or may not sound well in your listening environment, depending on such things as speaker placement and actual listening position. You may restore the speakers to in-phase operation by simply reversing the leads connected to one of the speakers. Try setting up both ways to find which sounds better to you. Note that phase integrity is maintained through the AFG for the left, right, center, and subwoofer channels.

Actual level adjustment of the surround channels, center channel, and subwoofer is a subjective process. The source material itself, the listening area, and personal preferences for tonal balance must be taken into account. Use the AFG in the matrix and wide modes for surround-encoded movies. Use the concert mode to add ambience and depth to musical performances. Generally speaking, don't set the level of the surround channel so high as to make it overwhelming. The surround signal is intended to supplement the main channel, not to be a separate channel that is always equal in level to the front channel. That is particularly true for surround-encoded movies.

The delay of the surround signal can be adjusted via R77 from about 5 to 35 milliseconds. In matrix operation, delaying the surround signal tends to acoustically mask any leakage of front channel information into the surround channel. Setting R77 to the center provides a delay of approximately 20 milliseconds. **R-E**

HOW TO



KEEP YOUR VCR HEALTHY

Troubleshooting VCR tape-loading problems

PETER M. HANSEN

ONE OF THE MOST COMMON PROBLEMS found in VCR's is the inability to properly load a tape. Before you try to fix any VCR, though, you should be somewhat familiar with basic VCR disassembly skills and simple servicing precautions. You can learn about the various components inside a VCR by reading our last article on VCR maintenance (**Radio-Electronics**, March 1989). That article covered basic VCR mechanism identification, cleaning techniques, and the necessary hand tools.

Tape-load problems

It is important that you clearly understand the difference between cassette-loading problems and tape-loading problems. A cassette-loading problem is where the cassette carriage assembly does not properly accept the cassette (the shell) into the VCR. A tape-loading problem is when the tape is not properly extracted from the cassette once the cassette is fully seated inside the VCR.

Figure 1 shows the basic VCR components. You should be somewhat familiar with them before attempting any servicing, but right now our main concern is the tape-loading process. To be able to see the internal components, you first have to remove the VCR's top cover and head shield. You may also have to remove the cassette carriage in order to fully access the components involved in the tape-loading process. Figure 2 shows the cassette carriage being removed from a VCR—there are usually four Phillips-head screws on the top of the assembly that secure it to the VCR chassis. Figure 3 shows the cassette carriage assembly by itself. The gear block and motor assembly on the right side of the carriage is the drive system that is used in front-loading VCR's to load the cassette into the VCR when it is first inserted.

The VCR's guide rollers and slant poles are what actually extract the tape from the cassette and guide it across the video head/drum assembly. After you select play or record, you will see the two guide posts start the tape-extraction process; the video drum starts to spin counterclockwise (it reaches 30 rpm in about 3 seconds), and the pinch roller starts its short movement toward the capstan shaft. It is the action of the pinch roller "pinching" the rotating capstan shaft that actually pulls the tape through the machine during play or record.

Most recent VHS VCR's use a dedicated DC motor to load the tape across the video-drum assembly. The motor is located either above or below the mechanism, and is usually driven by an integrated circuit that receives the motor load and unload signals from the VCR's main microprocessor. Figure 4 shows a typical tape-load

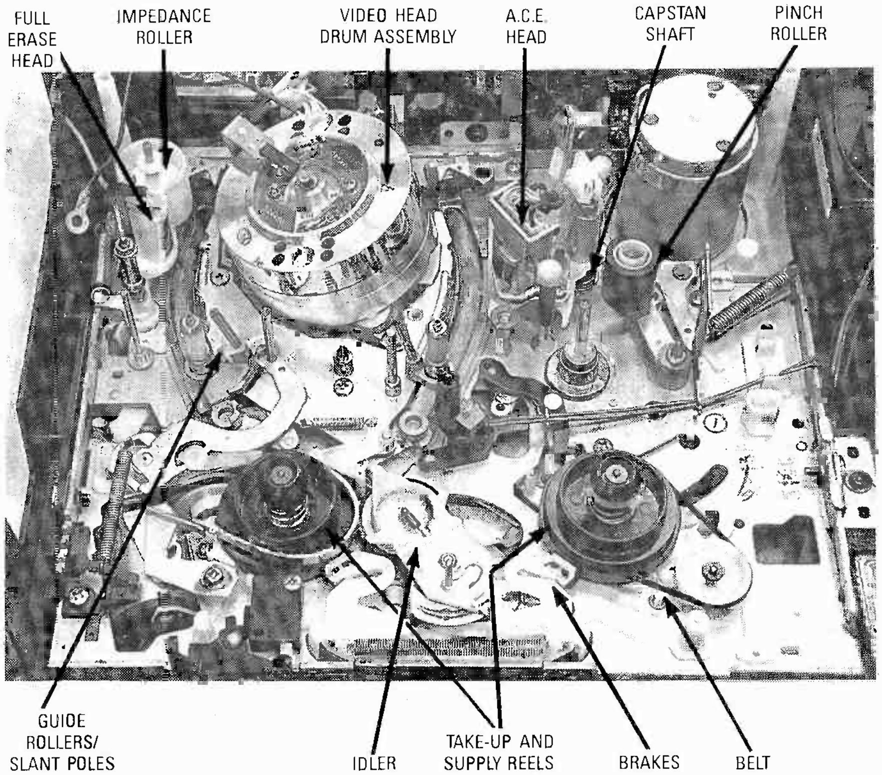


FIG. 1—MAJOR VCR COMPONENTS. You should be able to identify these basic mechanisms found in all VCR's.

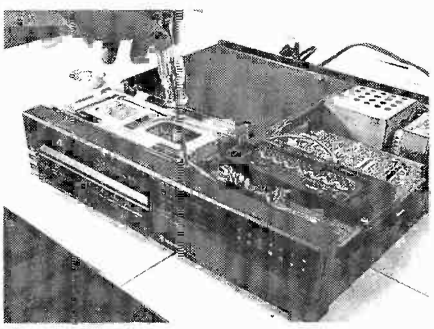


FIG. 2—THE CASSETTE CARRIAGE assembly is usually secured to the VCR chassis by four Phillips-head screws.

motor located on the bottom of the VCR's chassis; in this case, the unit is a later model Fisher VCR. In Fig. 5 we see a load motor that is located on the top of the mechanism, with the video drum behind it.

Tape-loading components

The load gear train is located (almost always) on the VCR's bottom side chassis. The load gear train is connected to the load motor via the load belt (or worm gear) and associated linkage rods and connectors. The load-gear assemblies are made out of hard plastic, and have one and sometimes two cam gears with grooves that contain a lubricant. Figure 6 shows a typical loading-gear train on the bottom side of the chassis.

To get at components on the underside of the chassis, first make sure that power is off and the unit is unplugged, and then remove the VCR's bottom plate. There are usually several Phillips screws securing the bottom plate to the chassis. Next, you have to identify the screws that secure the PC board to the chassis. Many times there will be identifying arrows printed on the PC board indicating which screws must be removed. If you remove the wrong ones, you may be dismantling the wrong thing.

In some VCR's, you must remove the front panel in order to release the PC board. Many times the front-panel assembly (which contains the switches, display, etc.) is secured to the chassis by small (fragile) plastic retaining tabs—give the unit a close visual inspection *before* attempting to remove it so that you don't crack anything! Remember that any mistake can cause you much grief—not to mention the added expense.

With the VCR placed in its service position (see Fig. 7), you can closely observe the loading components during a tape load. To do that, plug in the unit, insert an inexpensive test tape, and hit the play button. As soon as you hit play, you should see movement of the loading gear train as well as the the guide posts. On many units, you'll also see the cam gear as it shifts position from "stop" to "fully loaded." Sometimes a mirror placed on your workbench surface can help you see both sides of the VCR's loading mechanism simultaneously.

Diagnosing malfunctions

A very common malfunction in VCR's is cracked, dirty, or worn (slippery) load belts. The major symptom of that is that when the operator se-

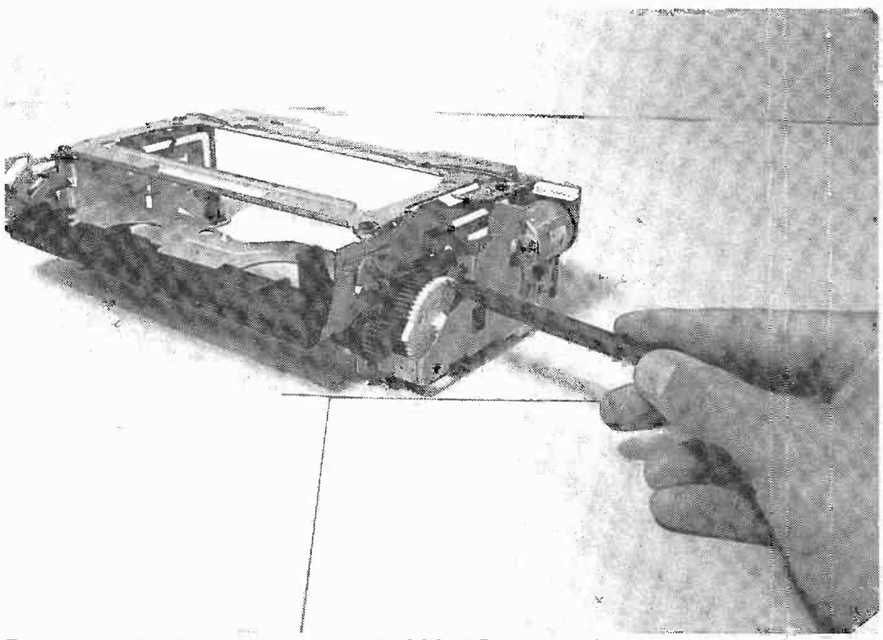


FIG. 3—THE GEAR BLOCK AND MOTOR ASSEMBLY on the right side of the carriage is the drive system that accepts the cassette into a front-loading VCR.

lects play or record, the guide posts will start their path toward the "V" stoppers (the metal brackets situated at the end of the loading grooves), but they will not reach the end of their path. Many times they will appear to have completed the load process, but closer inspection reveals that they only completed about 90% or 95% of the load process. The loading posts will then start retracting back toward the stop position and the video drum will stop spinning. Most of the time, that type of failure is due to a bad load belt.

Because the slipping load belt prevented the load posts from traveling their full distance, the microprocessor did not receive what's called the "load complete," the "after load," or, more simply, the "AL" signal. Some of the older units have a small microswitch embedded in the load gear train that is activated when the load posts are fully extended. However, most newer VCR's have infrared sensors built into the cam-gear assembly that transmit the various mechanical load stages during the tape-load mode to the microprocessor.

In an aborted tape-load attempt, you will also be able to see that the pinch roller does not come in contact with the capstan shaft. The pinch roller will come in contact with the capstan shaft only when the system microprocessor receives a load-complete signal.

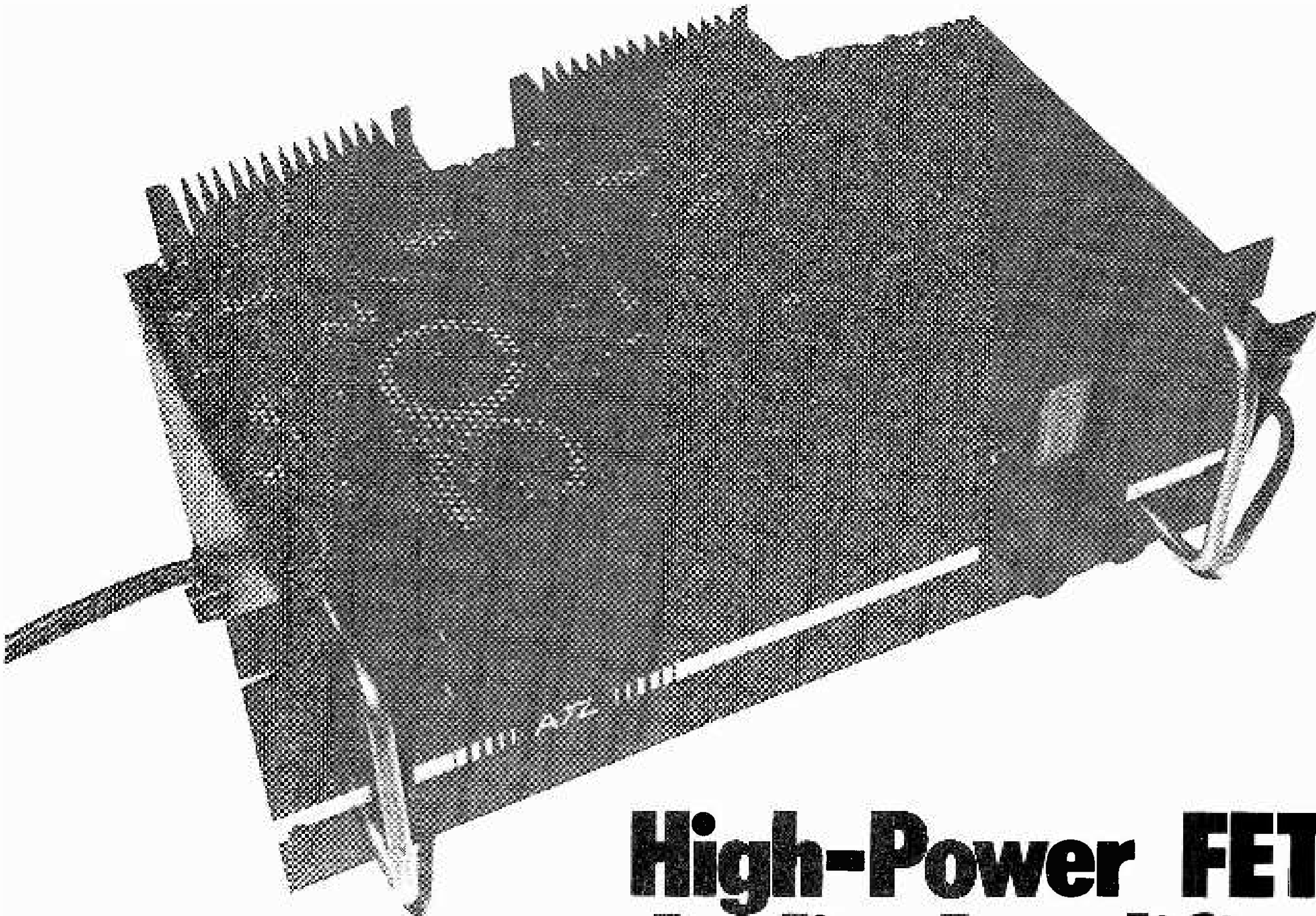
A simple test for a malfunctioning load belt is to "assist" the load process with your finger (see Fig. 8). With the VCR in its service position, and a tape inside the machine, select the play mode; you should have your index finger or thumb placed gently on the load-motor shaft. You will feel the rotation of the load motor shaft against your finger. Wait for the load process to be completed (when the load posts appear to have reached the end of their travel), and then "assist" the load process by manually turning the load motor shaft in the same direction as it was turning by itself. If the belt is bad, the action of your finger will most likely complete the load. The load-complete signal will now be received by the microprocessor, which will issue the signal to activate the pinch roller. A bad belt should be replaced, but sometimes you can extend its life a bit by cleaning the belt and applying some rubber revitalizer.

continued on page 164

FIG. 4—A TYPICAL LOAD MOTOR is located on the bottom side of the VCR's chassis.

FIG. 5—THIS LOAD MOTOR is located on top of the mechanism, with the video drum directly behind it.

Peter M. Hansen is the author of the *Viejo Method of VCR Maintenance and Repair* and president of Viejo Publications. The manual is available with or without the VCR-maintenance kit and training video. The kit contains VCR cleaning materials and an assortment of replacement belts, tires, idlers, etc. Contact Viejo Publications, 3540 Wilshire Blvd., Suite 310, Los Angeles, CA 90010. 1-800-537-0589.



High-Power FET Audio Amplifier

REINHARD METZ

Get high performance and high fidelity from this FET stereo amplifier. It feels equally at home in your living room or in a disco!

YOU'VE PROBABLY ALWAYS WANTED TO own a high-performance, high-power stereo amplifier. If you don't have one, there are two likely reasons why: You are not sure you need that much power and you are deterred by the cost. But these days, with the increasing popularity of digital audio disc players, there is a new motivation for owning a high-power amplifier that can faithfully reproduce a wide dynamic range without distortion. And while the cost of commercial high-power amplifiers is still high, we'll describe a very high-performance design that you can build at a reasonable cost. Just what do we mean by "high performance?" Table 1 summarizes the characteristics of our design.

One of the most important features of the design is the use of power MOSFET output transistors in a complementary configuration. Those transistors, by themselves, eliminate a number of the problems usually associated with their bipolar counterparts.

The highly desirable characteristics of power MOSFET's for audio amplifiers have been recognized for a few years. However, for many years only N-channel devices were available—only recently have their P-channel counterparts appeared at reasonable prices, making it possible to design amplifiers with remarkable performance but little complexity.

As we'll see shortly, MOSFET's aren't the only transistors used in the amplifier. Ahead of the output stage, a fully complementary bipolar design combines simplicity with high performance.

Why MOSFET's?

Although the evolution of power MOSFET's has primarily been (and still is) fueled by power-supply applications, there are a couple of reasons why MOSFET's make ideal devices for audio-amplifier output stages. First, they allow the design of amplifiers with very wide bandwidths, high slew rates, low distortion, and straightforward simplicity. Also, MOSFET's lack a secondary-breakdown mechanism. (Secondary breakdown in bipolar devices is a localized heating effect in which "hot spots" develop under high-current conditions. A hot spot then conducts even more current, creating more heat, which, in a positive-feedback manner, may lead to a catastrophic destruction of the device.)

Because of secondary breakdown, bipolar devices must be operated within a "safe" area that often falls far short of the device's stated static current and power-dissipation characteristics. Safe-operation-area limiter circuits (whose misoperation has often been notorious) must be used in bipolar circuits. Because MOSFET's do not exhibit secondary breakdown, simpler and more reliable designs can be used.

The characteristics of the MOSFET's used in this amplifier are shown in Fig. 1. They are, of course, voltage-controlled devices. When the gate-to-source voltage, V_{GS}, drops below about 3.5 volts, the drain-to-source current, I_D, quickly drops

TABLE 1—SPECIFICATIONS

Power output:
250 watts/channel into
a 4- or 8-ohm load

Frequency response (−3dB):
5 Hz to 1.1 MHz @ 1 watt
5 Hz to 330 kHz @ 250 watts

Distortion:
< 0.05% IM to 250 watts
< 0.05% THD 20 Hz–20 kHz

Signal-to-noise ratio:
> 100 dB

Damping factor:
> 500 to 1 kHz with 8-ohm load

Risetime:
< 0.5 μs @ 80 volts P-P

Slew rate:
> 160 volts/μs

to zero. That is called the *gate threshold voltage*, V_T. Above V_T, the *transconductance* (or transfer admittance) builds up to an asymptotic value, averaging about 3 amps of drain current per volt increase in gate-to-source voltage, V_{GS}. (Measured with V_{DS} constant, $\Delta I_D/\Delta V_{GS}$ = 3 siemens)

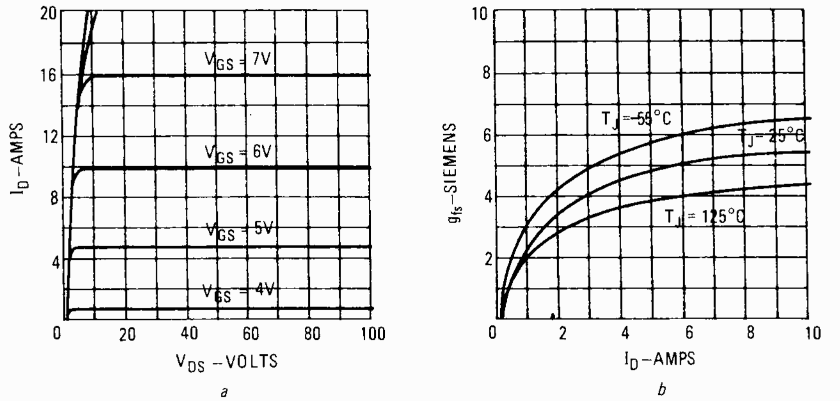


FIG. 1—MOSFET CHARACTERISTICS. Shown in *a* are the typical output characteristics of the IRF630. Shown in *b* is the typical transconductance as a function of drain current for the same device.

A look at the circuit

The stereo power amplifier consists of four main stages: input, voltage-amplifier, inverter/driver, and output. Since the MOSFET outputs are the center of attraction, we'll begin there and work our way backward. The amplifier schematic (for one amplifier channel) is shown in Fig. 2.

Transistors Q21 through Q28 are the N- and P-channel MOSFET power output transistors. Each one is capable of contributing a minimum of 6 amps of the output current for peak current requirements. Since the output transistors are in a common-source configuration, the output stage can have voltage gain, and the transistors must be biased with respect to the supply rails. The major advantage of that approach is that the bipolar driver-stage does not have to swing very much voltage, but the outputs may swing from rail to rail. (A common-drain output stage would require the driver to swing the entire output-voltage range which, with bias, would mean that either a pair of separate higher-voltage supplies would be required for the drivers, or that the output would not swing from rail to rail. That would make the stage operate far less efficiently.) The relatively high gate-capaci-

PARTS LIST

All resistors ¼-watt, 1% unless otherwise indicated. (5% types—values shown in parenthesis—can be substituted

R1—10,000 ohms, audio-taper potentiometer
R2—2050 (2000) ohms
R3, R4, R13, R14—10,500 (10,000) ohms
R5, R6, R11, R12, R22—100 ohms
R7—2490 (2400) ohms
R8—500 ohms, potentiometer
R9—2470 (2700) ohms
R10, R29—100,000 ohms
R15, R16—1000 ohms, 2 watts
R17, R18—1000 ohms
R19—5000 ohms, 10-turn potentiometer
R20—8660 (8200) ohms
R21—1500 ohms, 2 watts
R23–R26—511 (510) ohms
R27, R28—2000 ohms, 5 watts
R30—50 (47) ohms
R31–R38—24.9 (24) ohms
R39—162 (160) ohms
R40—5110 (5100) ohms, ½ watt
R41—4.64 (4.7) ohms
R42—4.64 (4.7 or 5) ohms, 10 watts

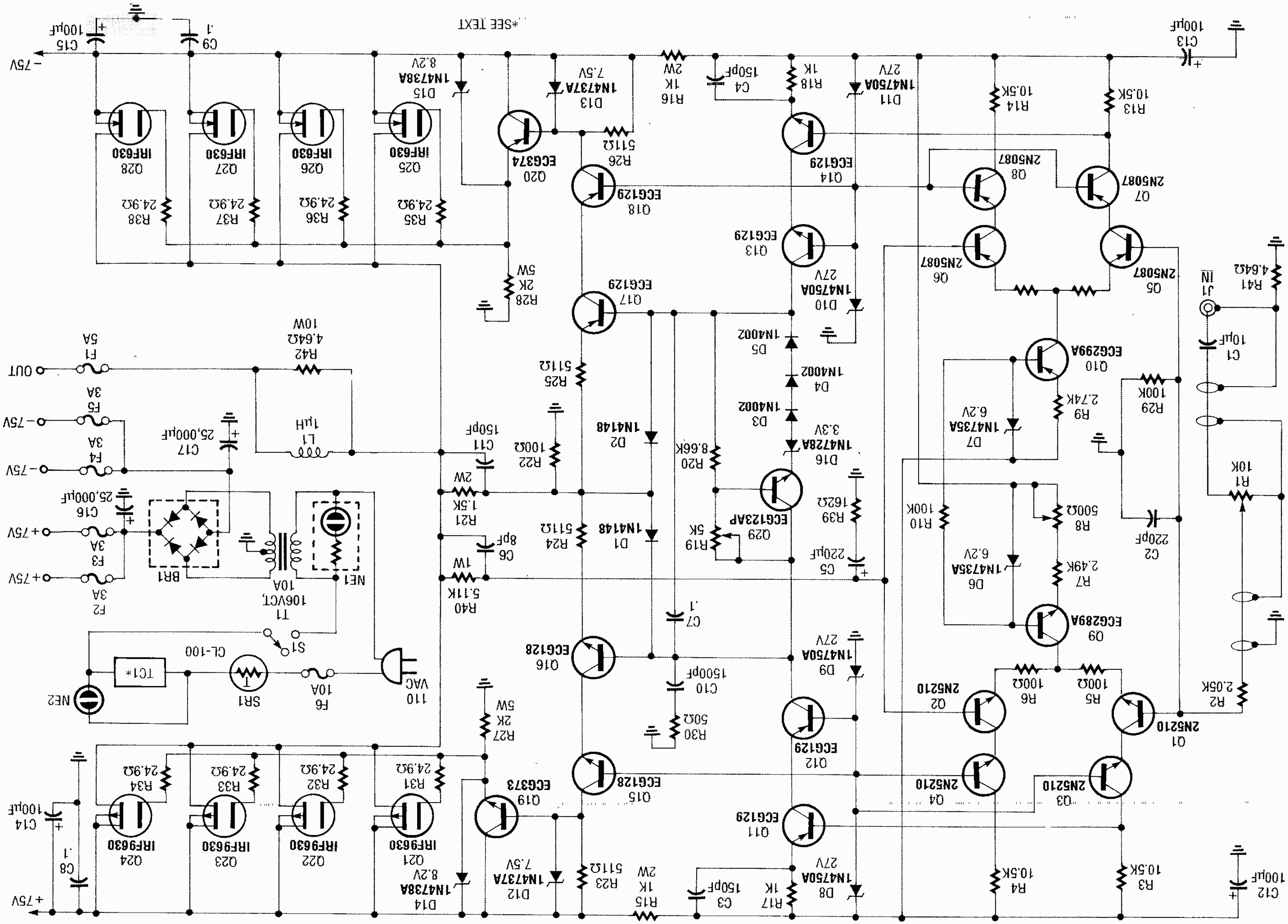
Capacitors
C1—10 μF, Mylar film
C2—220 pF, ceramic disc
C3, C4, C11—150 pF, ceramic disc
C5—220 μF, 63 volts, electrolytic
C6—8 pF, ceramic disc
C7—0.1 μF, 50 volts ceramic disc
C8, C9—0.1 μF, 100 volts, ceramic disc
C10—1500 pF, 50 volts, ceramic disc
C12–C15—100 μF, 100 volts, electrolytic
C16, C17— 25,000 μF, 75 volts, electrolytic (Sprague 253G075CF2A or similar)

Semiconductors
Q1–Q4—2N5210
Q5–Q8—2N5087
Q9—ECG289A or NTE289A
Q10—ECG290A or NTE290A
Q11, Q12, Q17, Q18—ECG129 or NTE129
Q13-Q16—ECG128 or NTE128
Q19—ECG373 or NTE373
Q20—ECG374 or NTE374
Q21-Q24—IRF9630
Q25-Q28—IRF630
Q29—ECG123AP or NTE123AP
BR1—25 amps, 400 PIV bridge rectifier
D1, D2—1N4148
D3–D5—1N4002
D6, D7, D21—1N4735A 6.2 volts, 1 watt, Zener
D8–D11, D23—1N4750A 27 volts, 1 watt, Zener
D12, D13—1N4737A, 7.5 volts, 1 watt Zener
D14, D15—1N4738A 8.2 volts, 1 watt Zener
D16—1N4728A 3.3 volts, 1 watt Zener

Other components
L1—1 μH (15 turns of No. 16 wire wound on R42—see text)
NE1, NE2—Neon bulbs with 100K series resistors.
F1—5 amps, fast-blow fuse
F2–F5—6 amps, fast-blow fuse
F6—10 amps, fast-blow fuse
T1—106 volts, center-tapped power transformer
S1—SPST power switch
J1—Phono jack for input

Miscellaneous
Heat Sinks, Wakefield 512 series, 2×7 inches or equivalent; TO-5 heat sinks for Q12, Q13, Q15, and Q18; chassis; handles; fuse holders; capacitor clamps; power cord; input jacks; binding posts; wire; hardware; insulators, etc.

