JANUARY 1990 / $2.95

ANNUAL CONSTRUCTION ISSUE

HAM RADIO

NEW

In this issue...

Computer Aided Design of Printed Circuit Boards