The following items are available from A&T Labs, Box 552, Warrenville, Illinois, 60555: Etched, drilled, plated-through PC boards, $25 each; Power transformer, $74 each; Set of 8 matched power FET's, $48, Drilled heatsink (type 512), $42. Add 5% shipping and handling, 12% for transformer. Illinois residents include 6.75% sales tax. Outside of U.S.A., add 5% extra for shipping.



+75V
C14 100μF
C8 .1
Q24 IRF9630
R34 24.9Ω
Q23 IRF9630
R33 24.9Ω
Q22 IRF9630
R32 24.9Ω
Q21 IRF9630
R31 24.9Ω
D14 1N4738A 8.2V
D12 1N4737A 7.5V
Q19 ECG373
R27 2K 5W
R23 511Ω
Q15 ECG128
Q16 ECG128
R15 1K 2W
C3 150pF
R17 1K
Q11 ECG129
D8 1N4750A 27V
Q12 ECG129
D9 1N4750A 27V
Q4 2N5210
Q2 2N5210
Q3 2N5210
Q1 2N5210
R4 10.5K
R3 10.5K
R6 100Ω
R5 100Ω
R2 2.05K
C12 100μF
NE2
TC1*
SR1
CL-100
S1
F6 10A
110 VAC
T1 106VCT, 10A
NE1
BR1
F2 3A
+75V
F3 3A
+75V
C16 25,000μF
C17 25,000μF
F4 3A
−75V
F5 3A
−75V
F1 5A
OUT
L1 1μH
R42 4.64Ω 10W
R40 5.11K 1W
C6 8pF
R21 1.5K 2W
C11 150pF
R22 100Ω
R24 511Ω
R25 511Ω
D1 1N4148
D2 1N4148
R30 50Ω
C10 1500pF
C7 .1
R19 5K
R20 8.66K
Q29 ECG123AP
D3 1N4002
D5 1N4002
D4 1N4002
D16 1N4728A 3.3V
C5 220μF
R39 162Ω
R10 100K
D6 1N4735A 6.2V
D7 1N4735A 6.2V
Q9 ECG289A
R7 2.49K
R8 500Ω
R9 2.74K
Q10 ECG299A
C2 220pF
R29 100K
R1 10K
C1 10μF
J1 IN
R41 4.64Ω
Q17 ECG129
Q18 ECG129
Q13 ECG129
Q14 ECG129
D10 1N4750A 27V
D11 1N4750A 27V
Q6 2N5087
Q8 2N5087
Q5 2N5087
Q7 2N5087
R14 10.5K
R13 10.5K
C13 100μF
R18 1K
C4 150pF
R16 1K 2W
R26 511Ω
D13 1N4737A 7.5V
Q20 ECG374
R28 2K 5W
D15 1N4738A 8.2V
Q25 IRF630
R35 24.9Ω
Q26 IRF630
R36 24.9Ω
Q27 IRF630
R37 24.9Ω
Q28 IRF630
R38 24.9Ω
C9 .1
C15 100μF
−75V
*SEE TEXT

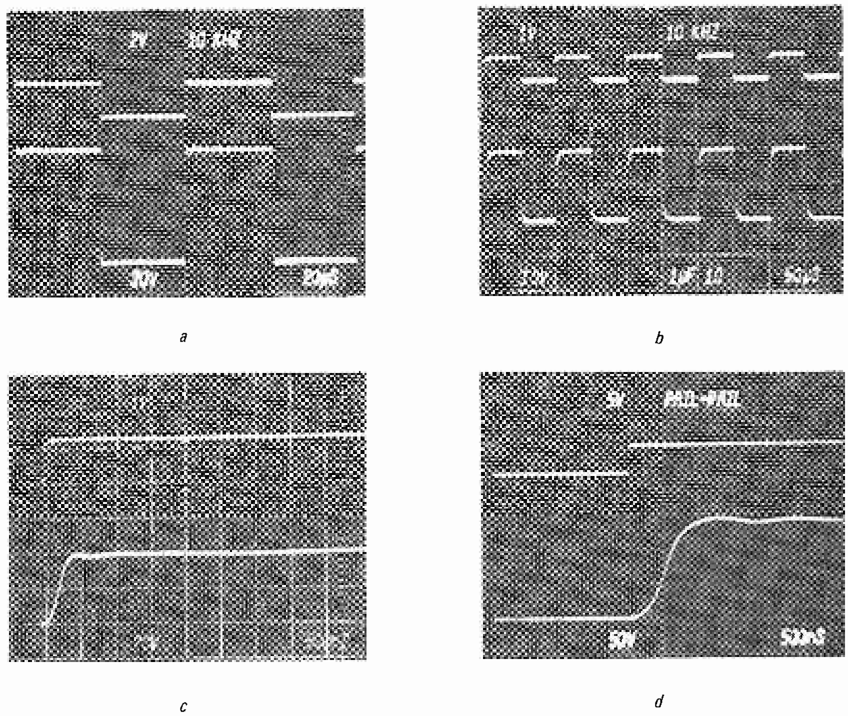


FIG. 3—AMPLIFIER RESPONSE CHARACTERISTICS. *A* shows the response to a 10-kHz squarewave input at 150 watts into an 8-ohm load, while *b* shows the response into a 1-ohm, 1µF load. Shown in *c* and *d* are the step responses at 50 watts and full output, respectively (both with input filter C2 removed). Note the excellent slew-rate and risetime capabilities.

tance of the power MOSFET's is also somewhat easier to drive in the common-source configuration.

Resistors R31 through R38 help to suppress the parasitic oscillations that might otherwise occur with the extremely fast transistors used. Zener diodes D14 and D15 limit the amount of drive available to the output. Finally, L1 and R42 serve to isolate the amplifier output from capacitive loads at very high frequencies.

The inverter/driver stage consists of Q15 through Q20. Its purpose is to deliver bias and drive signals to the FET output stage. Their basic requirement is to sit at about 3.5 volts with respect to the source, increasing about .3 volt per ampere of output current. Transistor Q29 forms a conventional voltage multiplier, which, in this case, multiplies the voltage across D3, D4, and D5 and D16 to about 7 volts. The 7-volt bias is presented to the bases of Q16 and Q17, which form the bottom transistors of a pair of complementary cascode amplifiers.

An output-stage gain of 10 is set by R21, R22, R25, and R26. Therefore, the voltage generated by Q29 is split in half and reflected up against the two supply rails as a pair of bias voltages across R23 and R26. Those voltages, along with the AC drive-signals from the previous stage, are passed along to emitter followers Q19 and Q20, which have the high-current drive capacity required by the gate capacitance of the output devices. Using cascode stages here, as well as in the input and voltage-gain sections, serves the dual purpose of splitting the emitter-collector voltage and power drops among two transistors per rail, while increasing the open-loop frequency response of the amplifier.

The voltage-gain stage consists of transistors Q11 through Q14, again configured as complementary cascode amplifiers. The collector loads for Q12 and Q13 are essentially the input impedance of Q16 and Q17. That is in the neighborhood of 50K, leading to a stage gain of about 50 (the quotient of 50K and R17 or R18). Capacitors C3 and C4 increase the frequency response of the stage. Zener diodes D8, D9, D10 and D11 set the base voltages for the upper transistors in the cascodes.

Now we'll look at the input stage, which consists of Q1 through Q8. Those transistors are connected as complementary-cascode differential amplifiers, supplied by current-sources Q9 and Q10. The gain is set at about 100 by the ratios of R3 to R5 and R13 to R11.

Resistor R8 is used to zero the output voltage by varying the collector currents of Q1–Q4, compensating for any V_{BE} offsets that may exist in Q1,Q2, Q5, and Q6. That is important, because with an extremely low output-impedance such as this amplifier has, even very low output offsets (in the tens of millivolts) can deliver many amps into a short.

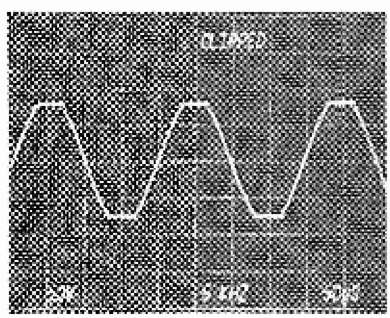


FIG. 4—FULL-POWER OUTPUT with a 5-kHz sinewave input. Note the clipping level is about ±75 volts.

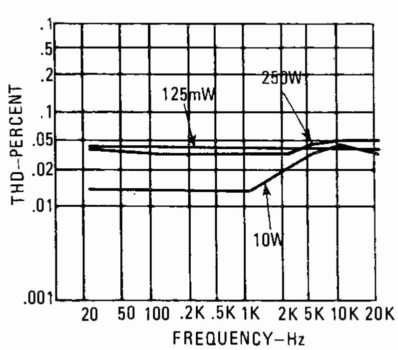


FIG. 5—TOTAL HARMONIC DISTORTION (THD) at 1 kHz.

The overall voltage-gain of the amplifier is set at about 30 by the ratio of R40 to R39. A 3-dB rolloff is set at about 3 Hz by C5. High-frequency compensation is provided by C10, R30, C6, and C11.

Some optional components are shown in the schematic, notably in the power-supply section. First, there is TC1, the thermal cutout made by Elmwood sensors (1655 Elmwood Ave., Cranston, RI 02907). It is normally closed, and opens at 70°C. Another optional component is SR1, an inrush limiter made by Keystone (Thermistor Div., St Marys, PA 15857). For home applications, those shouldn't be necessary. However, if you plan to run the amplifier continuously at high power (in a disco, for example), you should include all the protection you can.

Amplifier performance

Some of the response characteristics of the amplifier are shown in the oscilloscope photographs in Fig. 3. For example, in Fig. 3-a we see the response to a 10-kHz squarewave at 150 watts into 8 ohms. Figure 3-b shows the response with a 1-ohm, 1-µF load. Figures 3-c and 3-d show the step response at 50 watts and full output, respectively. (Those two risetime tests were made with input-filter capacitor C2 removed.) Figure 4 shows the full-power output with a 5-kHz sinewave input. Figure 5 shows the total harmonic distortion from less than 1 watt to 250 watts at 1 kHz.

Building the amplifier

It is essential that a printed-circuit board be used for the amplifier. Figures 6 and 7 show foil patterns for the component and solder side respectively. Note that one board is required for each channel. If you don't want to etch your own boards,

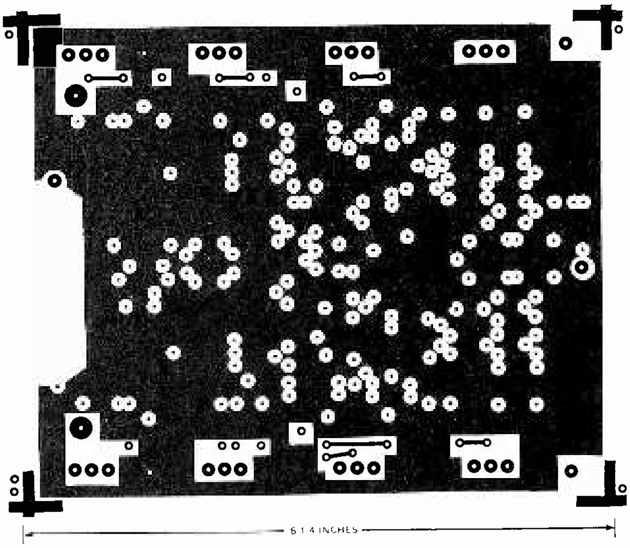


FIG. 6—THE COMPONENT SIDE of the amplifier board is mainly used as a ground plane.

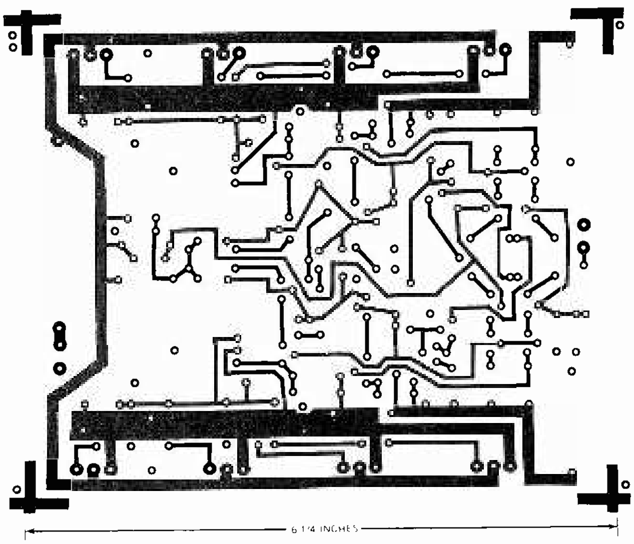


FIG. 7—THE SOLDER SIDE of the amplifier board. Remember that you need one board for each channel.

etched, pre-drilled, and plated-through boards are available; see the Parts List for information. If you *do* want to etch your own boards from the patterns shown, keep in mind that the board uses plated-through holes. You can, of course, get around that by soldering some of the components, including the output transistors, on both sides of the board. Note that the wiring to the output transistors is incorporated in the PC-board layout. That keeps the wire lengths to the output devices to a minimum. (It also simplifies construction by eliminating 48 wires, reducing the chance of error in that particularly critical area!)

Before we begin with the construction details, we should point out that the values shown in the schematic are for 1%-tolerance resistors. For most applications, it is not essential that you use such parts. Thus, the parts list also shows acceptable values for 5%-tolerance resistors. (One source for 1% resistors is Digi-Key Corporation, Highway 32 South, P.O. Box 667, Theif River Falls, MN 56701.)

Once you have your boards and components, you can begin construction by referring to the parts-placement diagram in Fig. 8 and by installing the fixed resistors. Check the values with an ohmmeter as you go, and be sure that the leads are sufficiently far from the ground plane!

Next, install capacitors, carefully checking values and ensuring that the polarized electrolytic types are properly oriented. Follow by installing the diodes, except for D3–D5. (Those three diodes mount on the output-transistor heat sink, and should not be installed yet.) Again, be careful of the polarity—the diode band indicates the cathode. Next, install the transistors (except for the output transistors Q21–Q28). Transistors Q19 and Q20 should be mounted with insulators and heatsink compound. (If you look closely at Fig. 9, you'll see some heatsink compound around those transistors.) Transistors Q12, Q13, Q15, and Q18 use TO-5-type heat sinks.

Adjust potentiometers R8 and R19 to their middle positions and install. (For R19, which is a multiturn potentiometer, you will need to use an ohmmeter.) You will have to make L1: Wind 15 turns of 16-gauge magnet wire on R42. Solder to the leads of R42, and install the assembly. The PC boards are now complete.

Preparing the heat sink

The Wakefield heat sinks that are used for the output transistors (see Fig. 10) were not chosen arbitrarily. Their design is almost 100% more efficient for natural convection applications than conventional designs of equivalent volume.

You can use other heat sinks but a minimum surface area of 800 square inches per channel is required. A flat-backed heat sink is desirable for the TO-220 package, but is not essential.

The Wakefield type 512 is available in a 14-inch long extrusion, which needs to be cut in half to yield the two 7-inch pieces called for. After you cut it, drill holes for the output transistors according to the layout shown in Fig. 11. To keep the transistor-mounting hardware to a minimum, you might want to drill and tap the heat sink. However, screws with nuts may also be used. The optional over-temperature sensor and thermal-compensating diodes D3–D5 should also be glued to the heat sink as shown in Fig. 11.

If you have a confined-space application, you can mount the two heat sinks back to back; they will then readily accept a muffin fan for forced convection. For home applications, however, we recommend natural convection—to eliminate the noise, filter, and/or temperature-sensing aspects typically associated with fans. We should make a final note that wiring length should be kept to a minimum, with less than 2 inches from transistor to PC board. Even with that length, a ferrite bead is necessary on each gate lead, and using coaxial cable is recommended.

Preparing the chassis

The design and construction of a chassis for the amplifier is not critical. The author's prototype was built with rack mounting in mind. It consists of an 8 × 17 inch bottom plate with 1 inch turned up at the front and back. The front plate is 19 × 17 inches. As shown in Fig. 10, the two heat sinks mount on the back of the unit, leaving a 2½ × 7-inch strip for a small plate where the input and output jacks and fuses are mounted. Finally, an 8¼ × 31-inch U-shaped piece of perforated metal makes up the cover.

Begin mounting the components with the transformer, bridge rectifier, filter capacitors, and fuse-holders. Then, mount the power switch, pilot lights, and level

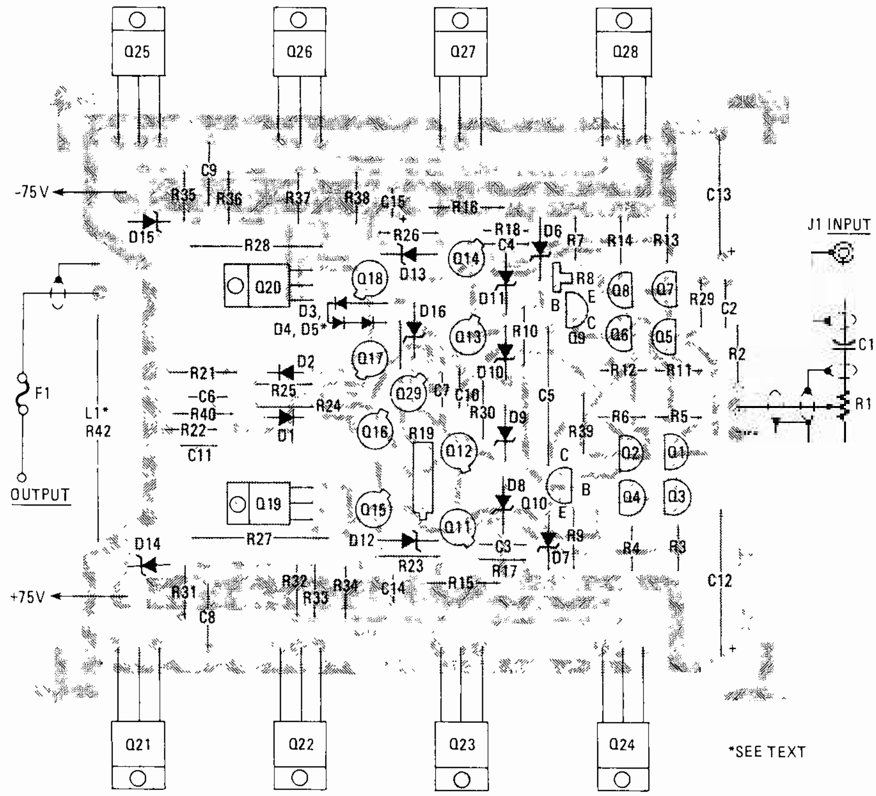


FIG. 8—PARTS-PLACEMENT DIAGRAM for the amplifier board. Refer to the text for information on mounting the output transistors (Q21-Q28) on a heat sink. Note that the pin labels for Q9 and Q10 are correct, but do not correspond to the package outlines shown. Be careful when installing them.

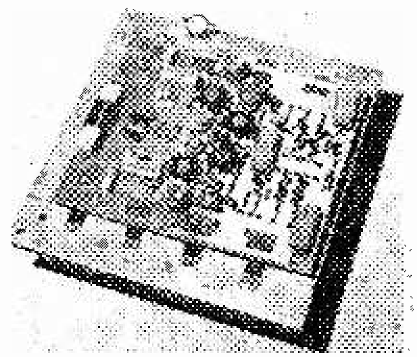


FIG. 9—AMPLIFIER BOARD is shown here mounted on heat sink. Note that Q12, Q13, Q15, and Q18 use TO-5 type heat sinks.

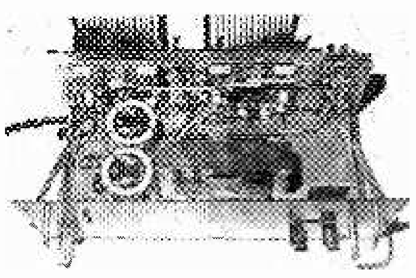


FIG. 10—COMPLETE STEREO AMPLIFIER with cover removed. The chassis configuration is not at all critical.

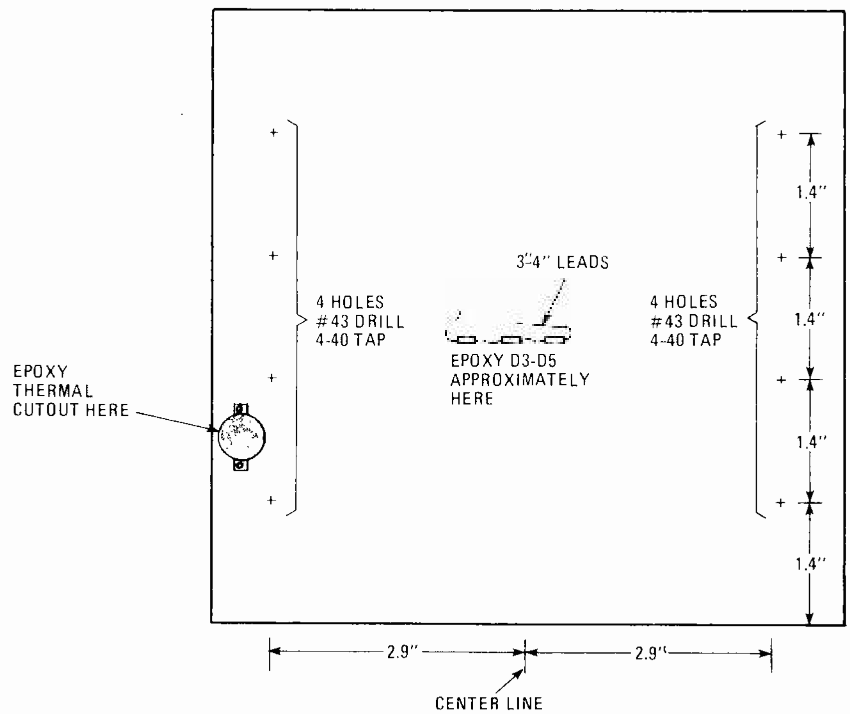


FIG. 11—HEAT-SINK DRILLING GUIDE. Note that some parts are fastened with epoxy to the heat sink.

controls on the front panel.

Next you'll have to make up a suitable mounting plate and install output jacks that are insulated from their mountings. Install the input-fuse holder and the power cord with a strain relief. Then wire the transformer primary and secondary as shown in the schematic. If you plan to use the optional thermal cutouts, leave a pair of wires to go to the heat-sink area. Use 18-gauge (minimum!) wire in the power supply. We recommend that you use some simple color code for the DC wiring—it will help reduce the possibility of errors during subsequent tests.

Locate a suitable single-point ground, such as a screw through the bottom of the chassis near the power supply, and attach the filter capacitors' common power-supply ground to it. If you use a 3-wire power cord, do not ground or terminate the cord's ground lead.

Checkout procedures

The amplifier checkout is by far the most important part of building this amplifier, so, shift into low gear and **proceed with great care through the following steps!**

First we strongly advise you to make a final visual check of all parts placements on the circuit boards and the power-supply wiring. Then, before applying any power, measure each supply terminal with an ohmmeter to ground. An initial low reading should slowly move up to high resistance as the capacitors charge. Install the main power fuse and, with the DC fuses F2–F5 not installed, apply power. Check the two supplies for ± 75 volts. Remove power, and discharge the filter capacitors through a 1K resistor.

Next, install a pair of ¼-amp fuses for F2 and F4. Measure the resistance from each power-supply input to ground on both driver boards. The reading should be greater than 100K. If it is, temporarily connect one board to F2, F4 and ground. Connect a clip-lead from the collector of Q4 to the collector of Q3. Connect another clip-lead from the collector of O7 to the collector of Q8. Temporarily clip-lead D3, D4, and D5 into the circuit. Apply power, and measure the voltage between the bases of Q16 and Q17. It should be near 7 volts. Adjust R19, and observe this voltage changing. Leave it at 6.8 volts. Measure the voltage from the emitter of Q19 to the +75-volt supply, and the voltage from the emitter of Q20 to the −75-volt supply. The sum of the two voltages should be about 6.5 volts. Remove power, discharge the filter capacitors, remove clip leads, and repeat with the other driver board.

Next, solder the output transistors to the driver board. Note that it is important that the transistors be matched (within each particular type) so that they will share the output current equally. A simple circuit for checking the matching is shown

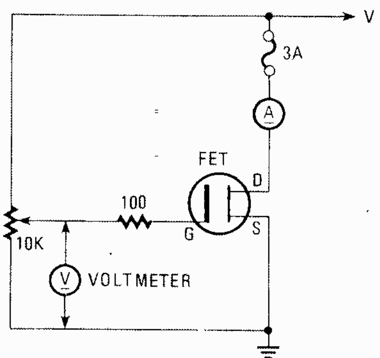


FIG. 12—TO CHECK THE MATCHING OF TRANSISTORS, you might want to use this simple circuit. Start by setting the potentiometer's wiper voltage to zero. Then turn it up to the desired drain current and measure the voltage as shown. For N-channel devices (IRF630), V should be +5 volts. For P-channel devices (IRF9630), V should be −5 volts.

PARTS LIST—BARGRAPH DISPLAY and CLIPPING INDICATORS

All resistors are ¼ watt, 5%, unless otherwise specified.

R43—24,000 ohms
R44, R46, R53—12,000 ohms
R45, R52, R70—22,000 ohms
R47, R54—1000 ohms
R48, R55—470,000 ohms
R49, R51, R58, R59, R61, R62—10,000 ohms
R50, R56—150 ohms
R57, R60—53,000 ohms
R63, R65—1200 ohms
R64, R66—7500 ohms
R67—350 ohms, 20 watts
R68—15,000 ohms
R69—2200 ohms, 5 watts

Capacitors

C18, C19—1 µF, 10 volts, electrolytic
C20—2.2 µF, 10 volts, electrolytic

Semiconductors

IC1—LM139 Quad op-amp
Q30—ECG291
D17, D18—1N4001
D19, D20—1N4741A 11 volts, 1-watt, Zener
D21—1N4735A 6.2 volts, 1 watt, Zener
D22—1N4744A 15 volts, 1 watt Zener
D23—1N4750A 27 volts, 1 watt, Zener
LED1, LED2—Standard red LED
DISP1, DISP2—NSM39158 logarithmic bargraph display with driver (National)

Other components

S2, S3—SPDT

The following items are available from A&T Labs, Box 552, Warrenville, Illinois, 60555: Etched, drilled, plated-through PC boards, $25 each; Power transformer, $74 each; Set of 8 matched power FET's, $48; Drilled heatsink (Type 512), $27. Add 5% shipping and handling, 12% for transformer. Illinois residents include 6.75% sales tax. Shipping 5% higher in Canada and outside U.S.A.

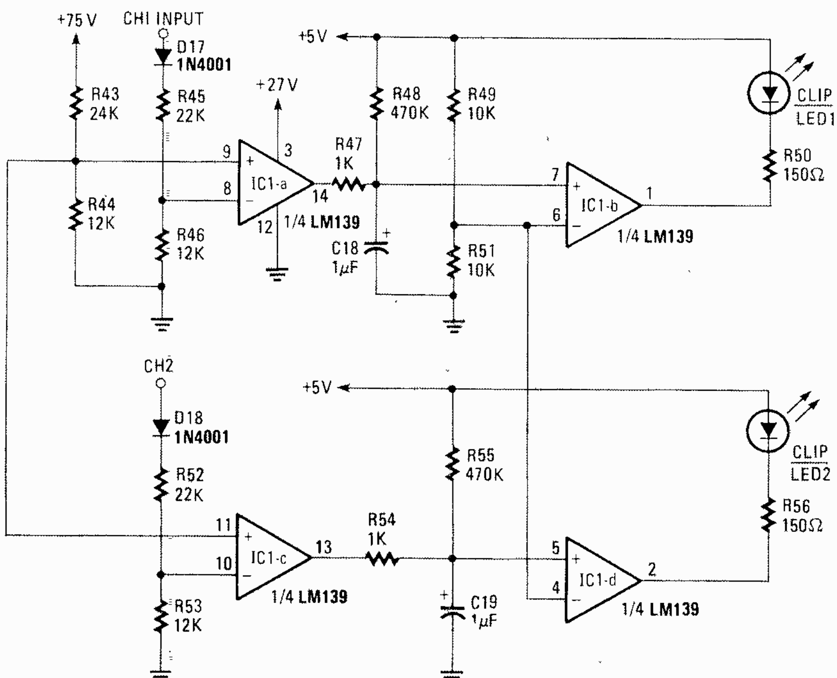


FIG 13—CLIPPING INDICATORS can be added to your amplifier, if desired.

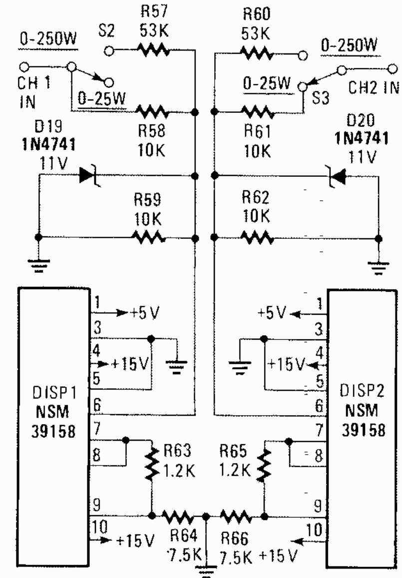


FIG. 14—BAR-GRAPH POWER METERS will certainly make a nice addition to any stereo amplifier.

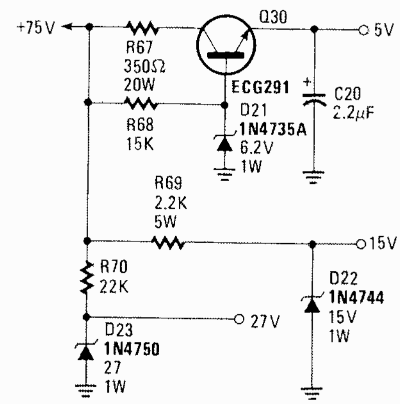


FIG. 15—THIS POWER SUPPLY is needed if the clipping indicators and bar-graph power meters are added. Note that Q30 requires a 10-watt heat sink.

in Fig. 12. They should be matched to be within 100 millivolts of gate voltage at 50 mA of drain current and 200 millivolts of gate voltage at 2 amps of drain current. Make the 2-amp measurement quickly, or with the transistor heat-sinked.

To mount the transistors, first bend the leads up at a 90-degree angle right at the point where their width changes. Spread the leads a bit and insert in board. Solder carefully while aligning the transistors as much as possible in a common plane. (They may temporarily be screwed to the heat sink as a holding fixture for this operation.) Solder short leads from D3–D5 to the bottom of the driver board, carefully observing polarity. Apply heat-sink compound and insulators to the transistors, and screw the driver and output-transistor assembly to the heat sink, using insulating shoulder washers. Tighten carefully.

Measure each transistor's tab (or case, if you are using TO-3's) to the heatsink. The readings should all be infinite, indicating no insulator shorts. (If you are using

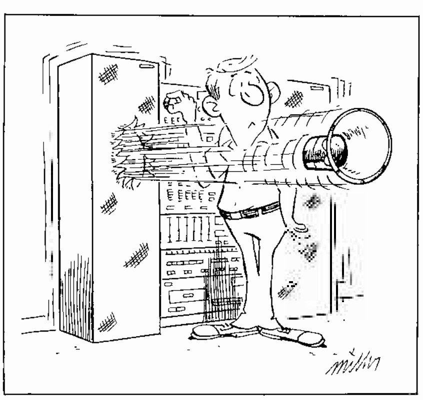
TO-3 output parts, it will be necessary to run individual leads to each transistor. When doing that, be extremely cautious: Double-check all your connections and keep your leads as short as possible. Don't forget to install a ferrite bead on each gate lead if you are using TO-3's. In no case should the wiring to the transistors be more than 2 inches in length.) Install the heatsink and driver assemblies.

Wire on channel to F2 and F4 with 18-gauge (minimum) wire. Connect a wire from the circuit board ground, near the output, to the chassis single-point ground. Install a ½-amp fuse for F2, and a milliameter for F4. Apply power, and check for a current through F3 of less than 500 mA. Also check that the output voltage at L1 is between ± 1 volt. If either of those tests fail, immediately turn off power, and look for the source of the problem before proceeding. Adjust R19 to set the current to about 200 mA, corresponding to an output idle current of about 150mA. Next, adjust R8 carefully to bring the output voltage at L1 as close as possible to zero. Turn off the power, and repeat for the second channel, using fuse positions F4 and F5.

Upon completion of those initial tests, finish wiring the remainder of the chassis. Run at least 18-gauge wire from each driver-board output, along with a ground from the board to the output binding posts. Shielded cable should be used from the level controls to the input jacks. The input-coupling capacitors mount at the level controls.

For continuous full-power applications, it will be necessary to use 5-amp fuses for F2–F5, and 8-amp output fuses for F1. However, for normal, or even loud general listening situations, it is advisable to use much smaller fuses to protect the speakers. It is usually sufficient to use 2-amp supply and 1- or 2-amp output fuses, and work up from there if necessary.

You may want to add clipping indicators and/or bar-graph power meters to your amplifier. The clipping indicator is shown in Fig. 13, the power meter, in Fig. 14, and the power supply needed for the two additions is shown in Fig. 15. **R-E**



AUTOMATIC TEST EQUIPMENT

ALLAN C. STOVER

Automatic test equipment is revolutionizing electronic testing and troubleshooting

WHERE TECHNICIANS AND ENGINEERS once tested products on work benches surrounded by test equipment and a maze of cables and wires, they now connect the product to *A*utomatic *T*est *E*quipment (ATE), press a button, and have a cup of coffee. Companies build ATE in all sizes and complexities, in both off-the-shelf and customized versions. The advent of ATE has revolutionized electronics troubleshooting.

A typical ATE approach

Figure 1 is a block diagram of a typical piece of ATE. It contains:

- A computer to control the test cycle, which can be a micro, mini, mainframe, or dedicated processor. The computer controls ATE over a bus, most often the *G*eneral *P*urpose *I*nterface *B*us (GPIB), although RS-232C and others are sometimes used. Some HP computers use a 16-bit parallel version called GPIO, very useful for in-house test panels. (See **Radio-Electronics**, July 1988, "General-Purpose Interface Bus".)
- A controller to sequence through test steps, control test equipment and the

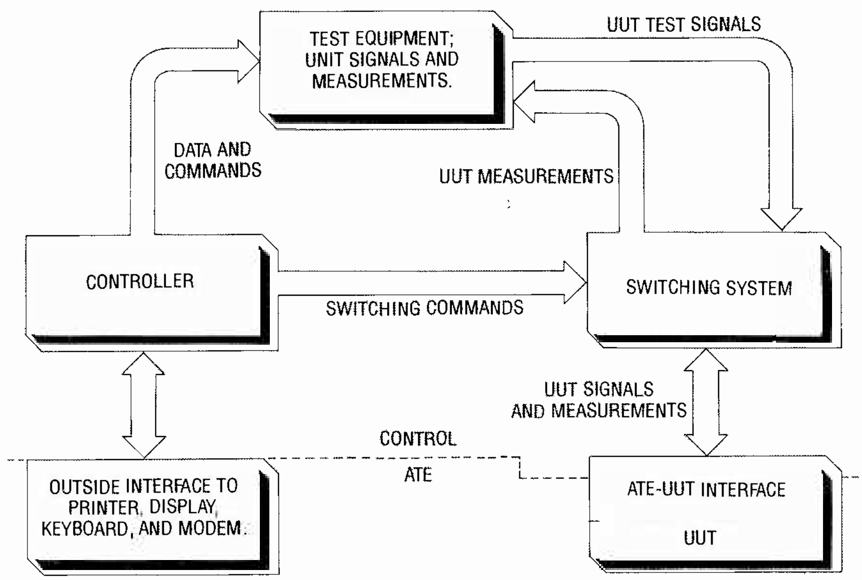


FIG. 1—A TYPICAL ATE BLOCK DIAGRAM. The test equipment provides test signals to the UUT through the switching system and interface, and the results are routed through to the test equipment for measurement. The controller sequences through the test cycle, and controls the test equipment, switching system, and interfaces.

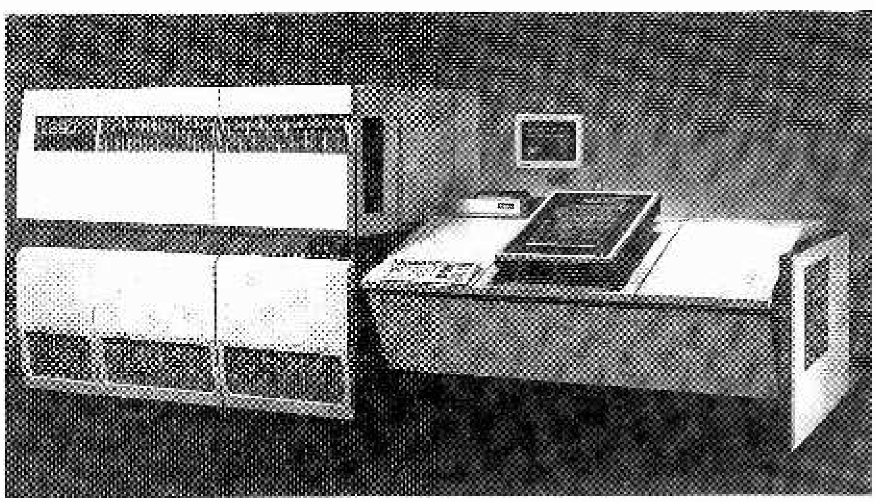


FIG. 2—TERADYNE L290 VLSI MODULE TEST SYSTEM. The test fixture with a UUT mounted on it is in the center of the operator console on the right. The console also contains a monitor, keyboard, printer, and analog and digital channel cards. The left console contains system and user power supplies, the DEC MicroVAX II, and analog instruments.

bus, read measurement results, perform calculations, and send results to a display or printer. Most "smart instruments" have memory and microprocessor control so an ATE controller can communicate via a bus, downloading computer programs to a smart instrument for use. While a controller is busy, a smart instrument can perform computations, and the controller can read the results later.

- A switching system to route signals between the *U*nit-*U*nder-*T*est (UUT) and the rest of the ATE. The switching system might route UUT digital signals to an ATE panel, and video to a frequency counter. Also, RF switches may route signals from a frequency synthesizer to the UUT input, then route UUT RF responses to a spectrum analyzer or power meter for measurement.
- Test equipment or circuitry to provide signals to the UUT and make measurements of UUT parameters. Most test equipment with GPIB capability can be used with ATE. Logic analyzers can analyze digital signals and provide results via GPIB, while spectrum analyzers and digital oscilloscopes can do the same for RF and analog signals. Also, RF generators and the function and pulse generators that modulate them can also be controlled via GPIB.
- An operator interface like a keyboard, display, printer, host computer over a network, or switch array.
- An interface between the UUT and the ATE, like a cable, a test fixture with pins to touch test points on a PC board, a fixture with cooling air and UUT connector, component sockets, or some combination. The interface type depends on what's tested; in some ATE, drivers and sensors handle signals to and from the UUT. They often have *R*andom *A*ccess *M*emory (RAM) to store the test patterns and UUT responses.

Types of ATE

There are versions available today for almost any electronic device. Some varieties may overlap two or more categories, while some may not fit any. The following types cover most versions:

- *I*n-*C*ircuit *T*est (ICT): This category can test PC boards for shorts, opens, continuity, and defective components. Some test only for shorts and opens, some only digital, and others both digital and analog. Most ICT memories have a component-characteristic library. The board is positioned on a "bed-of-nails" fixture, with an array of spring-loaded probes or pins connecting to test points on the board to test equipment, and the board is held down pneumatically, manually, or by vacuum. Sharp pins can penetrate coatings, while blunt pins make contact without damage. Drivers provide test signals, sensors measure responses, and RAM stores test patterns.
- Functional test: This variety tests signals at UUT inputs and checks for a correct response. Functional testers can test boards, assemblies, even entire systems. To test a board, the functional tester might input test signals at an edge connector, then check the response at the output pins on the same connector or a different one.
- Hot mockup, or known-good system: This incorporates an entire system known to be good (called a "gold" system). In testing a UUT subsystem, the known good one is removed, a questionable version is substituted, and the whole system is tested. If it passes, the UUT should be good because it operates as well as known good one. Hot mockup is most often built in-house, and can test only gold-system components. Since the

UUT may be far removed from system *I*nput/*O*utput (I/O), subtle faults may be missed, but it's economical and tests a UUT operationally.

- Comparison test: This compares a UUT and a gold unit of the same type, applying the same signals to both and comparing responses. If the UUT responses differ from those of the gold version, the UUT fails. A comparison test is economical because it avoids the need for large reference memory. The gold unit represents the correct response.
- Component test: This tests components ranging from VLSI and memory chips to resistors and capacitors. It's especially useful for digital devices, which use a myriad of high-speed test patterns.

A battle has been raging over functional versus ICT approaches. Functional supporters claim that a board can be tested only if signals are applied to simulate actual operating conditions, while ICT supporters claim that only individual components and subsections need be tested. Fortunately, many testers use both methods.

ATE software

Since ATE controllers manage test cycles, software is as important as hardware. Subtle software errors can result in passing defective UUT's. Since ATE uses computer-controlled hardware, a programmer must know the ATE, the UUT, and the commands and idiosyncrasies of the bus involved. An ATE processor uses the same instructions as in most computers for calculation, branching, and display. However, instructions that control hardware interfaces and bus devices, and that communicate with test equipment to read results are unique.

Many ATE manufacturers offer packages like component-characteristic libraries to keep prices competitive, since ATE software costs can exceed those of hardware. Interactive packages are also available to produce test programs from circuit data and test requirements provided by an engineer. Diagnostic software to locate UUT faults is also available. Many ATE systems have menu-driven hardware and software. Sometimes, ATE uses a "guided-probe" technique, where software guides a technician step by step, showing him which measurements to make.

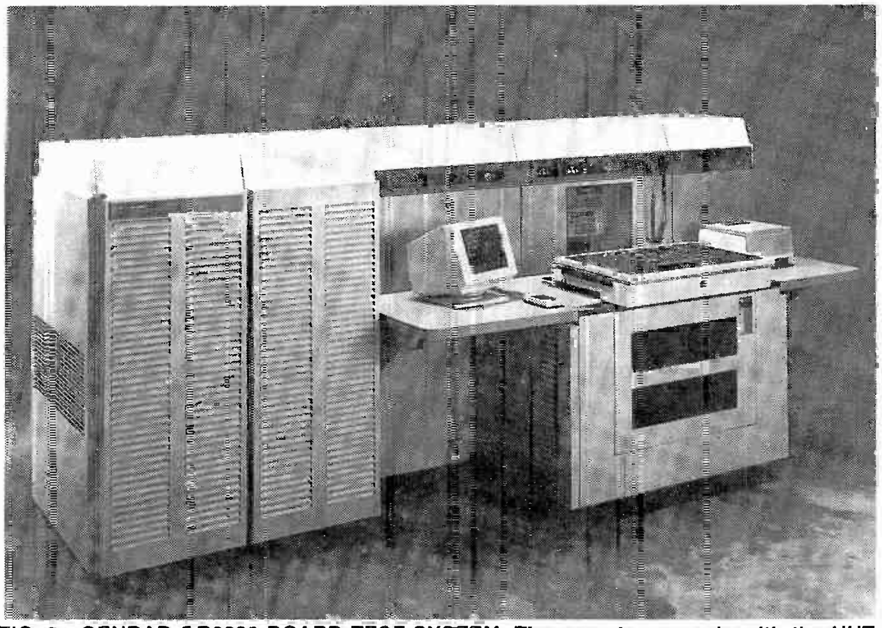


FIG. 3—GENRAD GR2282 BOARD TEST SYSTEM The operator console with the UUT fixture is at left. The GR2282 performs ICT and functional testing of digital boards.

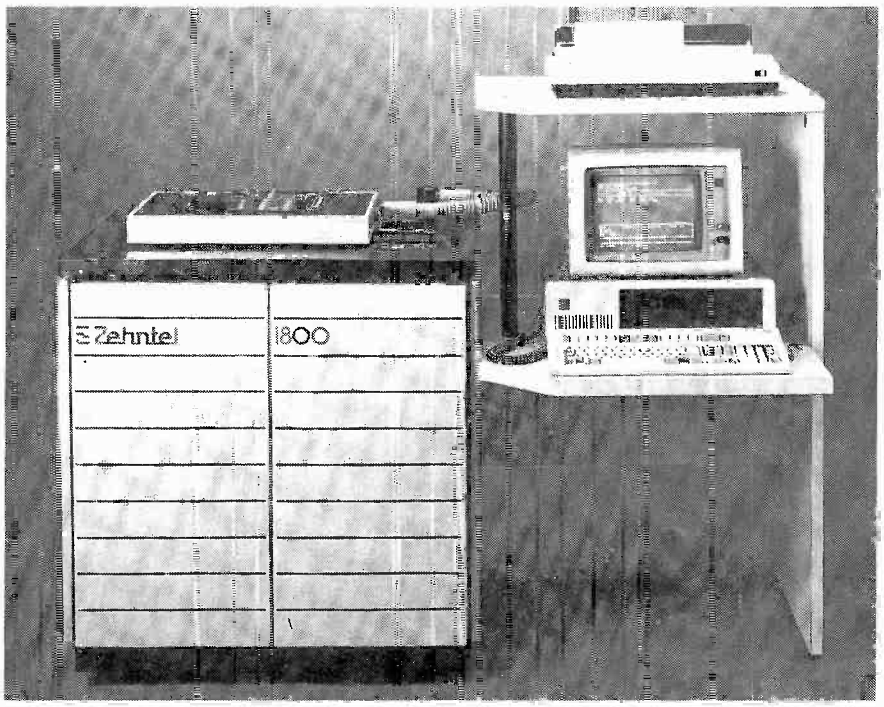


FIG. 4—ZEHNTEL 1800 BOARD TESTER A PC serves as controller, and the UUT fixture is on the console at left. Note the vacuum hose to the right. The 1800 is prewired for 640 analog/digital test points.

While technicians may balk at taking orders from a computer, they'll find it operates more methodically and rapidly for routine problems. Computers fail when problems are no longer routine and require human judgment. Even that may no longer hold true when ATE successfully incorporates *A*rtificial *I*ntelligence (AI) for fault isolation. With AI, ATE hardware can learn from its own mistakes.

ATE pro and con

Any discussion of ATE must include justifications before spending money for it. Here are some common favorable arguments:

- Speed: ATE gives a significant increase in test speed, until the number and complexity of the tests tax it enough to slow it down. Also, speed is limited by test-equipment performance, which may operate slowly via a bus or require settling/setup time.

FIG.5—THE FLUKE 900 DYNAMIC TROUBLESHOOTER uses comparison testing as a low-cost alternative to isolate faults to the component level without programming or knowledge of a board. The 900 captures timing errors, intermittent faults, and static device failures, and performs dynamic ICT tests on each IC while operating.

- Quality: We're all human, make mistakes, and are inconsistent. Once ATE hardware and software are error-free, they can operate almost perfectly without many human errors. However, getting it that way is difficult because of the complexity and volume of the software, involving thousands of lines of code, any one of which may conceal subtle errors.
- Lifetime operating cost: Installing ATE may be expensive, but if it operates faster, makes fewer errors, and requires less operator experience, it'll be cost-effective. That doesn't mean that an organization doesn't need experienced technicians. Someone has to fix UUT's when ATE can't find a fault, or fix the ATE itself. The work, then, should be more interesting, because ATE has done most of the repetitious testing.

Today's ATE

Let's look at some current off-the-shelf ATE. Figure 2 shows the Teradyne L290 VLSI Module Test System. The UUT test fixture is in the middle of the console at right, and can use bed-of-nails, edge-connector, or test-socket interface modes. The console contains analog and digital cards. The L290 has room for up to 1152 bidirectional test channels. The console at left contains analog instruments, voltage references, power supplies, and any user-supplied test equipment. A DEC MicroVAX II computer is the system controller, operating dedicated processors on its Q-bus. All L290 test programs are written in a variant of PASCAL.

A color monitor, keyboard, dot-matrix printer, and control console provide for human interaction, and an optional DECnet/Ethernet interface can link the L290 with other computers. The test-station console can rotate from 22.5 degrees to horizontal or vertical, to allow it to integrate with an automatic UUT handler or test-point prober. The L290 can use a guided-probe approach, where a hand-held, automatic probe examines the nodes leading to a failing output using a "fault signature" dictionary, operating at up to 80 MHz. When a fault is detected, diagnostic software is used to determine which nodes to probe in what order. The expected responses to the nodes can come from simulation software, or learned by the tester beforehand by probing good nodes manually.

Fault-simulation software uses a fault dictionary, which is a computer file containing a UUT's fault signatures for a given cause. Using it normally takes less time than guided probing, which requires manual probing and rerunning a test at each node. The two methods are often combined. Figure 3 shows a GenRad GR2282 Board Test System, which performs both ICT and functional testing on complex digital boards, also using a DEC MicroVAX II as system controller. Its software has a library of over 6,000 devices.

The GR2282 can handle up to 3,840 pins, each with 16K of driver and sensor memory behind it. The GR2282 has a variety of diagnostic software, including guided-probe diagnostics, and one routine that the manufacturer calls BusBust automatically identifies a failing bus component without operator intervention. The GR2282 uses a device known as a Scratchprobe to allow an operator to distinguish between defective components and assembly failures (like broken foils, poorly soldered joints, and bent leads).

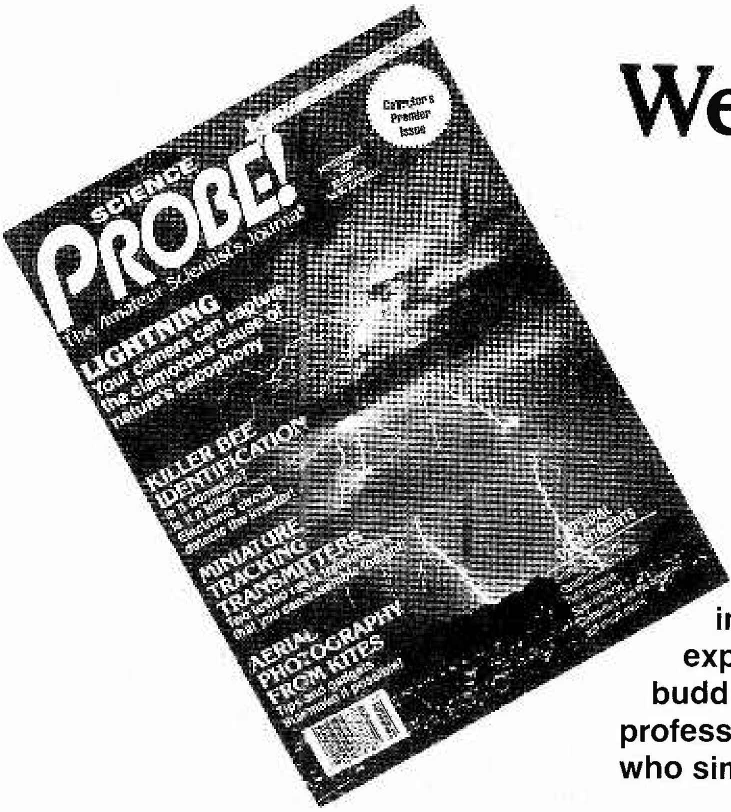
Figure 4 shows a Zehntel 1800 board tester, with 640 pins; this is a small, low-cost piece of ATE. The controller is a PC, using an MS-DOS spreadsheet environment. Test programs can be executed automatically; either a list of inputs to a given board is read in as a file of components and interconnections, or the configuration of a board is specified interactively. Both approaches generate a debugged test program and board input list. The 1800 has an expandable library of over 3,500 digital devices, tests for opens and shorts, and performs ICT of active and passive analog and digital devices. All of that adds up to a very thorough test.

Figure 5 shows the Fluke 900 Dynamic Troubleshooter, a low-cost alternative using comparison testing to isolate faults to the component level without programming or knowledge of a board. The 900 captures timing errors, intermittent faults, and static device failures, and performs dynamic tests on each IC while in-circuit and operating at speed.

Figure 6 shows a Locost 106 from Julie Research Laboratories, used for automatic calibration of test equipment and calibration standards like meters, precision dividers, resistance standards, platinum thermometers, and power supplies. The Locost 106 has precision DC/LF calibration standards under GPIB control of a PC or Hewlett-Packard 9826S desktop micro, reducing calibration times by 80% and minimizing operator error and the need for calibration experts to be present.

A variety of ATE is available to test almost anything. Each has hardware and software to test UUT's and perform diagnostics. It's worthwhile even for small companies, has revolutionized testing and troubleshooting, and is here to stay. You should understand that ATE, like most other things, isn't a panacea. However, it's a very powerful tool when used carefully by experienced technicians and engineers, and frees them to use their time more productively. R-E

FIG.6—THE JULIE RESEARCH LABORATORIES LOCOST 106. This version automatically calibrates test equipment and calibration standards. The desktop-computer controller is at top right.



Welcome to. . .

SCIENCE PROBE!®

The Amateur Scientist's Journal

Embark on an irresistible new journey into the realm of mystery, challenge, and exploration! The perfect magazine for the budding scientist, the serious amateur, the professional who would like to relax, and those who simply want to gaze at the stars.

SCIENCE PROBE! — the *only* magazine devoted entirely to Amateur Scientists! If you are fascinated by science in all its many forms . . . if you can't stay away from a microscope, telescope, calipers, or test tube — we invite you to share the wonders in every issue of **SCIENCE PROBE!** You will join a community of Amateur and Student Scientists who enthusiastically seek scientific knowledge or follow scientific pursuits for their own sakes and not merely as a profession.

Obtain your personal *premier* edition of **SCIENCE PROBE!** by visiting a quality Newsstand, Convenience Store, or Supermarket this Fall or by reserving your personal copy through the mail by completing the coupon below.

From the very first issue of **SCIENCE PROBE!** you will be involved in a world of scientific facts, experiments, and studies pursued by amateur scientists who are university students, inventors, academicians, engineers, or office workers, salesmen, farmers—whose *quest* is to probe into the mysteries of science and reveal them to all.

Plan to become a **SCIENCE PROBE!** reader!

Articles to appear in early issues of **SCIENCE PROBE!** are:

LIGHTNING—CAPTURE IT ON FILM
MONITORING ULTRAVIOLET FROM THE SUN
MOBILE-MOUNT EXPERIMENTAL WIND TUNNEL
CHECKING OUT ACID RAIN
AERIAL PHOTOGRAPHY FROM KITES AND BALLOONS
MINIATURE TRACKING TRANSMITTER
KILLER BEE IDENTIFICATION
HOW TO OBTAIN ANIMAL EYESHINE PHOTOGRAPHS

If you're fascinated by science in all its many forms, if you are compelled to experiment and explore, then SCIENCE PROBE! is your kind of magazine!

SCIENCE PROBE! EEHB
500-B Bi-County Boulevard
Farmingdale, NY 11735

Please forward my Premier Edition of SCIENCE PROBE! as soon as it comes off the press. I am enclosing $3.50-U.S.A. ($3.95-Canada) plus $1.00 for shipping and handling. Better still, please enroll me as a charter-member subscriber and send the next four (4) quarterly issues of Science Probe. I am enclosing $9.95-U.S.A. (Canada: $14.95 U.S.A. Funds)

☐ Premier Edition only ☐ First Four Issues (1 Year)

Offers valid in the U.S.A. and Canada only. No foreign orders.

Name ______________________

Address ______________________

City ______________ State ________ ZIP ______

All Orders payable in U.S.A. Funds only.

ON SALE AT QUALITY NEWSSTANDS, CONVENIENCE STORES AND SUPERMARKETS
STARTING SEPTEMBER 13, 1990 — $3.50-U.S.A. — $3.95-Canada

HOME-SECURITY COOKBOOK

In this survey of electronic security and alarm systems we take a look at miscellaneous circuits for use in the home or car.

RAY MARSTON

WHEN YOU THINK ABOUT HOME-SECURITY and alarm systems, probably the first things you think about are guarding windows, doors, and the perimeter of your property. That kind of protection is usually provided by opening or closing some kind of switch or breaking a light beam. However, sensors that are triggered by heat or light can be just as important to your personal safety. In this article we'll take a look at temperature-activated and light-activated alarms for the home, as well as burglar-alarm systems and immobilizer switches for cars or other kinds of vehicles.

Temperature alarms

Electronic temperature alarms can be used to indicate any one of the following conditions: over-temperature, under-temperature, temperature-deviation, or excessive temperature-differential. Some applications for electronic over-temperature alarms include using them as fire alarms, in a greenhouse, or a car or other vehicle. Electronic under-temperature alarms are used to indicate either a heating system failure, or the presence of frost and ice.

Temperature-deviation alarms are specialized devices that can sound an alarm whenever a temperature being monitored either exceeds or falls beneath some preset limit. Some useful domestic applications for this type of circuit include monitoring the temperature of tropical fish tanks or greenhouses.

Temperature-differential types of alarms are also specialized devices that are activated whenever the *absolute value* of the *difference* between two temperatures being monitored exceeds some preset limit. In this case, the actual individual values of the two temperatures are not involved in the circuit operation, only the magnitude of their difference. Temperature-differential alarms can be used in applications ranging from liquid level control and altimeters to solar heating systems.

Practical electronic temperature alarms can be built using a variety of different types of thermal sensors, including electromechanical thermostats, thermistors, or silicon diodes. Figure 1 shows a practical example of a simple, relay-aided fire or over-temperature alarm that is built using two electromechanical thermostats as temperature sensors.

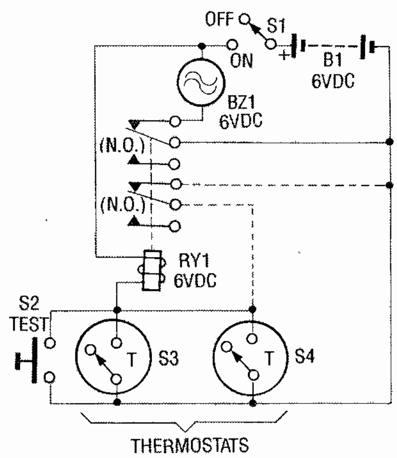


FIG. 1—A SIMPLE RELAY-AIDED fire or over-temperature alarm using thermostats S3 and S4 as temperature sensors.

Thermostats are typically Normally-Open (N.O.) temperature sensitive, SPST switches that are activated only when the temperature of their internal bimetallic element exceeds some preset limit. Whenever both thermostats are less than the preset temperature limit, their switches remain open, in which case both relay RY1 and buzzer BZ1 are turned off, and no current flows.

When the temperature of either or both of the thermostats exceeds their preset trip values, RY1 and BZ1 are turned on, sounding an alarm. Any number of thermostats can go in parallel, and the circuit can be checked by closing S2. This type of circuit is normally made to be non-latching, but can be made self-latching by using a second set of contacts for RY1, connected as indicated by the dashed lines.

If the thermostats to be used with the temperature alarm are intended to go in normal living areas, they should

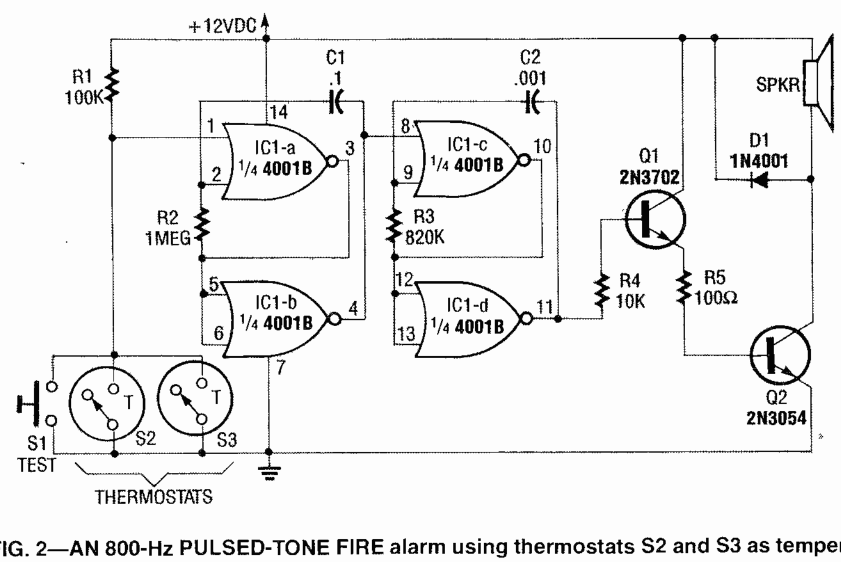


FIG. 2—AN 800-Hz PULSED-TONE FIRE alarm using thermostats S2 and S3 as temperature sensors.

be set to close at about 60–70°C (140–158°F). If the thermostats are supposed to go in fairly warm areas like furnace rooms or attics, they should be set to close at approximately 90°C (194°F).

Figure 2 shows an electronic fire or over-temperature alarm that generates an 800-Hz tone that's pulsed or gated on and off at 6-Hz. IC1-c and IC1-d are used as an 800-Hz astable multivibrator that is gated by IC1-b, and IC1-a and IC1-b are used as a 6-Hz astable multivibrator gated by the thermostats.

When both thermostats are open, the astable multivibrators are turned off, and approximately one microamp will flow in the circuit. When either or both thermostats close, the 6-Hz astable multivibrator made from IC1-a and IC1-b turns the 800-Hz astable multivibrator made from IC1-c and IC1-d on and off at 6 Hz. The operation is normally non-latching, and the pulsed tone stops whenever the thermostats re-open due to decreasing ambient temperature.

Thermistor-activated alarms

As a rule, thermostats respond rather imprecisely. A less expensive and more precise alternative is the thermistor, a semiconductor resistor with a Negative-Temperature-Coefficient (NTC). In an NTC component, resistance decreases with increasing temperature, implying a relatively high resistance at low temperatures, and a relatively low resistance at high temperatures.

Figures 3 and 4 show two practical versions of thermistor-controlled electronic temperature alarms. In each case, R6 can be any thermistor with a nominal value of approximately 5K and a variable range of approximately 1K–10K, at the desired operating temperature.

Figure 3 shows a precision thermistor-controlled electronic over-temperature alarm. The thermistor R6 controls IC1, a 741 op-amp, and transistor-driven relay RY1. In that case, IC1 is used as a voltage comparator, creating a temperature-dependent variable voltage on the non-inverting input (pin 3), which is compared with a fixed +6 volts DC on the inverting input (pin 2). The voltage on pin 3 is set to approximately equal to that of pin 2, which will rise as the temperature falls and fall as the temperature rises.

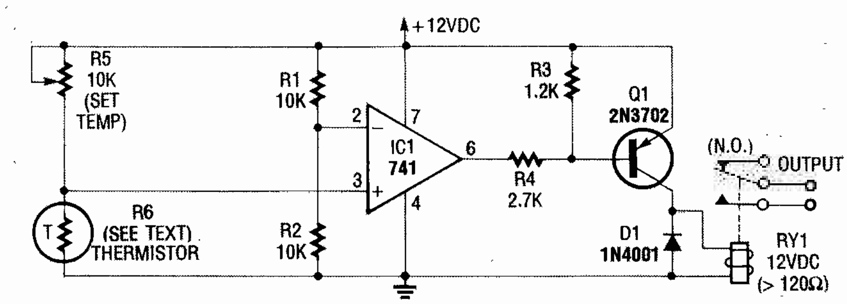


FIG. 3—A PRECISION OVER-TEMPERATURE alarm using thermistor R6 as a temperature sensor. To use that version as an under-temperature alarm, reverse the connections of pins 2 and 3 of IC1.

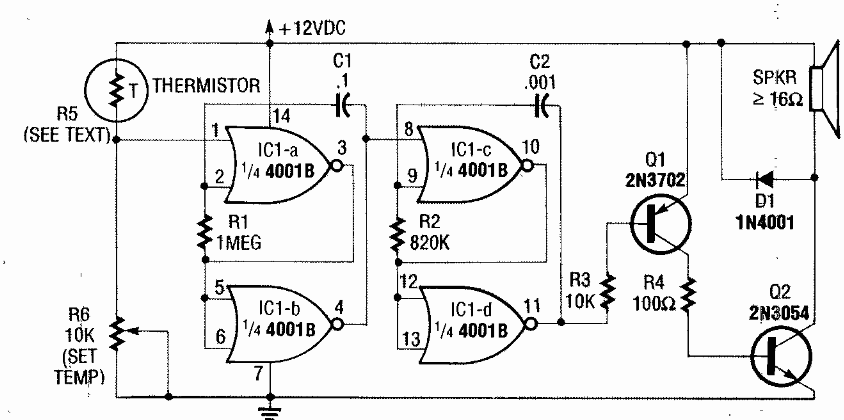


FIG. 4—AN 800-HZ PULSED-TONE under-temperature alarm using thermistor R5 as the temperature sensor.

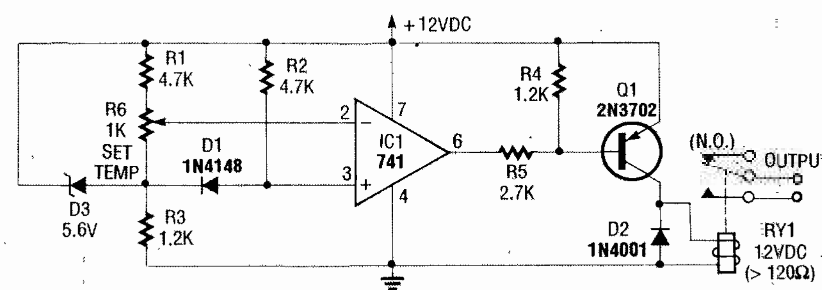


FIG. 5—AN OVER-TEMPERATURE ALARM WITH silicon diode D1 as the temperature sensor. To use that version as an under-temperature alarm, reverse the connections of pins 2 and 3 of IC1.

Whenever the temperature of R6 is beneath the alarm threshold temperature, the voltage on pin 3 exceeds the voltage on pin 2, and so the output, pin 6, saturates in the positive direction, going to +12 volts DC. As a result, both the base and emitter of Q1 are at approximately the same potential, and Q1 stays turned off, which keeps RY1 turned off.

As the temperature of R6 rises, the voltage on pin 3 falls, decreasing to the point where it's less than that of pin 2 at the threshold value. The output of IC1 then saturates in the negative direction, going to ground, which turns on Q1 and RY1 in succession, sounding an alarm. Because IC1 has high voltage gain, RY1 can either be turned on or off by temperature variations of a fraction of a degree around the threshold, as set with R5. This action can be reversed to create a precision electronic under-temperature alarm by transposing the connections of pins 2 and 3 of IC1.

Figure 4 shows a thermistor-controlled 800-Hz pulsed-tone electronic under-temperature alarm. It is similar to the over-temperature version shown in Fig. 2. Again, IC1 is used as a dual-astable multivibrator pulsed-tone

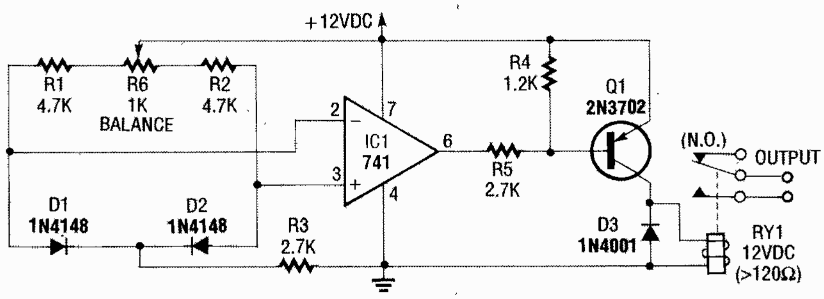


FIG. 6—DIFFERENTIAL-TEMPERATURE alarm using silicon diodes D1 and D2 as temperature sensors.

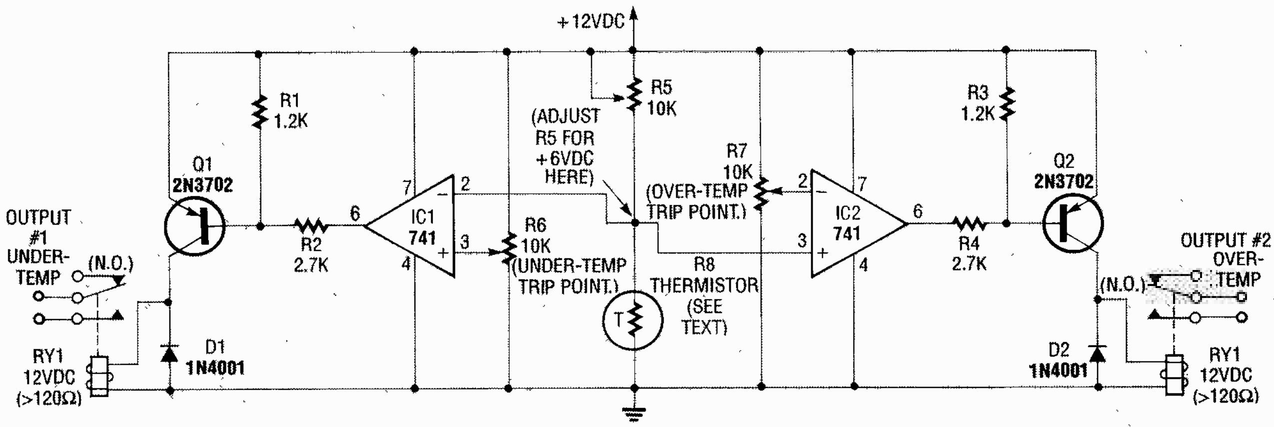


FIG. 7—TEMPERATURE-DEVIATION ALARM WITH independent over-temperature and under-temperature relay outputs, and thermistor R8 as the temperature sensor.

generator turned on by the voltage on pin 1 going toward ground, and turned off by the voltage on pin 1 going toward +12 volts DC. Pin 1 is connected to the junction of R5 and R6, with a low voltage at low temperatures and a high voltage at high temperatures. Thus, the dual-astable multivibrator is turned on whenever the temperature of thermistor R5 falls beneath a value preset by R6, generating a pulsed tone.

In practice, the precise gating point of IC1 is determined by its threshold value, which is some fixed percentage of the supply voltage. Consequently, the circuit shown in Fig. 4 turns on whenever the ratio of R5 to R6 goes beneath some exact value. The ratio of threshold value to supply voltage depends on the individual IC, but is independent of the supply voltage. The nominal value of that ratio is 50%, but it can range between approximately 30–70% for different IC's.

The circuit shown in Fig. 4 has excellent stability, and a sensitivity of approximately 0.5°C. The under-temperature trip point is preset by R6, and the circuit can also be used as an electronic over-temperature alarm by transposing the connections of pins 2 and 3 of IC1.

Diode-activated alarms

Silicon diodes make quite accurate and inexpensive sensors for electronic temperature alarms. They have a typical forward voltage drop of approximately 600 millivolts DC at 1 milliamp. If their current is constant, their forward voltage drop has an NTC of −2 millivolts DC/°C. Most silicon diodes have similar thermal characteristics, while their small mass, as in the case of the 1N4148, ensures a rapid thermal response.

Figure 5 shows a 1N4148 diode used as a temperature sensor in an electronic over-temperature alarm. In this circuit, Zener diode D3 regulates the voltage across the R1-R6 voltage divider to 5.6 volts DC. A constant reference voltage is presented to pin 2 of IC1. A temperature-dependent voltage with an NTC of −2 millivolts DC/°C occurs across D1—for every degree C in that D1 increases, its forward voltage drop will be reduced by 2 millivolts DC. A differential voltage will then appear between pins 2 and 3 of IC1. .

If the temperature dependent voltage across D1 exceeds the trip level set by R6, then RY1 turns on. Under that condition, a differential of 1 millivolt appears between pins 2 and 3, and both Q1 and RY1 turn on. Whenever the temperature of D1 goes beneath the trip level, the voltage on pin 3 goes above that of pin 2, driving the output of IC1 to positive saturation, turning Q1 and RY1 off.

The circuit in Fig. 5 has a sensitivity of approximately 0.5°C, and can be used as an electronic over-temperature alarm from below zero to above the boiling point of water. Conversely, to use it as an electronic under-temperature alarm, simply transpose the connections of pins 2 and 3 of IC1 as before.

Finally, the circuit shown in Fig. 6 shows a pair of 1N4148 silicon diodes D1 and D2 used as temperature sensors in an electronic differential-temperature alarm. It turns on only when the temperature of D1 exceeds that of D2 by greater than some preset amount, and is not influenced by the absolute temperature of either diode.

Bias currents are fed to D1 and D2, setting up a differential voltage between pins 2 and 3 of IC1. A differential trip temperature of the circuit is then established. Once the trip temperature is set, the differential voltage is influenced only by the difference in temperatures between D1 and D2. The circuit has a sensitivity of approximately 0.5° C, and can handle temperature differentials of up to 10°C.

Temperature-deviation alarms

Electronic temperature-deviation alarms activate whenever a temperature being monitored deviates from a preset value by more than a specific amount. They are useful for tasks such as monitoring the temperatures of tropical fish tanks or greenhouses. The temperature-deviation alarms discussed here combine both over-temperature and under-temperature circuits, sharing one or two common relays.

Fig. 7 shows a temperature-deviation alarm using two independent relay outputs, RY1 and RY2. Thermistor R8 is a temperature sensing component with a resistance that varies from 1K–10K, and is nominally 5K at its middle trip-range temperature. In order to calibrate the under-temperature and over-temperature trip points, first adjust R5 so that +6 volts DC appears across R8, when the thermistor is at its nominal mid-range temperature. The next step is to decrease the temperature of R8 to the required lower-temperature trip value, and adjust R6 so that RY1 just turns on. Finally, increase the temperature of R8 to the desired upper trip value, and adjust R7 so that RY2 just turns on.

Fig. 8 shows a different version of a temperature-deviation alarm, which uses a single relay output RY1, and temperature sensing thermistor R6. Under-temperature and over-temperature trip points are calibrated by first adjusting R3 so that +6 volts appears across thermistor R6, when this component is at its nominal mid-range temperature. Then, decrease the temperature of R6 to the required lower-temperature trip value, and adjust R4 so that RY1 just turns on. The last step is to increase the temperature of R6 to the desired upper trip value, and then to adjust R5 so that relay RY1 just turns on.

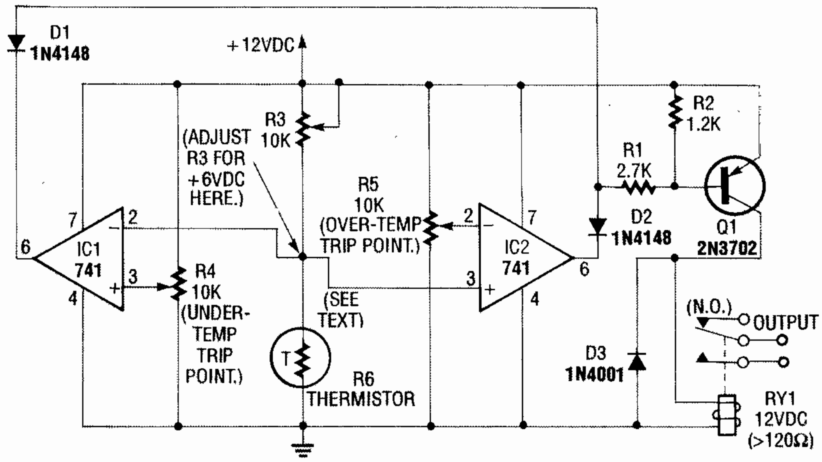


FIG. 8—TEMPERATURE-DEVIATION ALARM WITH single relay output, and the thermistor R6 as the temperature sensor.

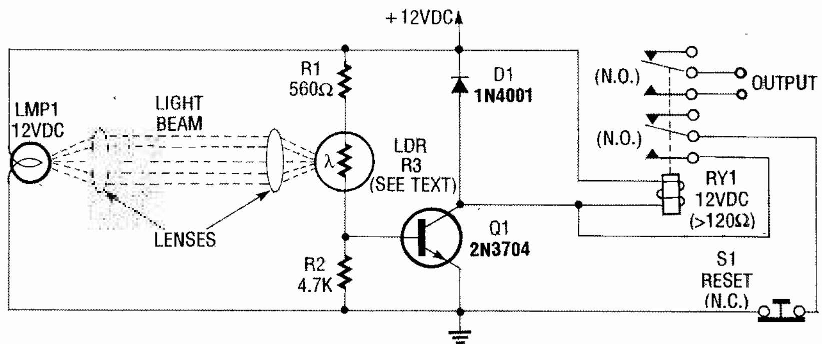


FIG. 9—SIMPLE SELF-LATCHING light-activated alarm, using Light Dependent Resistor (LDR) R3 as the light sensor.

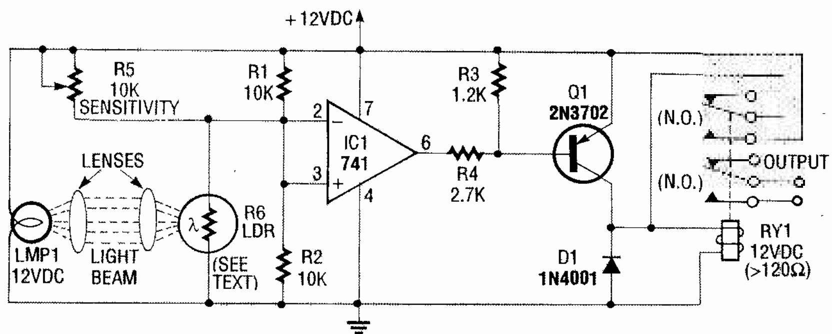


FIG. 10—LIGHT-BEAM SMOKE ALARM, using LDR R6 as the light sensor.

Light-activated alarms

Electronic light alarms are designed to sound an alarm when light enters a darkened area such as the inside of a storeroom or wall safe, or when smoke interferes with the passage of light into a photocell. Several useful versions of electronic light alarms are shown in Figs. 9–12, all of them using a Light Dependent Resistor (LDR) as the sensor.

An LDR is a photocell that offers a relatively high resistance on the order of hundreds of kilohms when in darkness, and a low resistance on the order of hundreds of ohms when illuminated. The several different types of electronic light-alarm circuits discussed here can use any general-purpose LDR with a face diameter of 3–12 mm.

Figure 9 shows one method to use an LDR in a simple, self-latching type of light-activated alarm. When the LDR R3 is in darkness, it has a very high resistance, resulting in Q1 and RY1 being turned off. When the LDR is illuminated, its resistance significantly decreases, turning on Q1 which activates RY1 and sounds an alarm. The series combination of R3-R1-R2 acts as a voltage divider to bias Q1, with R3-R1 as the upper half, and R2 as the lower half.

One defect with that type of circuit is that it has a fairly low fixed sensitivity. Figure 11 shows an improved version of a light-activated alarm. Better temperature sensitivity and

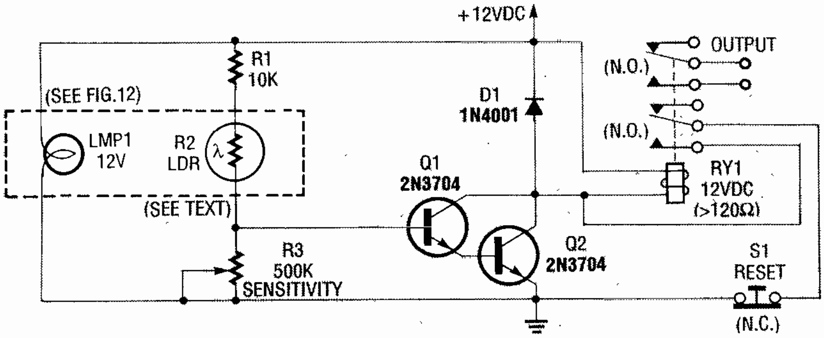


FIG. 11—IMPROVED LIGHT-ACTIVATED ALARM using LDR R2 as the light sensor. The modifications shown with the dashed lines refer to the reflection-type smoke detector shown in Fig. 12.

user adjustibility is achieved in this circuit by replacing Q1 with a Darlington pair and using a variable 500K resistor R3 in place of R2.

Smoke alarms

An LDR can be used to build a smoke alarm by either light-projection or light-reflection methods. In the light-projection method shown in Fig. 10, a beam of light is projected onto the face of the LDR and its sensitivity is adjusted so that a small decrease in light level caused by the introduction of smoke into the beam will activate the alarm.

A somewhat more satisfactory and sensitive method is to use the reflective approach shown in Fig. 11. The presence of smoke actually *increases* the total light level reaching the LDR, instead of decreasing it. This example uses the Darlington pair Q1-Q2 as mentioned above to increase the sensitivity, and provides R3 to adjust the sensitivity.

The box in the dotted line in Fig. 11 refers to the drawing shown in Fig. 12. When the reflection-type smoke detector box is used, both the lamp, LMP1, and the LDR, R2, are mounted in an open-ended, light-excluding box, with an internal screen that prevents the light from LMP1 from falling onto R2. The heat from LMP1 convects air into the bottom of the box, and expels it from the top. The inside of the box is painted matte black; its construction permits air to pass through, but excludes external light.

If the convected air currents are smoke-free, no light will fall on R2, and its resistance will remain very high. If the air currents do contain smoke, the smoke reflects the light from LMP1 back onto R2, resulting in

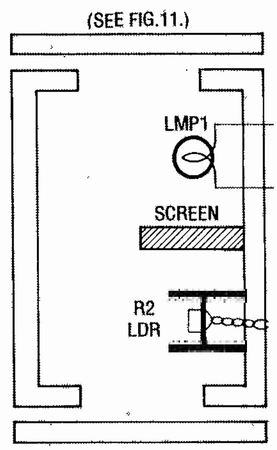


FIG. 12—SECTIONAL VIEW OF reflection-type smoke detector.

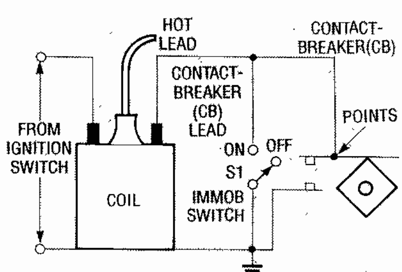


FIG. 13—CONTACT-BREAKER immobilizer switch in parallel with the contact-breaker points.

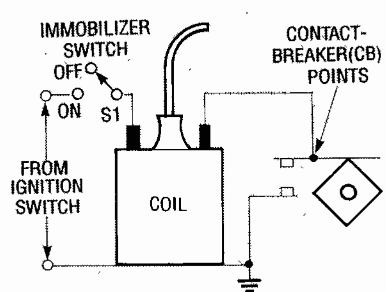


FIG. 14—IGNITION IMMOBILIZER switch wired in series with the contact-breaker points.

a decrease in resistance which is then detected. To use that version of electronic light alarm, simply replace the LDR with the assembly shown in Fig. 12, and add LMP1 as is indicated. All three versions of electronic light or smoke detector alarms shown in Figs. 9–11 can be made non-latching, if you prefer, by the use of a single-contact relay for RY1.

Car immobilizers

There are two basic types of electronic anti-theft devices for cars or other vehicles, the immobilizer switch and the burglar alarm. In this section, we'll discuss the advantages and disadvantages of different versions of car immobilizer alarms.

In the immobilizer version shown in Fig. 13, the immobilizer switch is wired in parallel across the contact-breaker points, thus it will work on any cars without electronic ignition. The switch disables the vehicle when it is closed, and provides excellent protection, especially if the wiring is well-concealed at the end of the switch that goes to the contact-breaker points.

Figure 14 shows an immobilizer switch in series with the ignition switch. The engine operates only when the switch is closed. More reliable protection is provided by the parallel switch connection because a skilled thief can bypass the immobilizer switch and ignition switch by connecting or "hot wiring" a jumper lead from the battery to the S1 terminal of the coil.

An immobilizer switch can be wired in series with the starter solenoid, as shown in Fig. 15, or in series with an electric fuel pump, as shown in Fig. 16. When the immobilizer switch is wired in series with an electric fuel pump, the thief can start the engine, but will only be able to drive it a short distance until the fuel pump stops operating. The only disadvantage to the method shown in Fig. 16 is that it works only for cars with electrical fuel pumps.

The flaw in the circuits shown in Figs. 13–16 is that they are manually operated, and will work only if the owner or operator of the car remembers to use it. By contrast, the immobilizer circuit shown in Fig. 17 turns on automatically when the engine is started using the ignition switch, but can be turned off by pressing a hidden push-button switch S1.

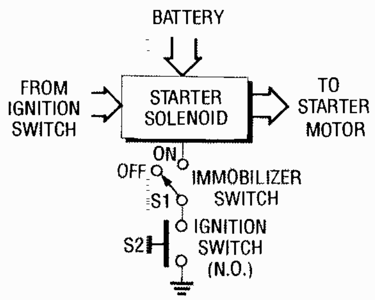


FIG. 15—STARTER-MOTOR immobilizer switch wired in series with the ignition switch.

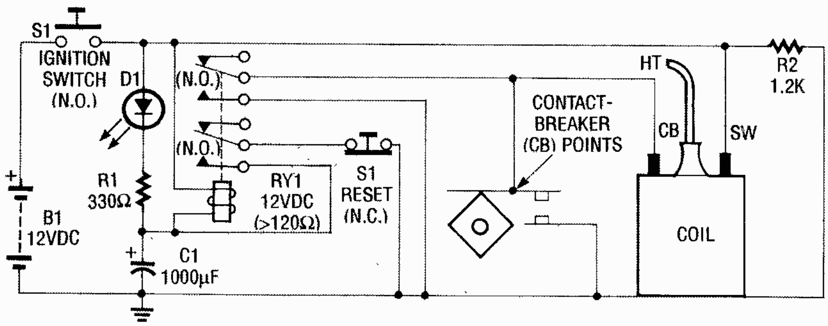


FIG. 17—SELF-ACTIVATING IMMOBILIZER switch circuit, for use with the contact-breaker points in a car.

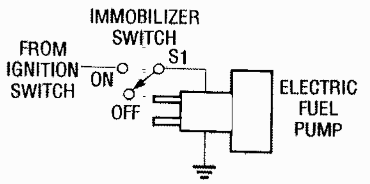


FIG. 16—FUEL-PUMP immobilizer switch wired in series with the electric fuel pump.

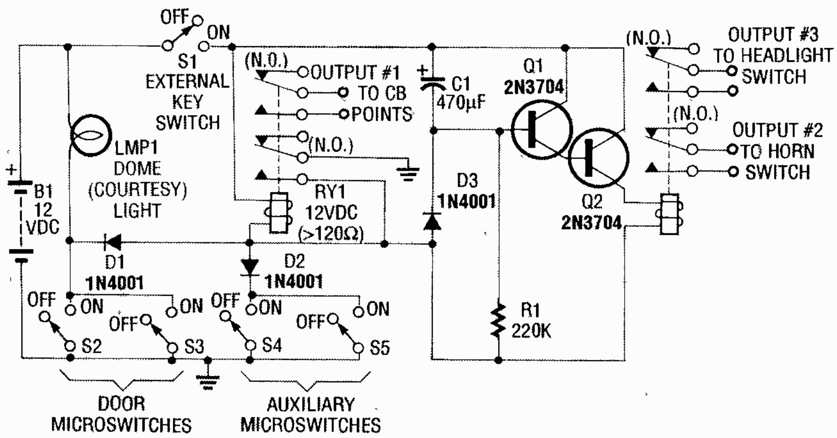


FIG. 18—MICROSITCH-ACTIVATED ANTI-THEFT burglar alarm system and immobilizer switch that turns the horn and lights on to sound an alarm, and then automatically turns them off after four minutes.

Car burglar alarms

An electronic burglar alarm for a car or other vehicle should sound an alarm and possibly immobilize the engine during or after a break-in. The electronic alarm system needs an ON/OFF switch which can be either internal or external to the car. However, if you make the switch internal, you will need a time delay to enable you to get in and out of the vehicle without sounding an alarm.

Electronic burglar-alarm circuits for cars that use internal ON/OFF switches tend to be complex, expensive, fairly unreliable, and give only poor protection at best, since thieves will usually have 15 seconds or more before an alarm will sound. The use of an external ON/OFF switch in an electronic burglar alarm is more efficient than an internal switch and provides excellent protection because it sounds an alarm the instant a door is opened.

One disadvantage of a common type of burglar alarm is that when it is activated, the horn and lights continue to operate until they are either turned off by the owner, or the battery goes dead. That limitation is overcome by using the type of burglar alarm shown in Fig. 18. Relay RY2 turns off automatically after approximately four minutes, as determined by the time constant R1 × C1.

Finally, the version of vehicular

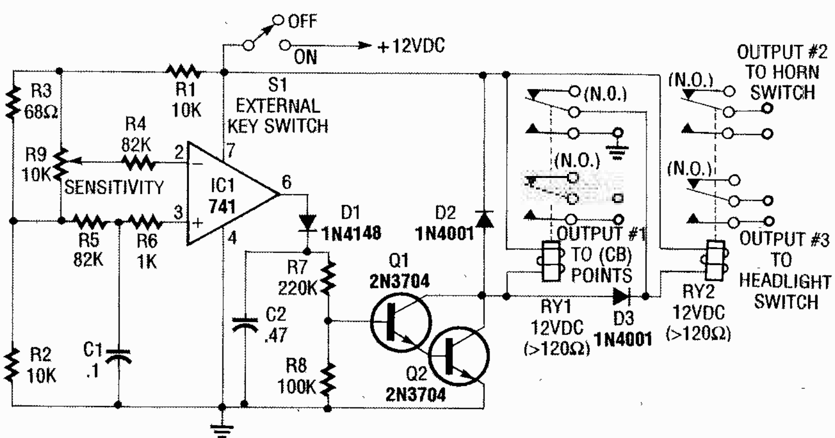
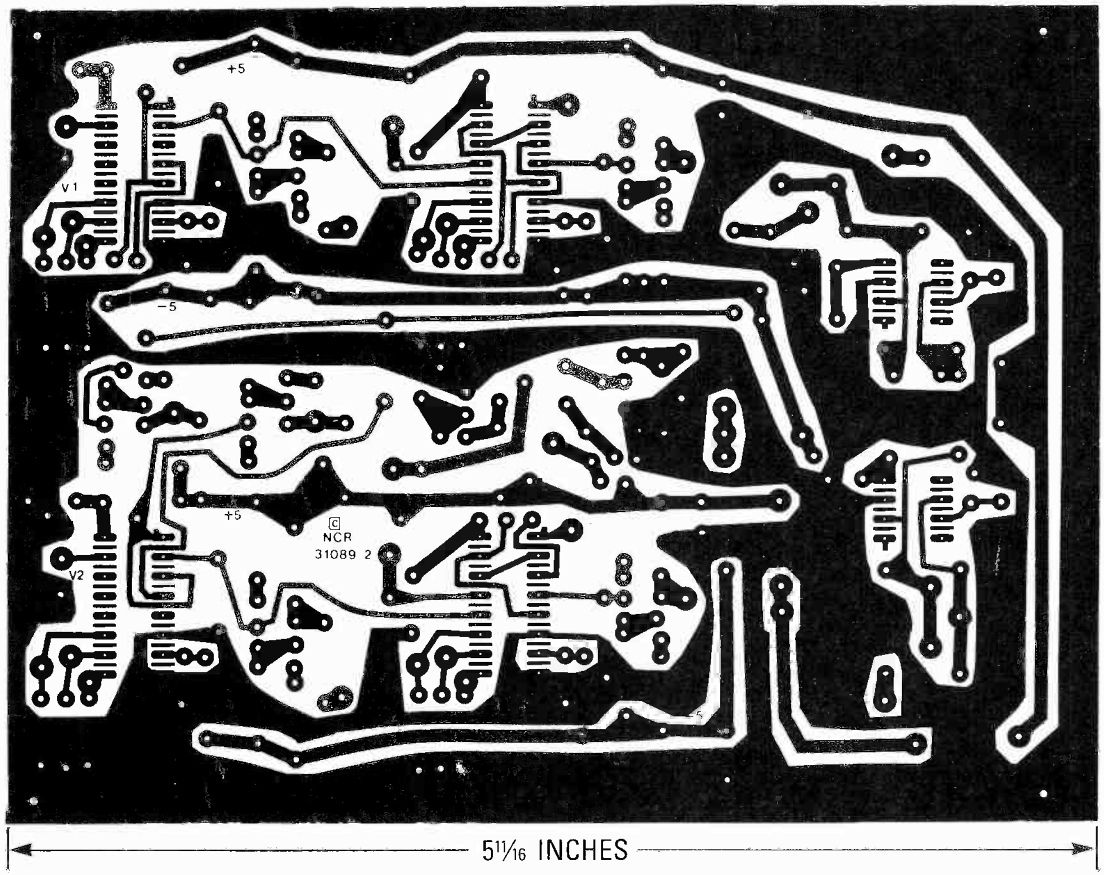


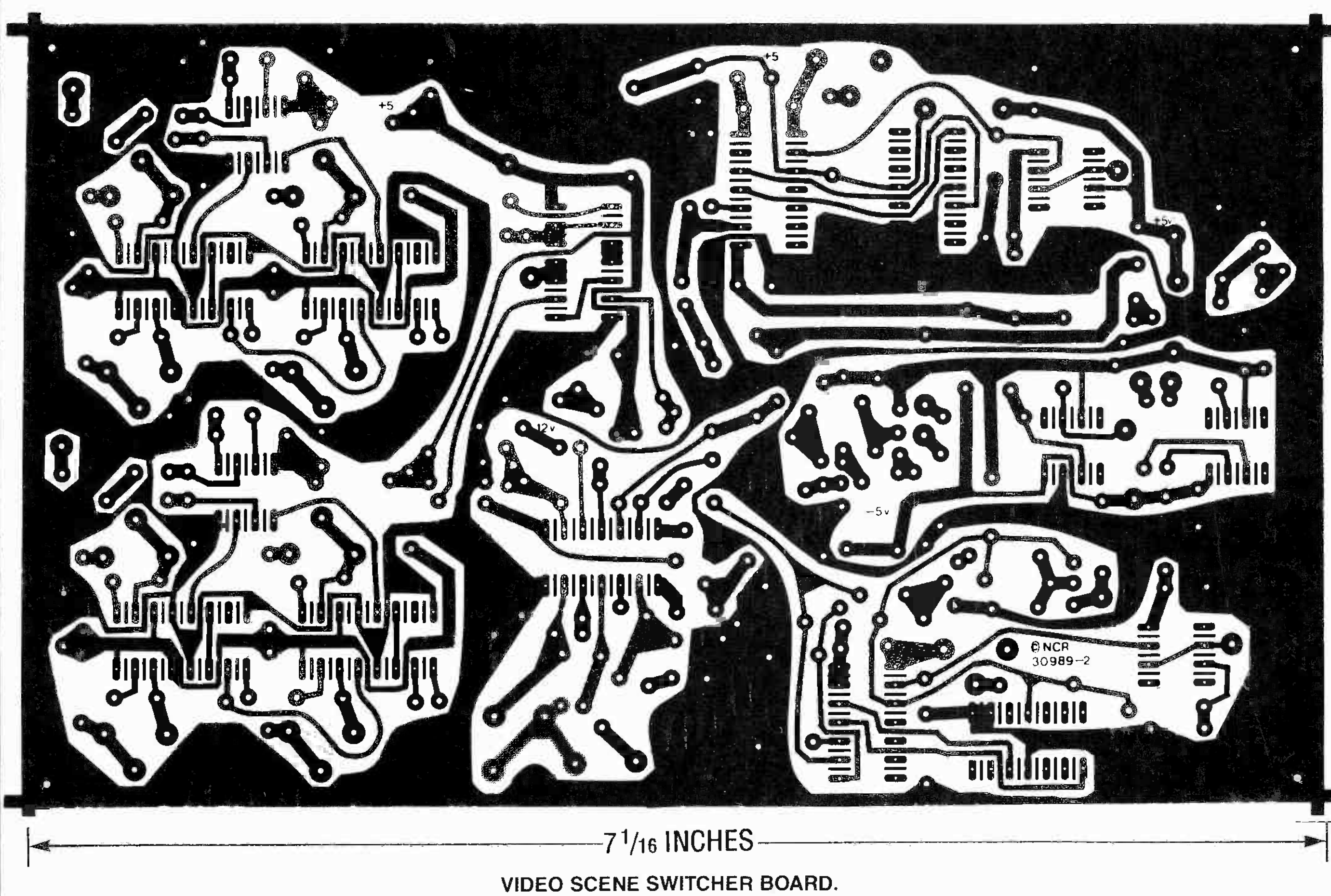
FIG. 19—VOLTAGE-SENSING ANTI-THEFT burglar alarm system and immobilizer switch for cars and other vehicles.

electronic burglar alarm shown in Fig. 19 detects a small decrease in battery voltage that occurs when a light or the ignition switch is turned on, which will cause a load on the battery.

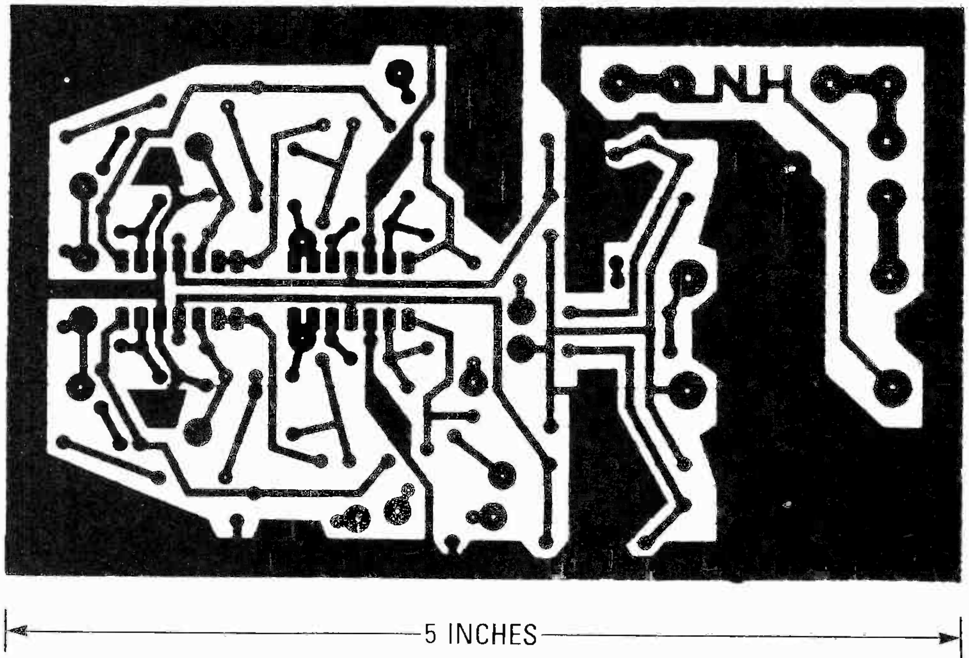
Instead of using microswitches, C1 will "remember" the mean battery voltage and apply it to pin 3 of IC1, while the instantaneous battery voltage is applied to pin 2. If the battery voltage falls beneath its mean value, the output of IC1 goes high, turning on RY1 via Q1-Q2. The contacts for both RY1 and RY2 work as shown in Fig. 18. **R-E**



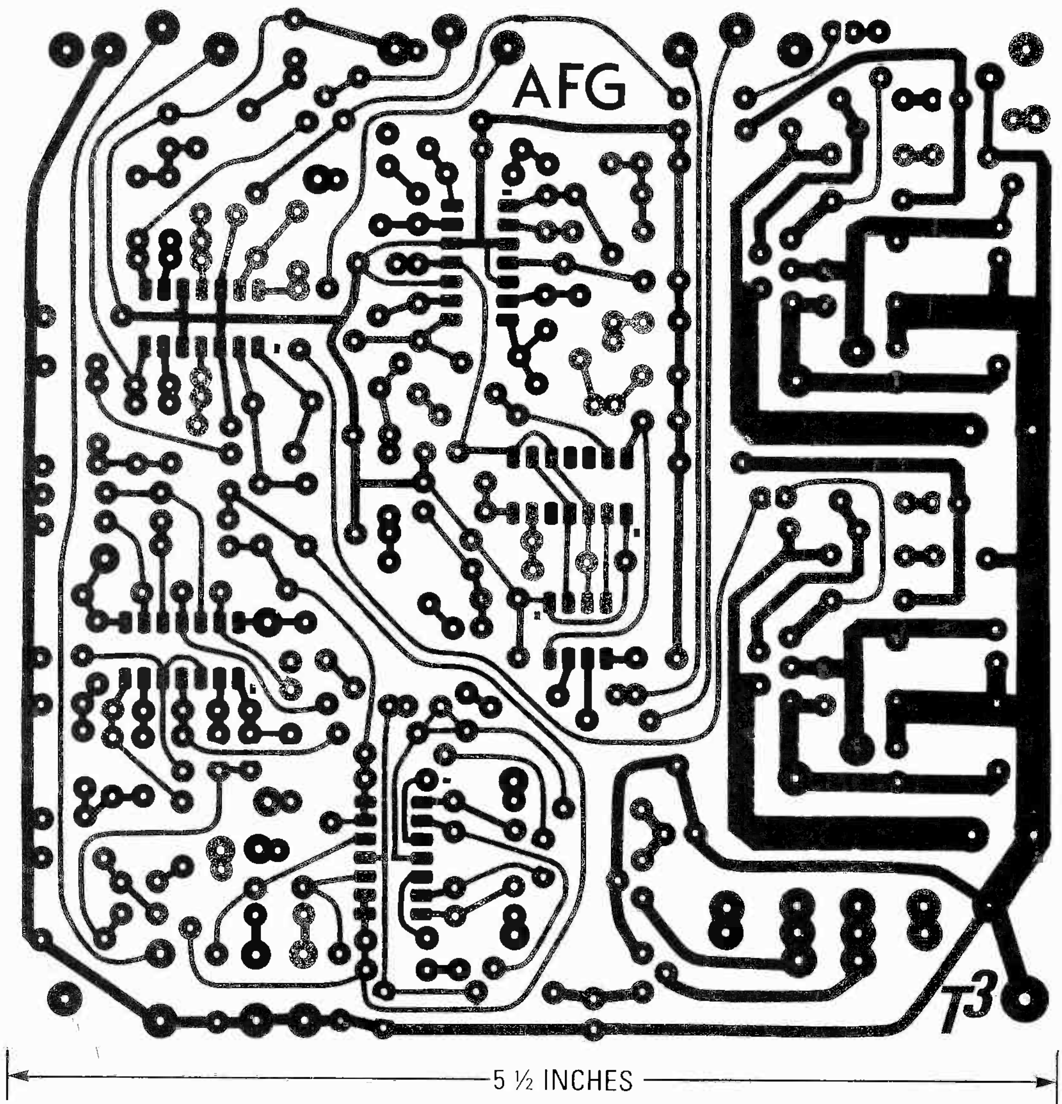
VIDEO SCENE SWITCHER BOARD.



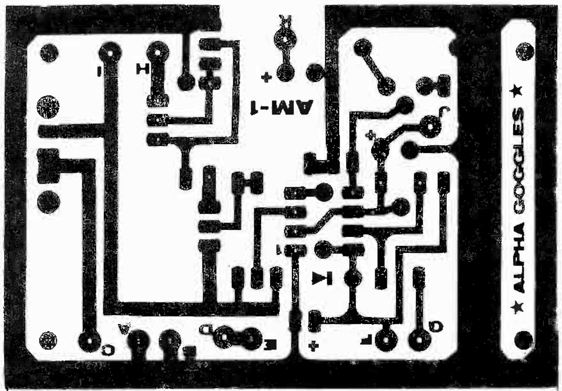
VIDEO SCENE SWITCHER BOARD.



BUILD THE SUBWOOFER SIMULATOR using this board.

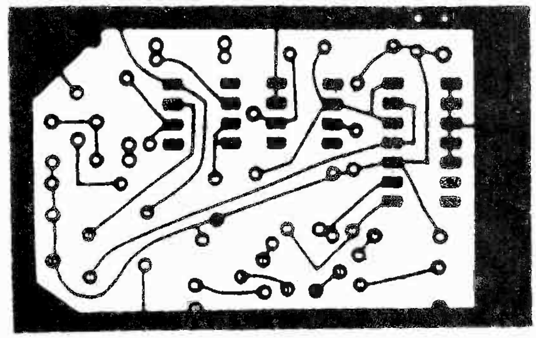


ACOUSTIC FIELD GENERATOR foil pattern.



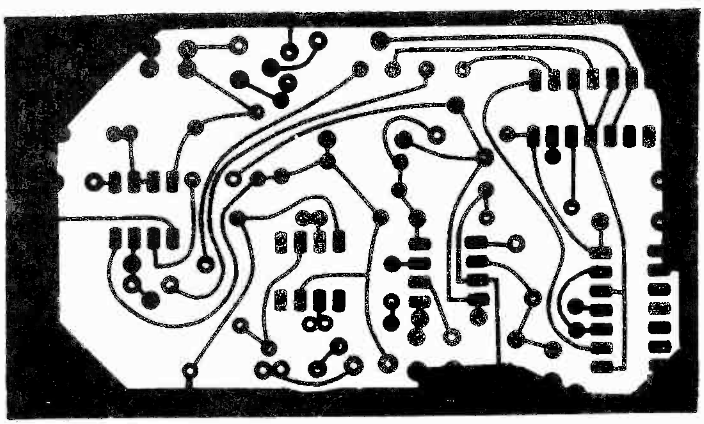
2 7/8 INCHES

ALPHA MEDITATION GOGGLES foil pattern.



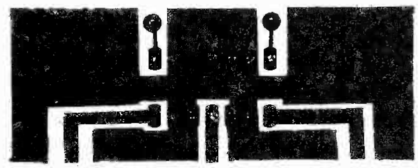
2¾ INCHES

THE IR EXTENDER foil pattern.



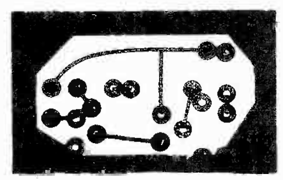
3 5/8 INCHES

A/B RECEIVER.



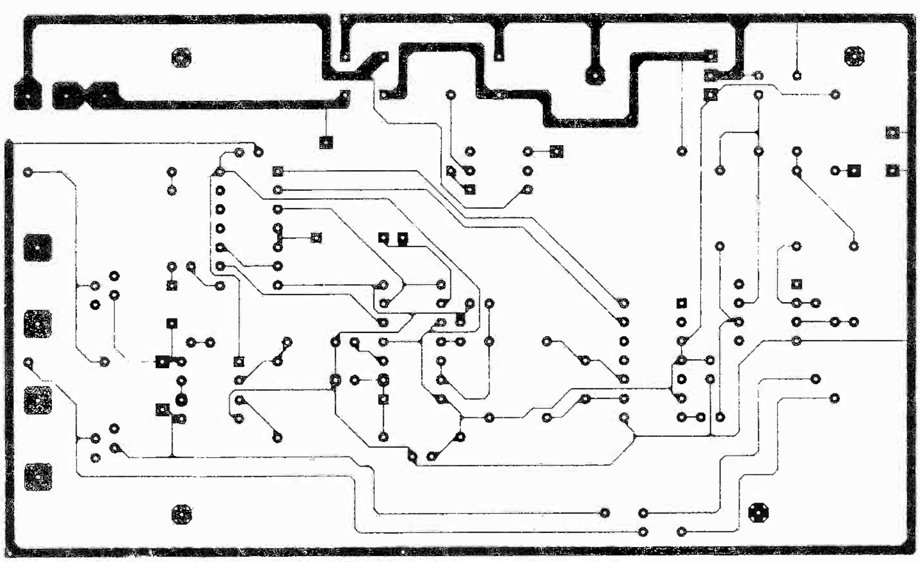
2 1/8 INCHES

A/B RELAY MODULE.



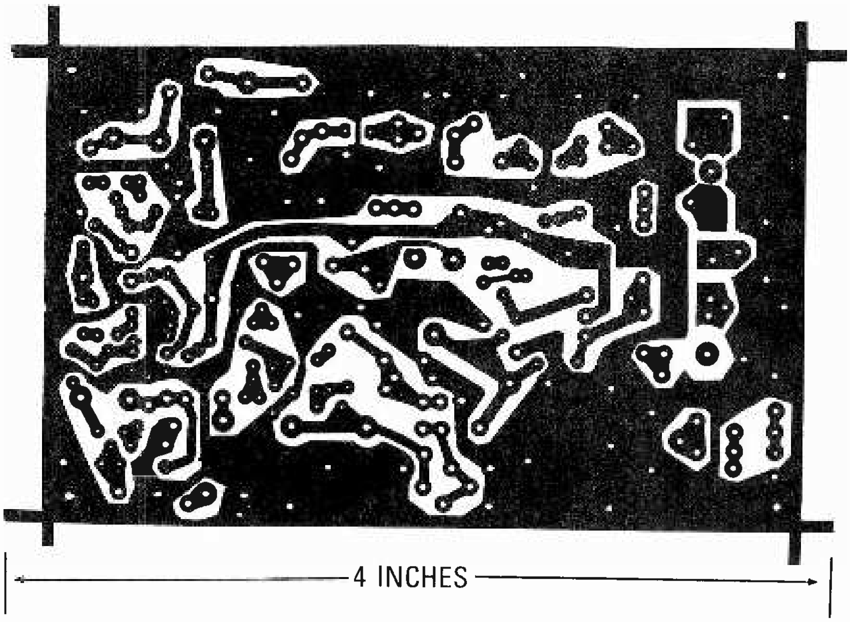
1 3/8 INCHES

A/B TRANSMITTER.

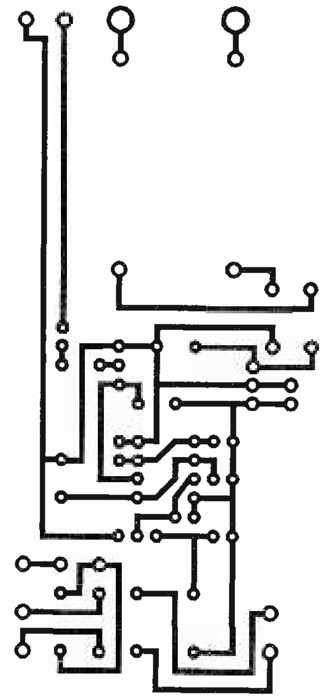


4 3/4 INCHES

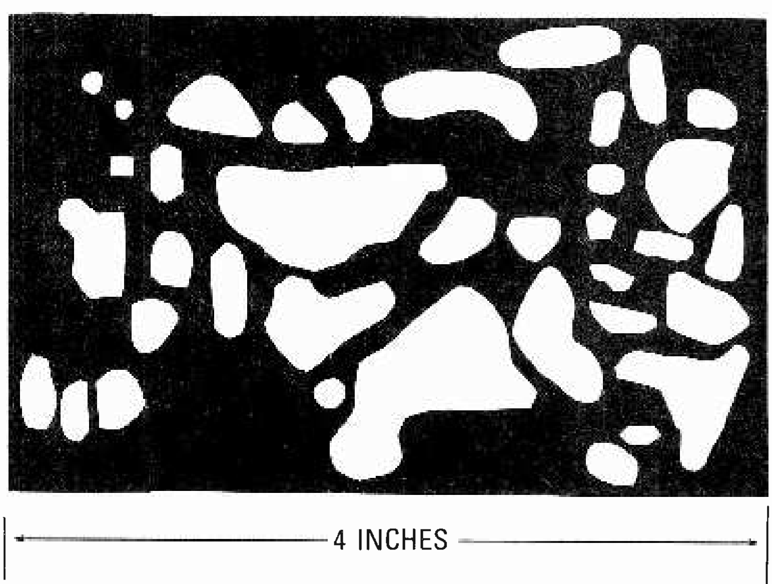
FAXMATE FOIL PATTERN.



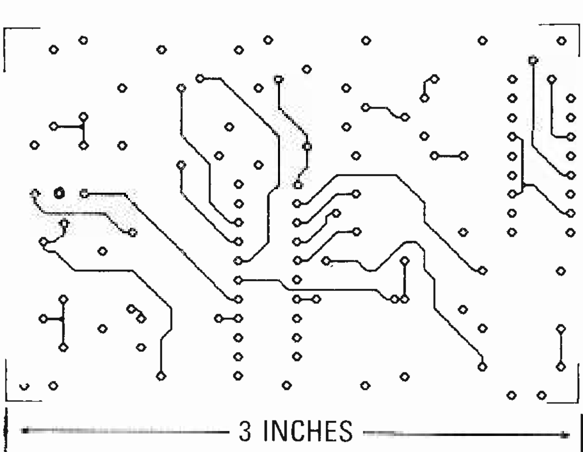
FOIL SIDE OF TV TRANSMITTER.



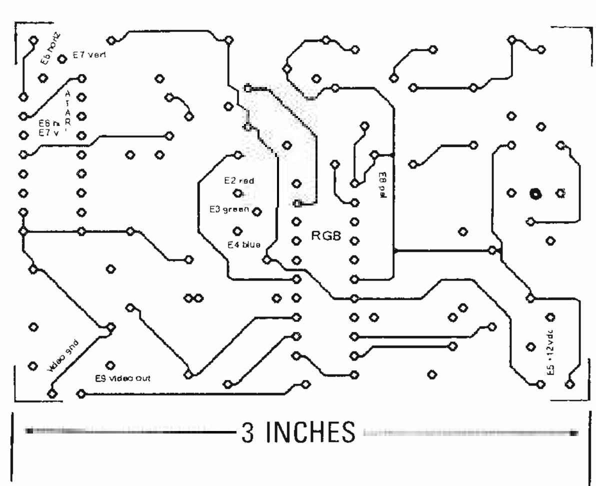
Audio-muting circuit's solder-side foil pattern ▶



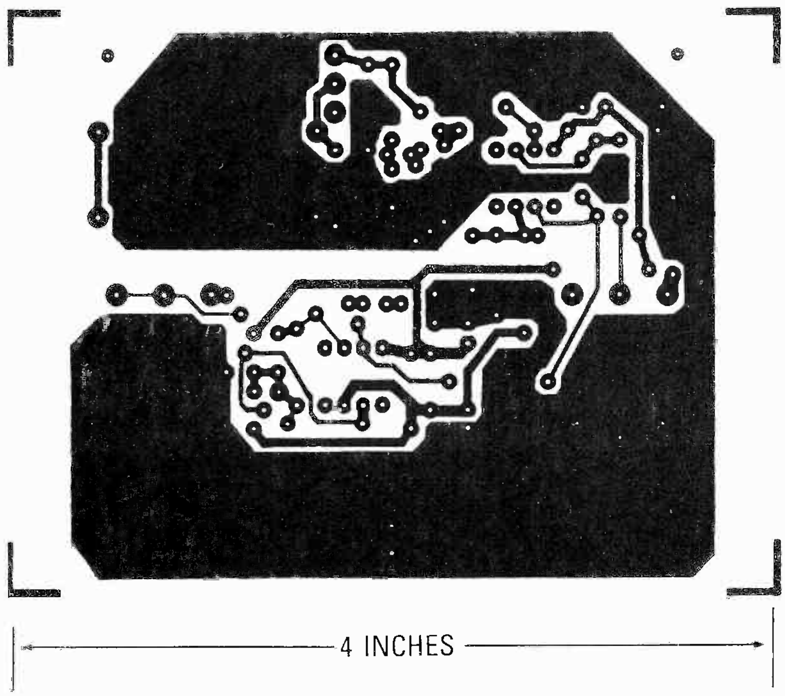
COMPONENT SIDE OF TV TRANSMITTER.



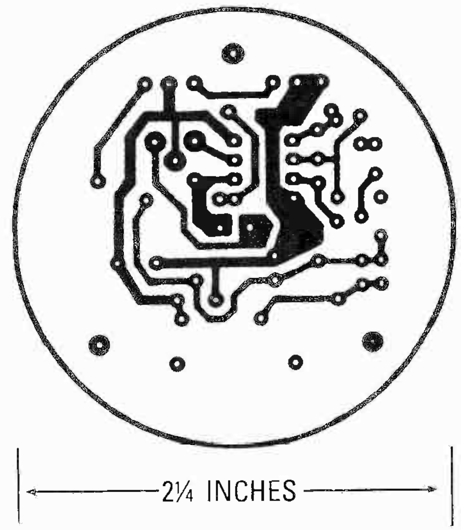
COLOR CONVERTER SOLDER SIDE.



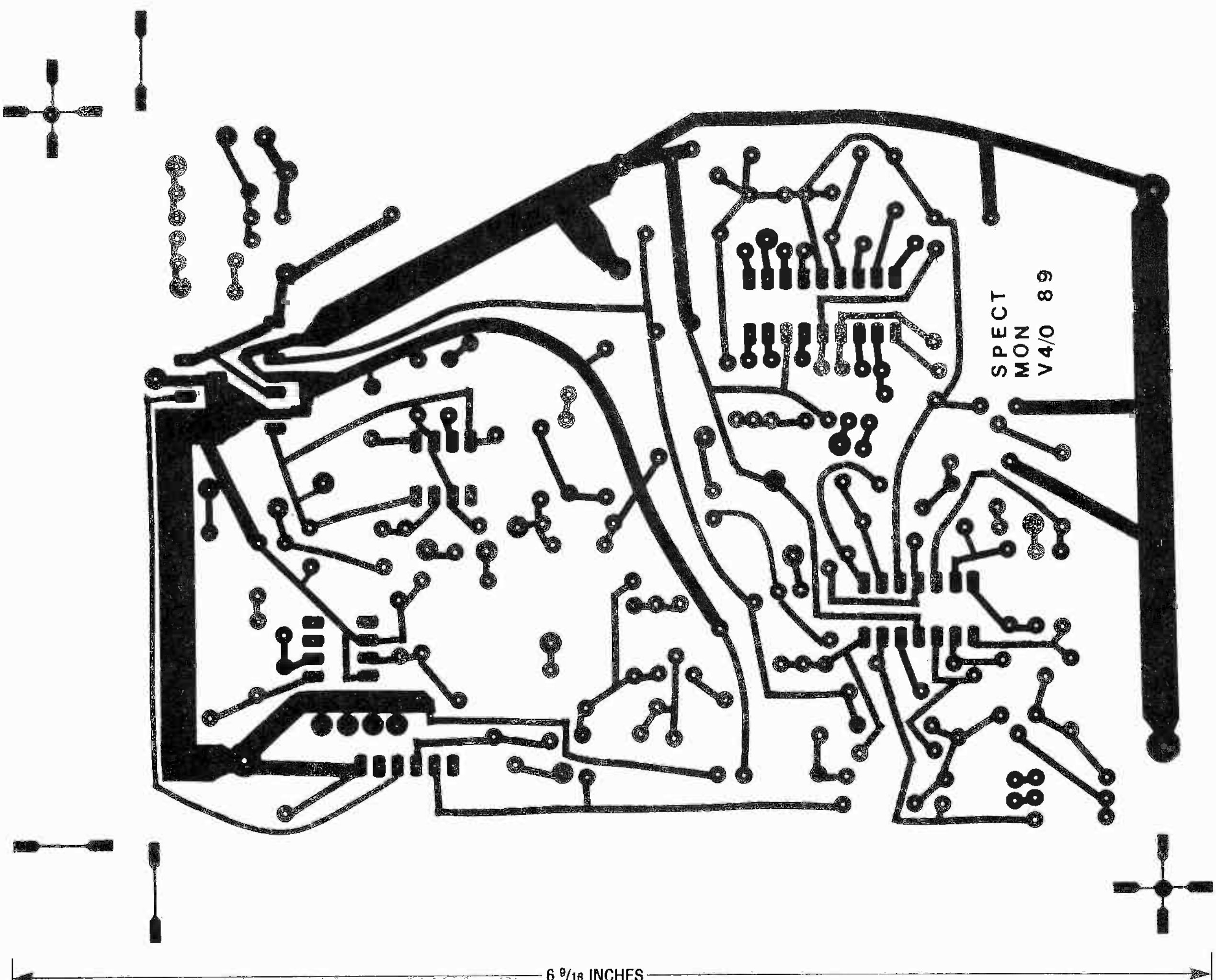
COLOR CONVERTER COMPONENT SIDE.



THE LBC'S RECEIVER BOARD.

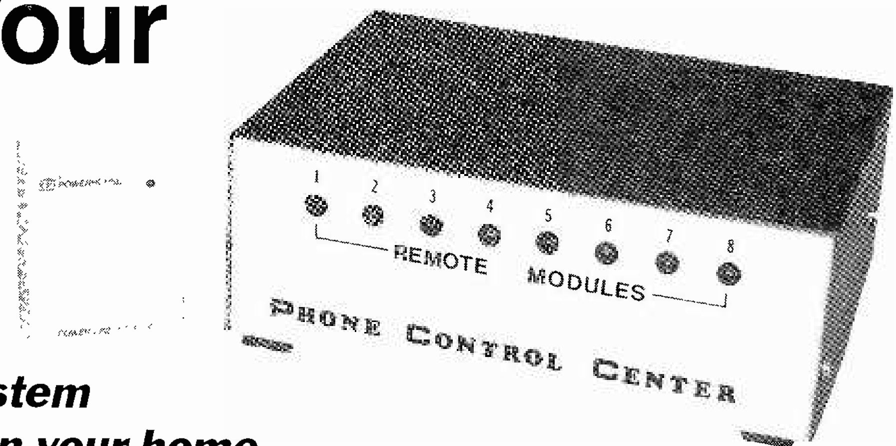


THE LBC'S TRANSMITTER BOARD.



SPECTRUM MONITOR FOIL PATTERN.

Control Your Home Through Your Telephone



Build this X-10 compatible controller system and let every telephone in your home control lights and appliances.

RONALD J. DALEY

WHETHER YOU'RE A REMOTE-CONTROL fanatic, or just an average home owner, you may be interested in our innovative X-10 compatible telephone controller. Imagine the convenience of coming home to stereo music and air-conditioning, or the secure feeling of a lived-in home while you're away, all controlled by any Touch-Tone phone! This can also be a useful device for the visually impaired or the handicapped.

The phone control center (PCC) is compatible with the popular and easily available X-10 system. The PCC can control any remote X-10 module via a Touch-Tone phone. The X-10 Powerhouse control console transmits coded signals to remote plug-in modules over your existing house wiring via carrier-current modulation techniques. The coded signals determine which remote modules turn on and which turn off. With the PCC, you can control up to eight modules with any home or business phone. Any new extension phone, even if it's cordless, automatically becomes a controller—one unit does it all!

Not only can you control remote modules with your cordless phone from several hundred feet away, but the PCC has a home security connection to command "ALL LIGHTS ON" when an on-premise alarm system is activated. If an alarm system is not used, the input can be wired to a remote switch for manual operation of that security feature. Another option available in the PCC is a status monitor with eight light-emitting diodes (LED's) that indicate which of the remote modules are on or off.

You may wonder if your PCC will interfere with another PCC unit in a different house—you don't want to get a call from your neighbor complaining that his lights keep flashing on and off when you're operating your PCC! There's no need to worry about that because the PCC software uses specialized codes to prevent inter-system interference. Up to 16 PCC controllers can be used on the same power line.

Circuit theory

At the heart of the system is the 8035, an 8-bit microcomputer with an on-board RAM, programmable timer, and 24 I/O ports, 11 of which are reserved for the databus that interfaces with the RAM and the dual-tone multi-frequency (DTMF) receiver IC. Two hardware interrupts are used, one to recognize a valid tone, and the second to control a 4-second timer. Figure 1 shows a block diagram of the system.

Besides the microcomputer circuitry shown in Fig. 2, the PCC has three other sections; the telephone interface, power-supply/RF oscillator, and optional status indicator. The telephone interface shown in Fig. 3 provides a high-impedance differential connection to the phone line to reduce line loading and noise susceptibility. The output signal from pin 6 of IC7 is amplified and capacitively coupled to IC8, a DTMF receiver.

A 3.58-MHz TV color-burst crystal is used in IC8, which contains all the necessary on-board circuitry (discriminators, filters, clocks, timers, and decoders) to detect and validate individual Touch-Tone signals. Once a tone has been validated, the processor is interrupted and IC8 immediately resets for the next tone pair.

The power-supply is shown in Fig. 4; a full-wave rectifier, D2 and D3, is filtered by C9 and regulated by IC5 to provide +5 volts DC to the PCC. A heat sink for IC5 is built into the PC board. The +12 volts DC unregulated input to IC5 is also needed to power IC7.

The status indicator shown in Fig. 5 has eight LED's in series with 860-ohm line dropping resistors going to IC6, a 74LS164 8-bit parallel-output serial shift register. The 8035 provides the necessary clocking and data levels to control the interface. The 74LS164 in turn provides the necessary output voltages for the LED's on the front panel.

The RF oscillator, zero-crossing detector, and AC house wiring in-

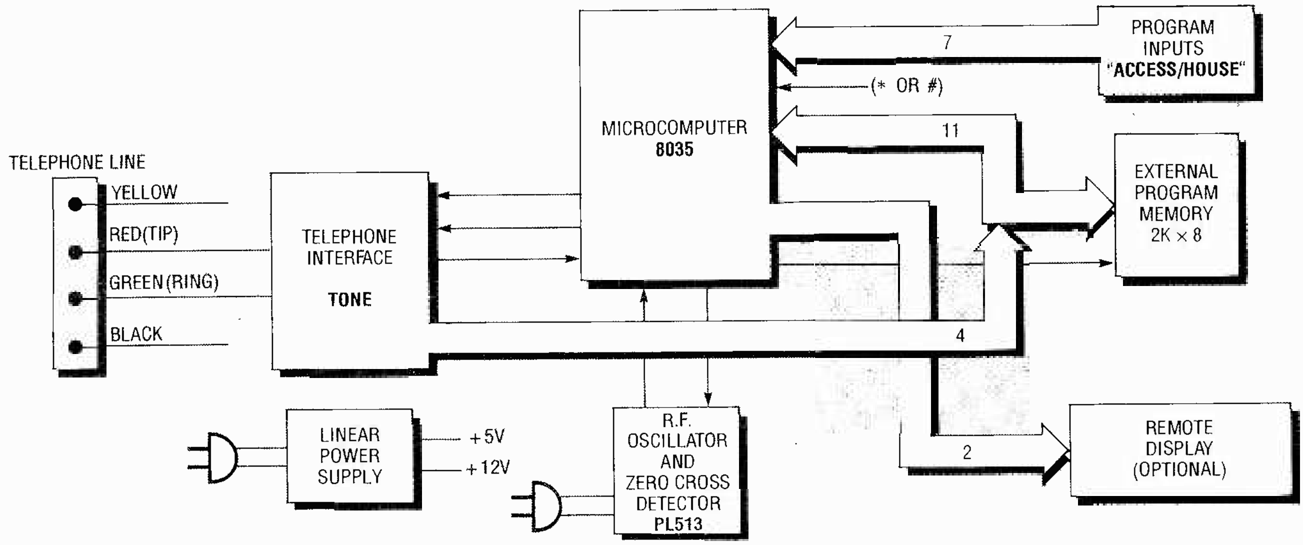


FIG. 1—BLOCK DIAGRAM OF THE PCC. The heart of the system is the 8035, an 8-bit microcomputer which interfaces with the program memory and the telephone tone decoder circuit.

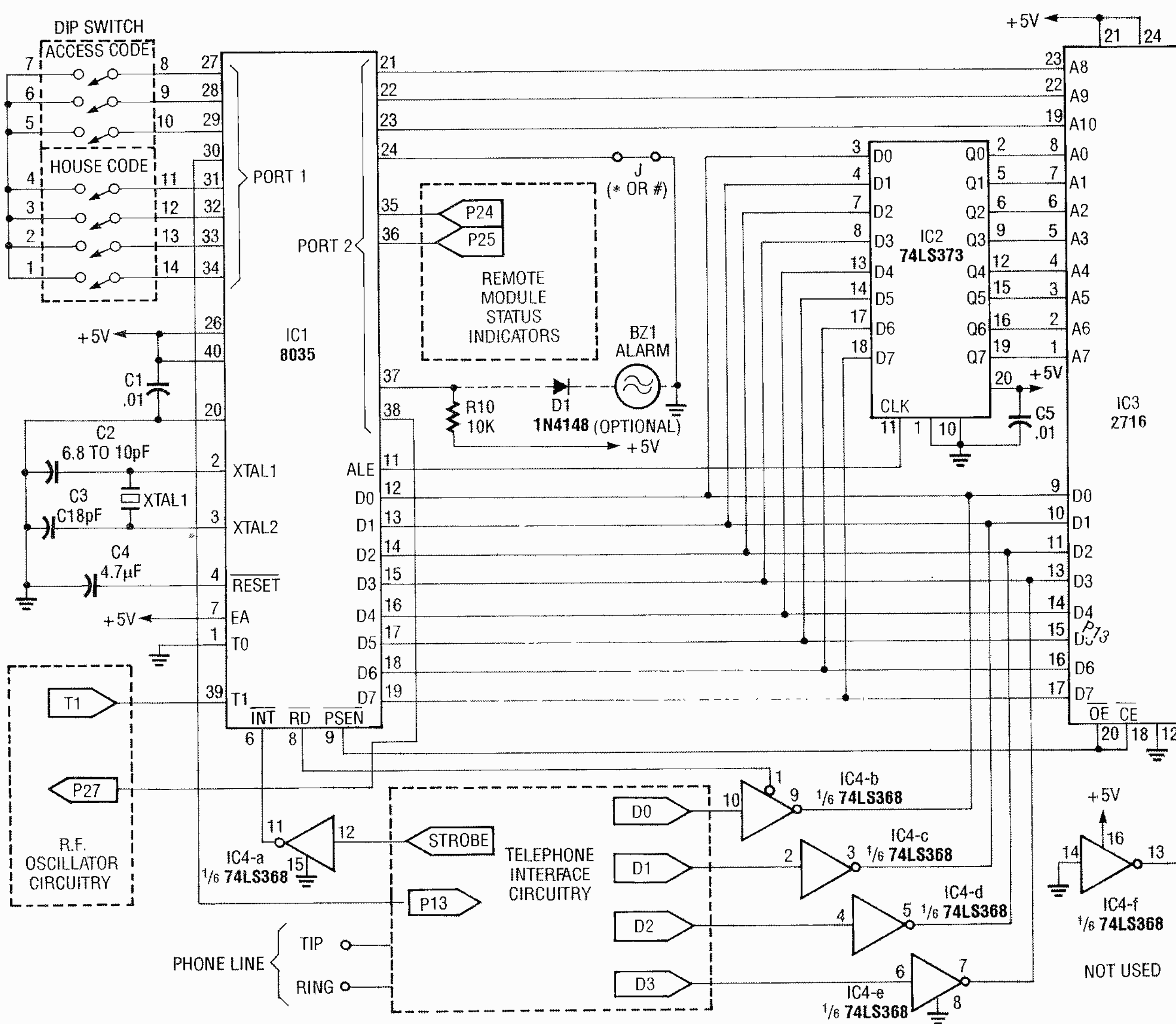


FIG. 2—MICROCOMPUTER INTERFACE CIRCUITRY. An on-premise alarm can be connected between the cathode of D1 and ground, which will turn "ALL LIGHTS ON" when activated.

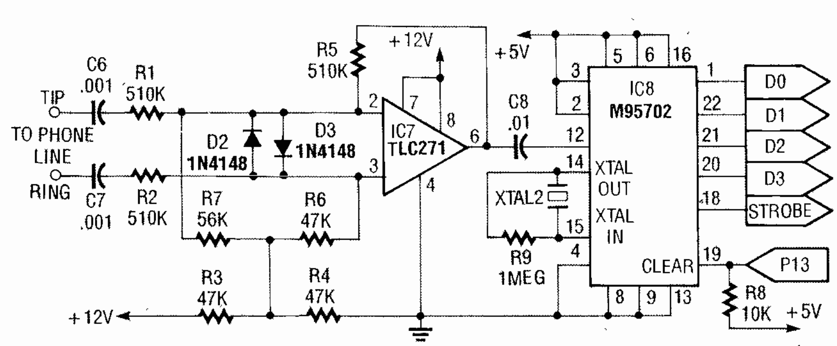


FIG. 3—THE TELEPHONE INTERFACE CIRCUITRY provides a high impedance, differential connection to the phone line. The amplified signal from pin 6 of IC7 is capacitively coupled to IC8, a DTMF receiver.

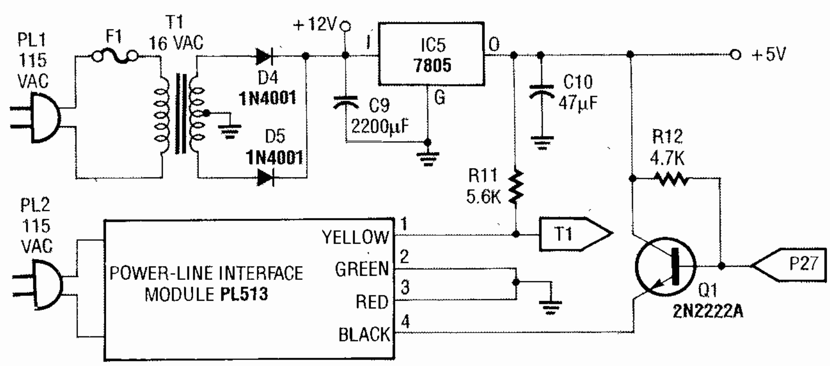
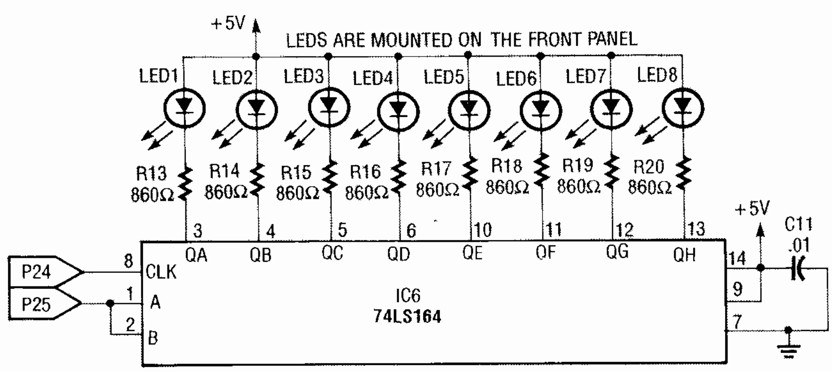


FIG. 4—THE POWER-SUPPLY AND RF OSCILLATOR circuitry; this is a basic linear type power-supply. The +5 volts DC from IC5 provides power to the PCC.



5—THE STATUS INDICATOR circuitry centers around IC6, an 8-bit parallel output, serial shift register.

terface are all contained in the PL513 power-line interface developed by X-10 to let others interface with the vast variety of remote modules. Since the X-10 code is patented, licensing is automatically granted to the purchasers of the power-line interface. The user must provide the necessary interface and control to the PL513.

The remote modules are controlled by pulse-width modulating (PWM) your AC power lines at 120-kHz. The ON cycle lasts for 1 millisecond, and the OFF cycle for 1.6 milliseconds. The exact timing is crucial for proper operation of the PWM transmission; Fig. 6 shows a typical waveform of that transmission line.

Synchronization of the remote modules is established when the coded signal is transmitted within 200 microseconds of the AC zero-crossing point. The encoded message is then transmitted to either operate the remote modules individually, or to address a specific group all at one time. The latter occurs when you command "ALL LIGHTS ON" or "ALL LIGHTS OFF."

The transmission begins with a start code, followed by a house code, and either a number or function code. With the exception of the start code, the remaining codes are all four or five bits, transmitted during the first half of the AC cycle, followed by their complement during the second half. Table 1 contains the PCC house codes, and Table 2 lists the module number and transmission codes. A binary "1" is transmitted as a 120-kHz burst lasting 1 millisecond, and a binary "0" is no burst. The start code "1110" consists of three 1-millisecond bursts in each of the first three half-cycles, followed by a binary "0" (no burst) in the fourth cycle. The start code synchronizes the remote modules in receiving and decoding messages that are transmitted from the PCC. To increase system reliability, each command block is transmitted twice, lasting eleven AC cycles each.

Software

The PCC software is available from the source in the parts list as a separate item. Anyone having access to the necessary software tools can easily modify the program as needed.

The main PCC control loop is shown in Fig. 7. The program starts with the initialization of all software control variables, and then reads the microswitch settings (both house and access codes) that were previously programmed by the user. The program waits about seven seconds for the user to define the remote light modules then runs the system diagnostic check. If the PCC is working, the diagnostics will

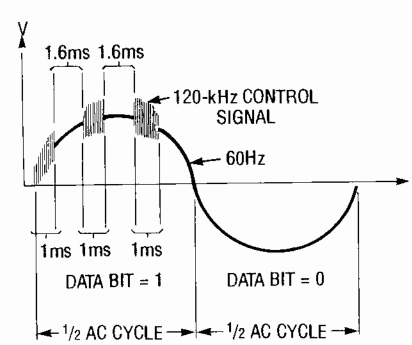


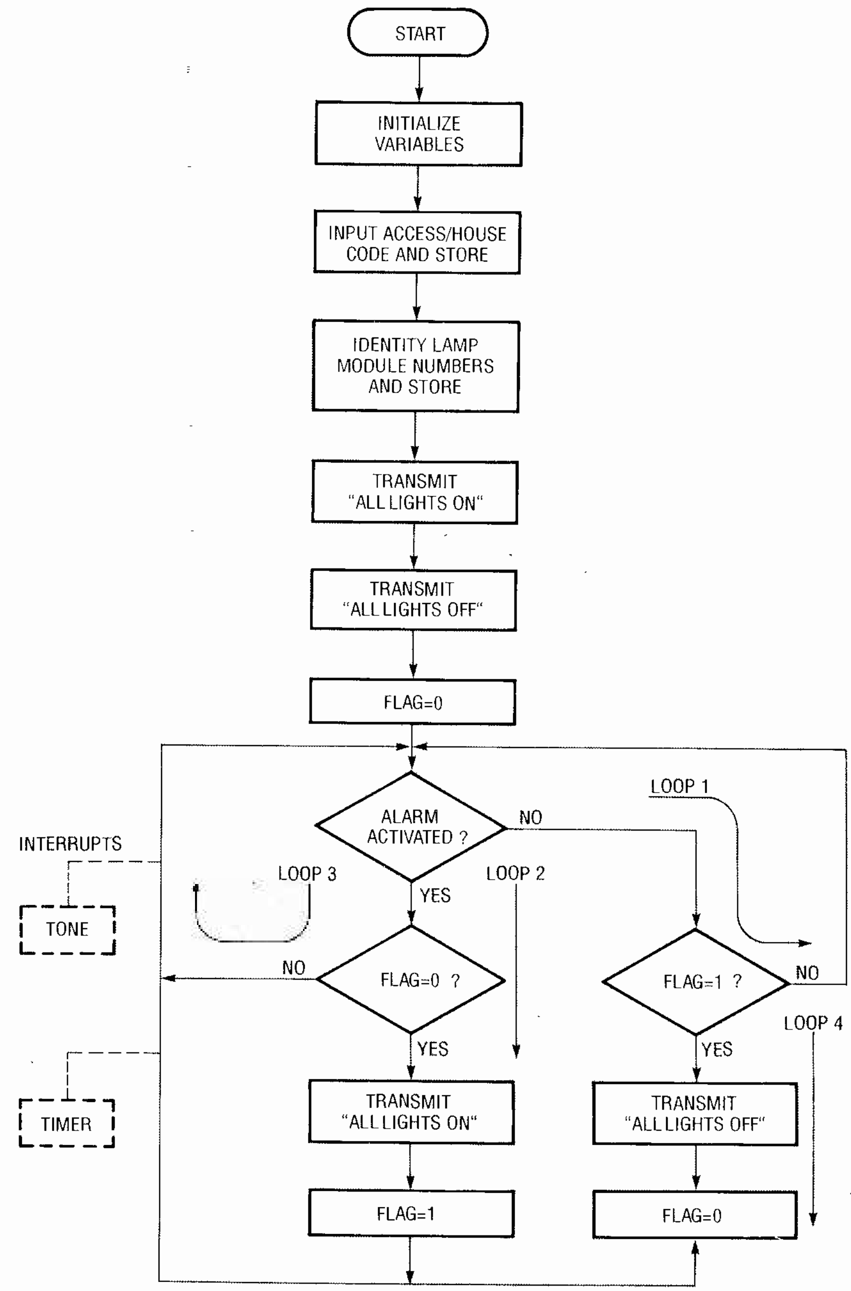
FIG. 6—A TYPICAL 60-Hz AC transmission consists of a pulse-width modulated waveform. A 120-KHz frequency is superimposed on the sine-wave during the 1-millisecond ON pulse, according to the specific code that is transmitted (see Tables 1 and 2.)

TABLE 1—HOUSE CODES

House Code	Transmission Code			
A	0	1	1	0
B	1	1	1	0
C	0	0	1	0
D	1	0	1	0
E	0	0	0	1
F	1	0	0	1
G	0	1	0	1
H	1	1	0	1
I	0	1	1	1
J	1	1	1	1
K	0	0'	1	1
L	1	0	1	1
M	0	0	0	0
N	1	0	0	0
O	0	1	0	0
P	1	1	0	0

turn all lamp modules on for about one second then turn them all off. The status indicator is updated for one second, then it will display blanks.

The program spends most of its time in control loop 1 waiting for activity. If an alarm is enabled, the software enters control loop 2 to turn on all the light modules, followed by control loop 3 until the alarm has been disabled, at which time control loop 4 turns off all the light modules, then the cycle repeats. During that interval, the two interrupt routines, shown connected by dotted lines, are enabled.



7—A FLOW CHART OF THE controllers main loop.

The tone-interrupt routine shown in Fig. 8 is entered any time a valid DTMF signal is detected by the telephone interface circuit. That routine is primarily made up of six control loops identified as 5–10. The routine is activated during start-up when the user enters the remote light module information. During that time, the software variable "MODE COMPLETE" is set equal to 2, and control loop 5 is entered each time a light module identification is entered. When the user enters the access code, control passes to loop 8 if the codes are valid, otherwise control is passed to loop 7. In loop 7, the software variable "MODE COMPLETE" is set equal to 1. Any further tone information is ignored by the PCC and software control is channeled to loop 10 until the "TIMER" interrupt routine re-initializes the software variables, taking about four seconds. If the access code is entered correctly, loop 9 remains active until the PCC is inactive for four seconds, or the user terminates the PCC by entering "*" or "#".

The second "TIMER" interrupt, shown in Fig. 9, is enabled by the "TONE" routine. It increments a 4-second hardware/software timer that suspends PCC operation when it's inactive for at least four seconds.

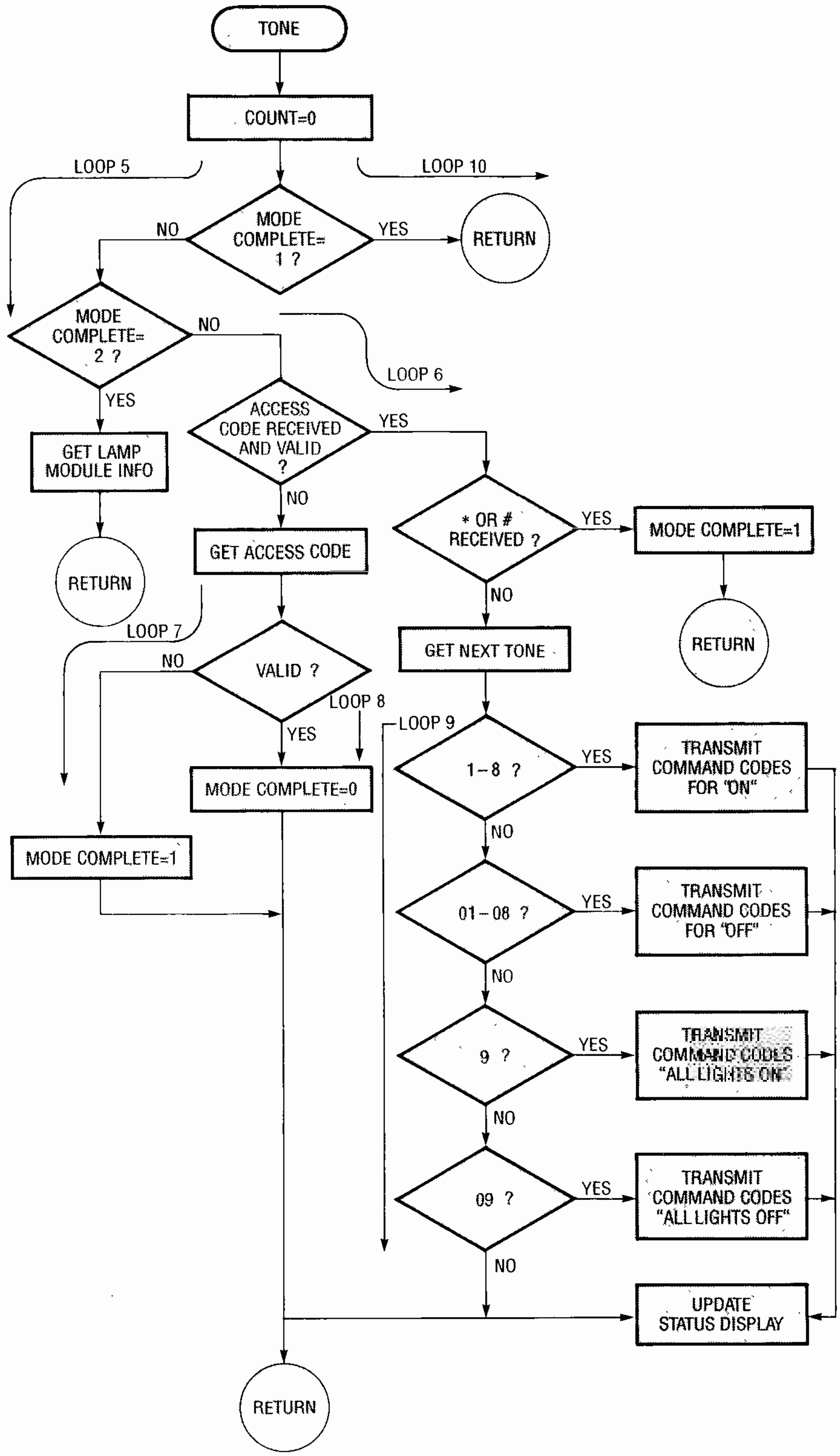
The 8035 has an internal 8-bit counter under program control. The clock input, T1, is derived from the AC zero-crossing detector incorporated in the PL513, which increments the counter every 8.3 milliseconds when enabled. Since the maximum time obtained before overflow is 2.1 seconds (256 × 8.3 milliseconds), the 4-second timer gets the job done by accumulating multiple overflows in a register under software control.

Construction

The PCC is built on a double-sided PC board, the foil patterns of the component side and solder side are shown in this article. An etched and drilled PC board is available from the source in the parts list.

Install all components according to the parts placement diagram shown in Fig. 10, a view of the inside of a completed PCC is shown in Fig. 11. Use DIP sockets for all IC's, and make sure they're correctly positioned. When installing T1, the dot on the transformer should match that of pin 1 on the parts placement diagram, which is the primary AC side connected to F1. When connecting the PL513 to the PCC, match the pin numbers with the correct wire color code as shown in Fig. 4.

The AC power cord goes to the PC board at the locations shown in Fig. 10 after one side is connected to the fuse holder. If the alarm function is used, install



8—A FLOW CHART OF THE TONE interrupt service routine.

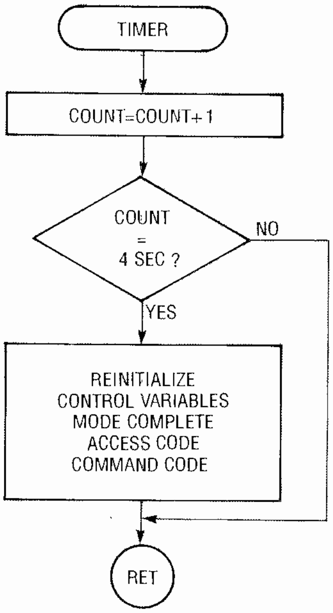


FIG. 9—THIS IS A FLOW CHART timer routine.

two wires at the locations shown in the parts placement diagram to an alarm system with a normally open contact. Connect the status LED's as shown in Fig. 10, and mount them on the front panel with grommets, or other suitable hardware.

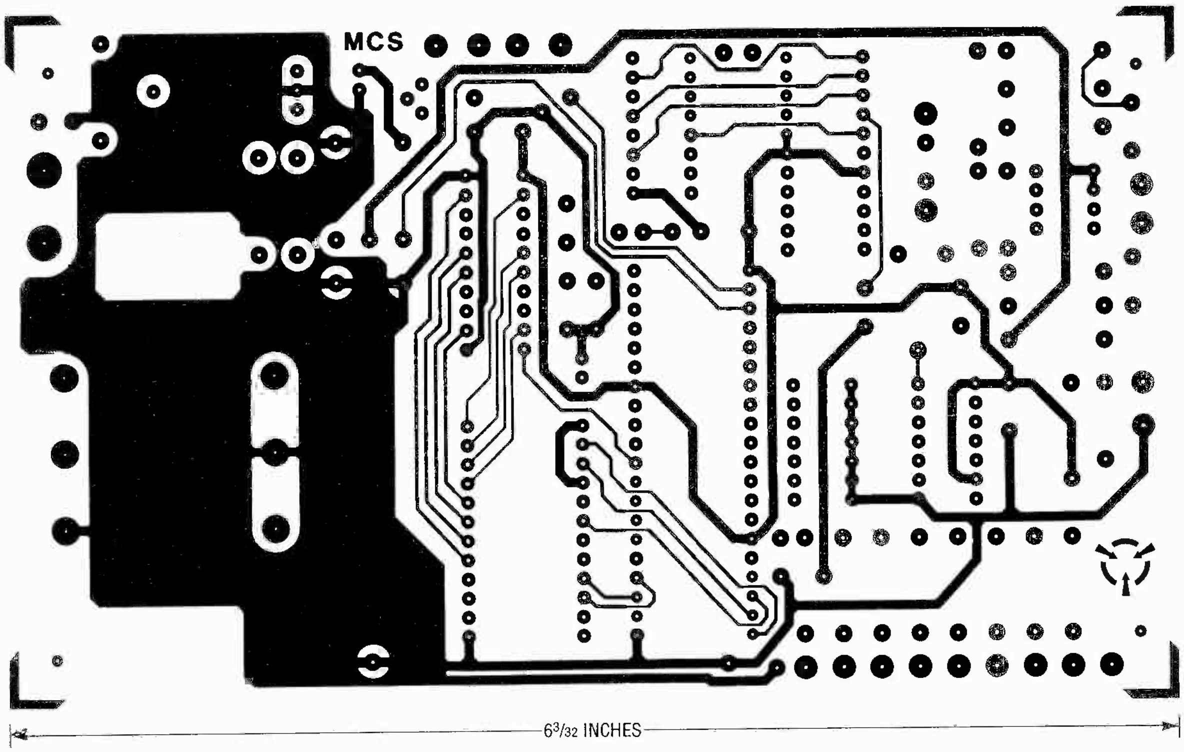
Connect the phone-line tip (green) and ring (red) connections as indicated. If you buy the complete PCC kit, two 6-foot modular phone extension cords are included with modular phone jacks attached. Since the PL513 uses the same modular phone connector as the local phone company, label the two cords at the end of the plug to avoid wrong connections.

Any connection to the phone line is controlled by the Federal Communications Commission (FCC), Part 68, and your local telephone company. Since each telephone company may have its own regulations, we suggest you contact yours before making any connections to the phone line. In general, the FCC is concerned that no disturbances of any type occur on a phone line; all connections to it must be made through standard plugs or jacks so the device can easily be disconnected if suspected of causing interference. The PCC has been designed to meet those requirements. Let's see how easy it is to program and checkout the PCC.

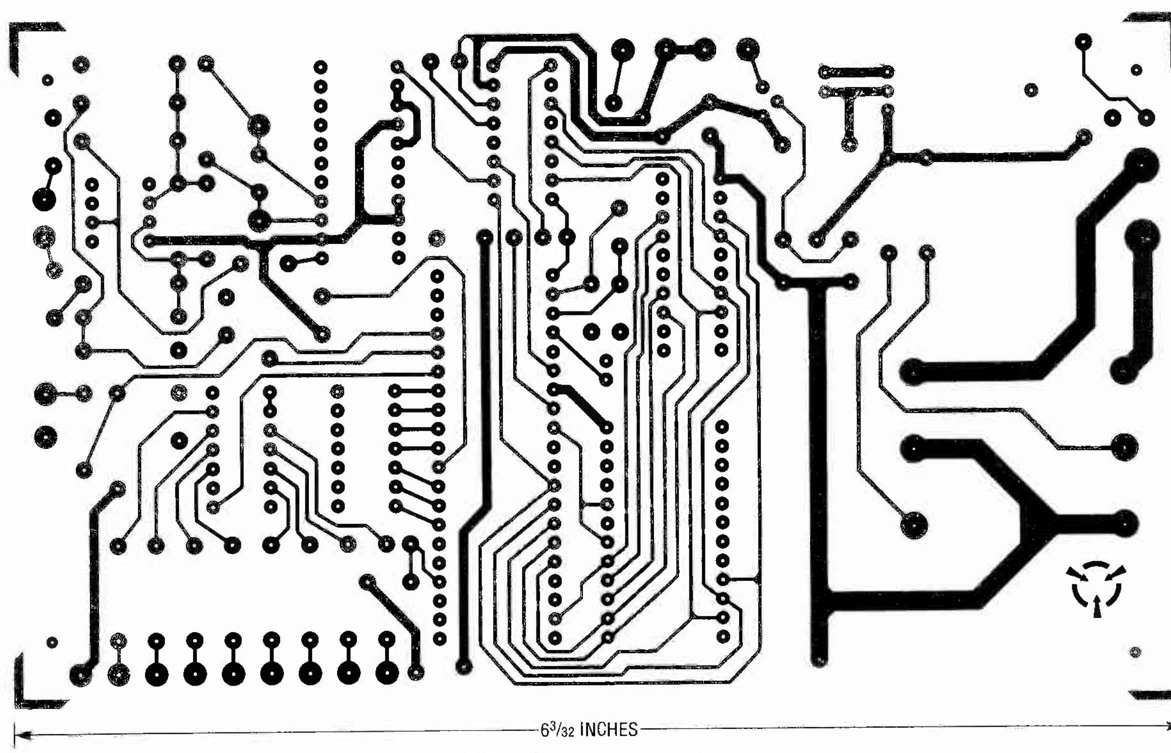
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1, R2, R5—510,000 ohms
R3, R4, R6—47,000 ohms
R7—56,000 ohms
R8, R10—10,000 ohms
R9—1 megohm
R11—5600 ohms
R12—4700 ohms
R13-R20—860 ohms
Capacitors
C1, C5, C8, C11—.01 µF, ceramic disc
C2—6.8 to 10 pF, ceramic disc
C3—18 pF, ceramic disc
C4—4.7 µF, electrolytic
C6, C7—.001 µF, ceramic disc
C9—2200 µF, electrolytic
C10—47 µF, electrolytic
Semiconductors
D1, D2, D3—1N4148 switching diode
D4, D5—1N4001 rectifying diode
Q1—2N2222A NPN transistor
IC1—8035 microprocessor
IC2—74LS373, 8-bit latch
IC3—2716, 2K × 8 EPROM
IC4—74LS368, hex bus drivers
IC5—LM7805, +5-volt regulator
IC6—74LS164, 8-bit parallel output serial shift register
IC7—TLC271, op-amp
IC8—M95702, DTMF receiver
Other components
S1—SPST microswitches 1–7
T1—16 volts AC, 260-mA center-tapped secondary winding transformer
XTAL1—6-MHz crystal
XTAL2—3.58-MHz crystal
PL513—X-10 power-line interface module, available from X-10 (USA) Inc., Anova Electronics, Leviton, General Electric, Pittway Corporation or Radio Shack.
Miscellaneous: AC line cord, PC board, LED's, LED mounting hardware, ¼-amp fuse, fuse holder, 2 modular phone extension cords, and 3 strain reliefs.
NOTE: The following items are available from Master Control Systems, P.O. Box 504, Ellington, CT 06029: A kit of all parts including a programmed EPROM, an etched, drilled and plated-through PC board, and miscellaneous items, $135.00; a programmed EPROM, $20.00; an etched, drilled and plated through PC board, $35.00; program listing, $10.00. Please add 5% for postage and handling in the U.S., 10% for foreign orders. Connecticut residents include 7.5% sales tax. Allow 2 to 4 weeks for delivery.

Programming the PCC

The first step in programming the PCC is to enter the house code and access code into the PCC via the seven slide switches on S1. The house codes, identified as letters A–P, allow independent operation of up to 16 PCC controllers. Table 3 shows the switch settings for the 16 house codes. Select one house code and set switches S1–S4 to their ap-



SOLDER SIDE OF THE PCC BOARD.



COMPONENT SIDE OF THE PCC BOARD.

propriate positions. Select an arbitrary access code (1–8) from Table 4, and set switches S5–S7 as indicated. The house code and access code is set only once, although you may wish to change the access code occasionally for security reasons.

The remote X-10 modules you're using have both a unit code and a house code, which must be properly set. The house code (A–P) on *all* modules should be set to the specific house code you chose. Each module should be assigned its own unit code (1–8), corresponding to the power outlet locations used with them.

The PCC has the capability of commanding "ALL LIGHTS ON" to the remote modules. A problem that arises with that command, as you might imagine, is that you may want to turn on *only* the light modules, not the modules that control other appliances. To circumvent that problem, you can program only the light modules you wish to turn

TABLE 2—MODULE NUMER AND TRANSMISSION CODES

Module Number Code	Transmission Code
1	0 1 1 0 0
2	1 1 1 0 0
3	0 0 1 0 0
4	1 0 1 0 0
5	0 0 0 1 0
6	1 0 0 1 0
7	0 1 0 1 0
8	1 1 0 1 0
"ALL LIGHTS ON" = 9	0 0 0 1 1
"ALL LIGHTS OFF" = 09	0 0 0 0 1

on with the "ALL LIGHTS ON" command. That task is accomplished the first time the PCC is plugged into an AC outlet. First, enter the access code as previously discussed, then enter "9" ("ALL LIGHTS ON"), and finally, enter the *light* module numbers. This is a one-time operation that is optional.

After the last module number is entered, the PCC delays for four seconds, then transmits "ALL LIGHTS ON" followed by "ALL LIGHTS OFF," while updating the status indicators. The status indicators let the user

TABLE 3—HOUSE CODE SWITCH SETTINGS

S1	S2	S3	S4	House Code
ON	ON	ON	ON	A
ON	ON	ON	OFF	B
ON	ON	OFF	ON	C
ON	ON	OFF	OFF	D
ON	OFF	ON	ON	E
ON	OFF	ON	OFF	F
ON	OFF	OFF	ON	G
ON	OFF	OFF	OFF	H
OFF	ON	ON	ON	I
OFF	ON	ON	OFF	J
OFF	ON	OFF	ON	K
OFF	ON	OFF	OFF	L
OFF	OFF	ON	ON	M
OFF	OFF	ON	OFF	N
OFF	OFF	OFF	ON	O
OFF	OFF	OFF	OFF	P

know if the lamp module information was entered correctly, and are also a useful diagnostic tool.

Checkout

After you've programmed the house code and access code you intend to use with the PCC, connect the telephone-interface modular phone jack (tip and ring conductors) into any modular phone jack in your house. Now connect the other modular phone cord (PL513 pins 1–4) into the PL513. First plug the PL513 into an AC outlet, *then* plug in the PCC.

If you buy the PCC kit, the built-in diagnostic program will assist you in the checkout. The diagnostic program is divided into two parts; it checks the operation of the power-supply, processor, and status display, and verifies the user's programming and interfacing with the PL513.

Immediately after applying power, the eight status LED's will light for about one second, then go blank. About four seconds later, the PCC will transmit "ALL LIGHTS ON," then one second later will transmit "ALL LIGHTS OFF." At that time, all the X-10 modules with the same house code as the PCC will go on, then off. If they do not, verify the house code you programmed is the same one used on the remote modules. If the diagnostic program has run successfully, then only the telephone interface needs to be checked. Assume, for checkout purposes, that your

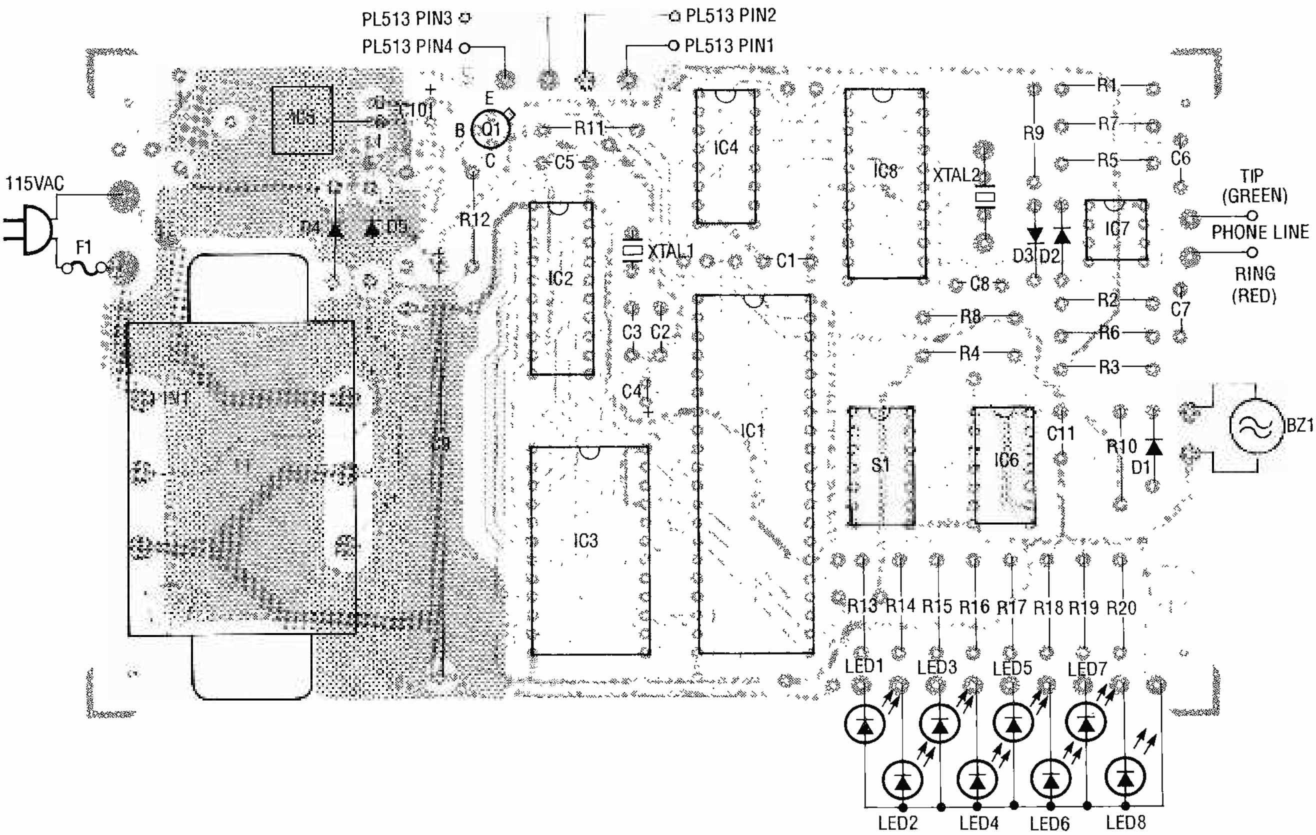


FIG. 10—THIS IS THE PARTS PLACEMENT DIAGRAM of the PCC. The LED's are mounted on the front panel, and the fuse is mounted on the bottom enclosure.

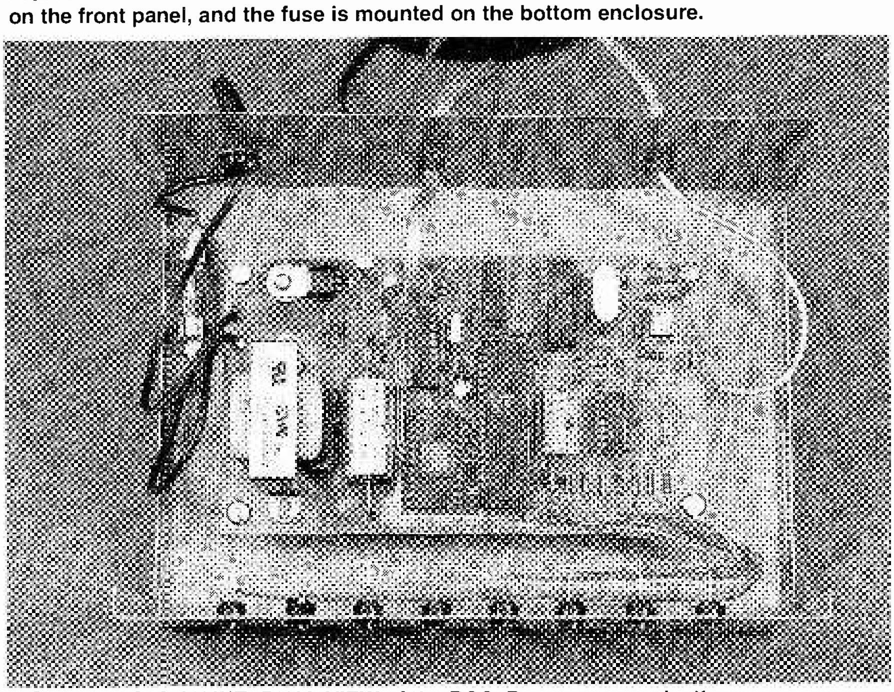


FIG. 11—THIS IS AN INTERNAL VIEW of the PCC. Be sure you make the proper connections to the phone line and the PL513 unit.

system has a remote module number "3" with an assigned access code of "5." Remove the handset from the phone cradle and dial "2," "5," "*," or "#." Within four seconds dial "3," then "0," " 3." Verify that remote module "3" went on, and then off, as did the status indicator monitor position 3. If you haven't already done so, remember that you can identify specific *light* modules to the PCC after the unit is plugged in.

Operation

The PCC is easy to operate and doesn't interfere with normal telephone use. To address a remote module, just lift the handset, dial the access code, then the remote module number. The PCC uses a three digit access code; the first digit is always "2," the second is "1"–"8" (the access code you programmed in S5–S7), and the third is "*" or "#."

To turn a module off, simply precede the module number with a "0." For example, if the assigned access code is "6," and you want to turn modules 1 and 3 on

TABLE 4—ACCESS CODE SWITCH SETTINGS

Switch Setting			Access Code
S5	S6	S7	
ON	ON	ON	1
ON	ON	OFF	2
ON	OFF	ON	3
ON	OFF	OFF	4
OFF	ON	ON	5
OFF	ON	OFF	6
OFF	OFF	ON	7
OFF	OFF	OFF	8

MARKET CENTER

PC BOARD BASICS

continued from page 23

The only exception to that rule has to do with IC legs. Since all the IC's are going to be socketed (soldering IC's to the board is a really bad idea), and since the socket should sit flush against the surface of the board, it will be hard to solder the socket's pins on both sides of the board. You can use a wire-wrap socket and leave the socket slightly above the board, but the legs on a wire-wrap socket are thicker than normal, so you'll have to use larger pads to accommodate the larger holes. You could also use the more-expensive machined sockets.

Another alternative is to add a small trace to the IC pin and put the feedthrough there (see Fig. 4). It's a bit more cumbersome but it's going to make your job a lot easier later on. **R-E**

LIGHT BEAM

continued from page 44

A completed light-beam communicator should also have both its transmitter and receiver aligned with one another. Just aim the communicator at a nearby wall, and you should see the light spot in the viewfinder of the receiver. Adjust if necessary.

There are a lot of other "fun" uses for the light-beam communicator besides two-way communication. You can "listen" to an airplane flying overhead, or to waterfalls, waves, and sprinkler systems. Car headlights going past you also have their own sound. If an insect flys through another unit's light beam, you can actually hear its wings beating. **R-E** and module 5 off, the sequence would be

- access code: "2," "6," "*," or "#"
- address modules: "1," "3," "0," "5"

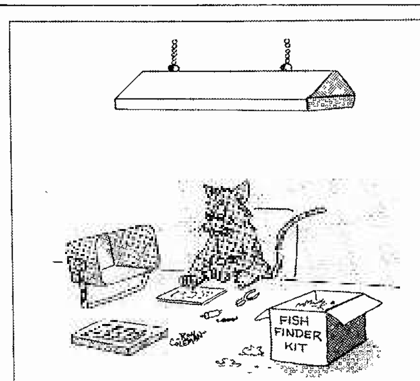
The PCC also works after a call has been placed or an incoming call is received. That way, if you hear a strange noise while talking on the phone, just activate the system as previously described. If you have an answering machine, you control the PCC the same way as if you were home. When the answering machine finishes its recorded message, enter the access code, then address the remote modules.

As a safeguard to the system, an internal timer monitors PCC activity. If PCC activity is suspended over four seconds, or the phone is being used to make an outside call, the PCC is temporarily inhibited and the access code must be reentered to enable it.

The PCC can indicate the remote module ON/OFF status for single remote module commands as well as when the "ALL LIGHTS ON" or "ALL LIGHTS OFF" function is addressed. For instance, if you program the controller to turn on modules 1, 2, and 5, LED's 1, 2, and 5 would light on the front panel. If the "ALL LIGHTS ON" command is used (function code 9), all eight LED's would light, unless you previously programmed only the *light* modules to turn on with that command. In that case, only the LED's corresponding to the light modules would light on the status indicator.

That's all there is to building and operating the PCC. We think you'll find this to be a handy addition to your electronic repertoire.

R-E



RGB TO NTSC

continued from page 62

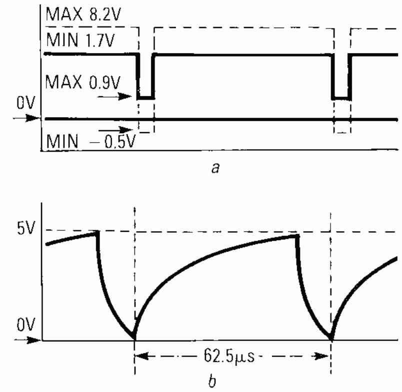
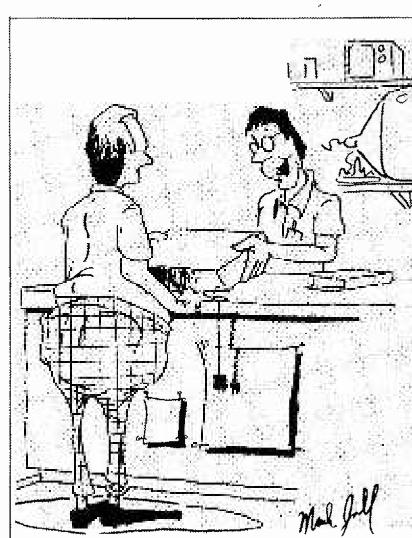


Fig. 7 *WAVEFORMS OF A PROPERLY OPERATING CONVERTER. At (a) is the signal at pin 2; at (b), the signal at pin 1.*

IC1 for the waveform shown in Fig. 7-*a*.

Image but no color. Check pins 3, 4, and 5 of IC1 to make sure that all three of the RGB signals are getting through. Check pin 1 of IC1 for the waveform shown in Fig. 7-*b*. If adjusting C1 has no effect, then the RC network R7/C13 is out of tolerance. Either replace C13 with a more accurate capacitor or place a trimmer potentiometer in series with R7, and adjust the trimmer until the waveform is correct.

Good luck and enjoy your new computer-TV screen. **CD**



"It keeps spitting out the tapes? Maybe it just has better taste in movies."

TV TRANSMITTER

continued from page 20

put. Don't couple L9A too close to L9—just enough for about 1 volt across the 47-ohm resistor.

Final assembly

If you're building the 2-watt version, now is the time to install Q6 and Q7, and then L10 through L13. You may now install the chip capacitors C26, C28, C29, C30, and C31, but don't overheat them! Make sure that the PC board is tinned in the areas where chips are installed. The best way to install them is to first tack-solder one side to hold it down, solder the other side, and then go back and resolder the first (tack-soldered) side.

Figure 6 shows you how to solder chip components. Use a 25-watt iron with a pointed tip. Fine-point needle-nose pliers or tweezers should be used to manipulate the chip capacitors.

Finally, install C34 and a suitable length of small-diameter 50-ohm coax to J2. Check all joints for solder bridges. Make sure that the metal case of Q7 is soldered to the ground plane (top side), and connect its leads to the PC-board underside using as little lead length as possible.

Apply power and quickly adjust C25, C27, and C33 for maximum power into a 50-ohm load connected to J2. You can use a 47-ohm, 2-watt carbon resistor, or the dummy load which can be assembled as shown in Fig. 7. An RF probe can be connected to the hot side of the resistors (center conductor of connector) to read the RF voltage, but an RF power meter is nice to have.

You should get at least 1.5 watts (about 8.5-volts RMS) into the 50-ohm load, which should become warm when operating. Power-supply current will be about 500 mA. Now adjust R33 for an output voltage about half that, or a quarter the power as read on the power meter, if used. Leave the RF load connected as you proceed to the next step.

For either the low- or high-power unit, adjust R33 for about +6 volts at point A (emitter of Q12). Connect a frequency counter to point A, and adjust C40 for exactly 4.500 MHz. Now apply video and audio signals to J3 and J1, respectively. Watch the transmitted image on a TV receiver tuned to the transmitter frequency; adjust the video gain (R32) for best picture contrast and stability, then adjust the audio level (R22) until its level is comparable to a commercial station. Now alternately adjust R32 and R33 for maximum video contrast without seeing any side effects such as instability, audio buzz, or other evidence of clipping. You may also wish to go over all tuning adjustments again for best results. The finished PC board is shown in Fig. 8

Enclosure

Mount the PC board in a shielded metal-case, as shown in Fig. 9, and connect leads from the board to suitable jacks for J1, J2, or J2A, and J3. Also provide a suitable connector for the 12-volt supply, if desired. The transmitter case can house an AC supply, or batteries for portable operation. Use the right size *Ni-Cd* batteries to handle the 100-mA drain (low power), or 500-mA drain (2-watt unit). Use a BNC-type fitting for the antenna jack, J2.

A suitable antenna would be a 6-inch whip or a center-fed dipole, 12-inches long. For amateur TV, a linear amplifier may be installed between J2 and the antenna for greater power output. For the low-power version, use the 6-inch whip antenna. **R-E**

ADVERTISING INDEX

RADIO-ELECTRONICS Experimenter's Handbook does not assume any responsibility for errors that may appear in the index below.

ADVERTISING SALES OFFICE

Gernsback Publications, Inc.
500-B Bi-County Blvd.
Farmingdale, NY 11735
1-(516) 293-3000
President: **Larry Steckler**
Vice President: **Cathy Steckler**

For Advertising ONLY
516-293-3000
Fax 1-516-293-3115
Larry Steckler
publisher
Arline Fishman
advertising director
Denise Haven
advertising assistant
Christina Estrada
advertising associate
Kelly McQuade
credit manager

Subscriber Customer Service
1-800-288-0652
Order Entry for New Subscribers
1-800-999-7139
7:00 AM - 6:00 PM M-F MST

SALES OFFICES

EAST/SOUTHEAST
Stanley Levitan, Eastern Sales Manager
Radio-Electronics
259-23 57th Avenue
Little Neck, NY 11362
1-718-428-6037, 1-516-293-3000
Fax 1-718-225-8594

MIDWEST/Texas/Arkansas/Okla.
Ralph Bergen, Midwest Sales Manager
Radio-Electronics
540 Frontage Road—Suite 339
Northfield, IL 60093
1-708-446-1444
Fax 1-708-446-8451

PACIFIC COAST/ Mountain States
Marvin Green, Pacific Sales Manager
Radio-Electronics
5430 Van Nuys Blvd. Suite 316
Van Nuys, CA 91401
1-818-986-2001
Fax 1-818-986-2009

VCR REPAIR

continued from page 126

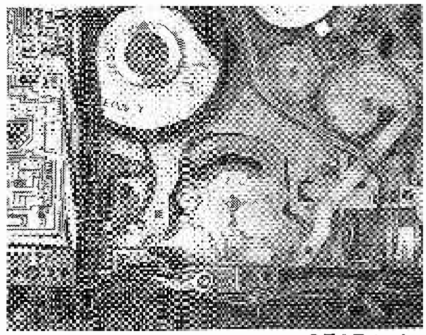


FIG. 6—A TYPICAL LOADING GEAR train is usually covered by a protective plastic guard that must be removed for servicing. This gear train is on the bottom of the chassis.

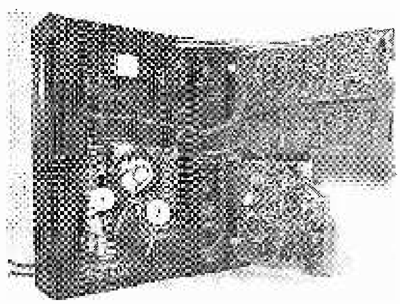


FIG. 7—A VCR IN ITS SERVICE POSITION. A mirror on your workbench surface will allow you to see both sides of the VCR simultaneously.

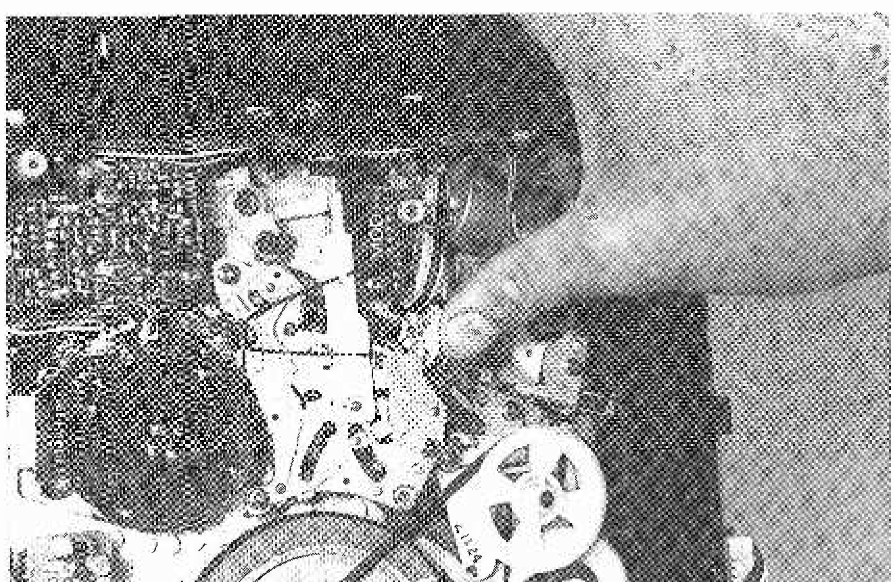
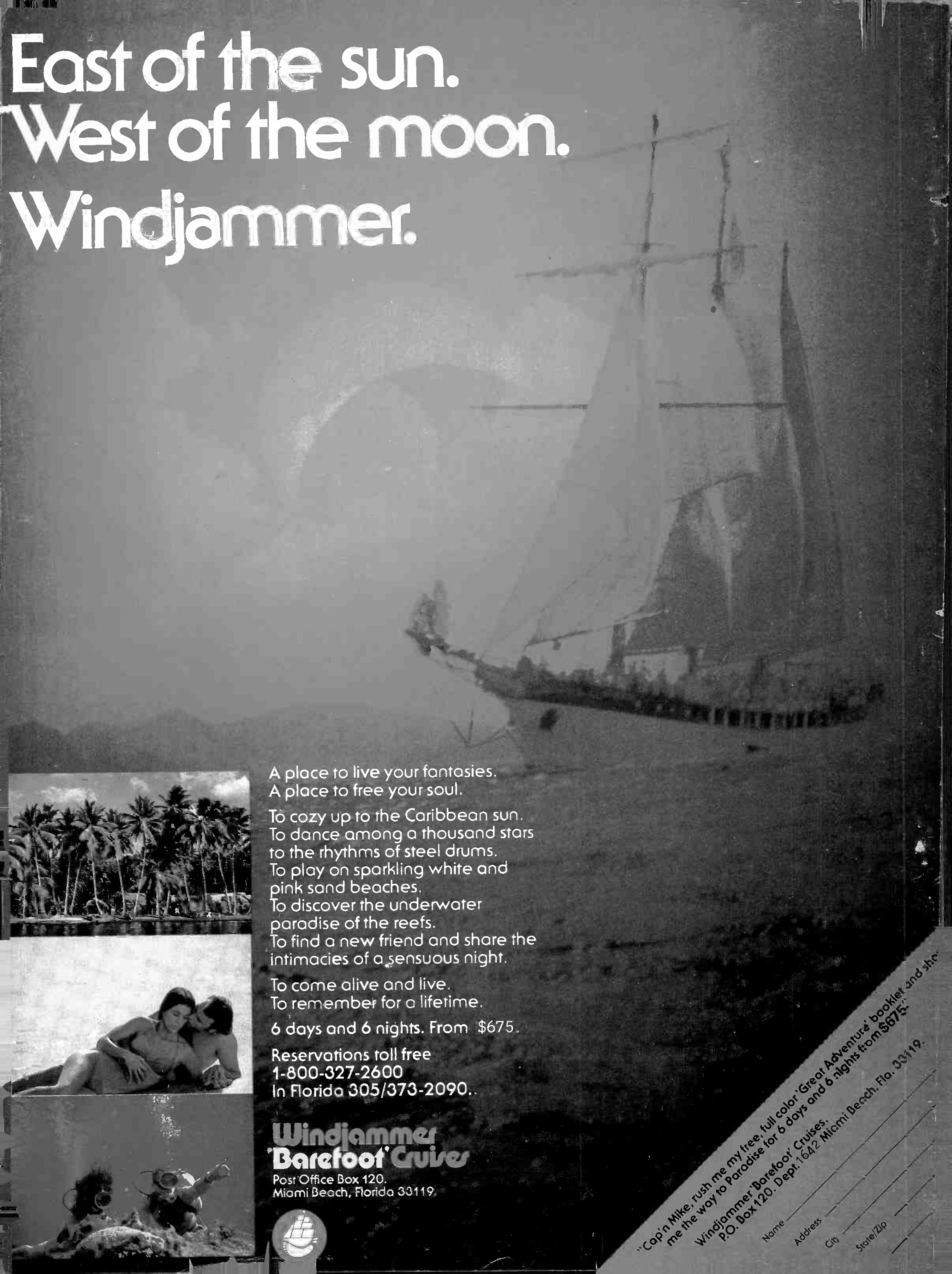


FIG. 8—A MALFUNCTIONING LOAD BELT is can be tested by "assisting" the load process with your finger.

Sometimes the lubricant that is applied in sliding tracks and to various components dries up and hardens. That can cause much added friction for the load components, and may cause the load to be aborted. If that's the case, you have to dismantle the assembly, clean off the dried-up lubricant, and apply a fresh coat. It is best to use a cleaner like acetone for removing the old lubricant. It is also a good idea to first take a photo or make a quick sketch of an assembly before dismantling it for cleaning, so that everything goes back correctly. Many times there will be small alignment arrows imprinted on the gears themselves—pay careful attention to any arrows, as they must be exactly aligned during reassembly.

If the load belt appears to be good, and there is no dried-up lubricant, then you have to inspect the load gears for any signs of cracking—especially hairline cracks. Any gears that show signs of cracking must be replaced. Note that load motors do not usually go bad, but if there is excess freedom of shaft movement, or any signs of excessive friction in the motor, it may have to be replaced.

Another quick test of the load system is to perform a tape "load" by hand, with the unit unplugged and no tape inserted. That will provide an unobstructed view of the loading mechanisms as they operate. Also, the loading process will be greatly slowed down, so you'll be able to see—and perhaps even feel—exactly when a problem occurs. Then you can determine which part might be causing it to happen. To perform the test, turn the load-motor shaft by hand and observe the unit's operation. **R-E**


East of the sun.
West of the moon.
Windjammer.
A place to live your fantasies.
A place to free your soul.
To cozy up to the Caribbean sun.
To dance among a thousand stars
to the rhythms of steel drums.
To play on sparkling white and
pink sand beaches.
To discover the underwater
paradise of the reefs.
To find a new friend and share the
intimacies of a sensuous night.
To come alive and live.
To remember for a lifetime.
6 days and 6 nights. From $675.
Reservations toll free
1-800-327-2600
In Florida 305/373-2090.
Windjammer
'Barefoot' Cruises
Post Office Box 120.
Miami Beach, Florida 33119.
"Cap'n Mike, rush me my free, full color 'Great Adventure' booklet and sho
me the way to Paradise for 6 days and 6 nights from $675."
Windjammer 'Barefoot' Cruises.
P.O. Box 120. Dept. 1642 Miami Beach, Fla. 33119.
Name
Address
City
State/Zip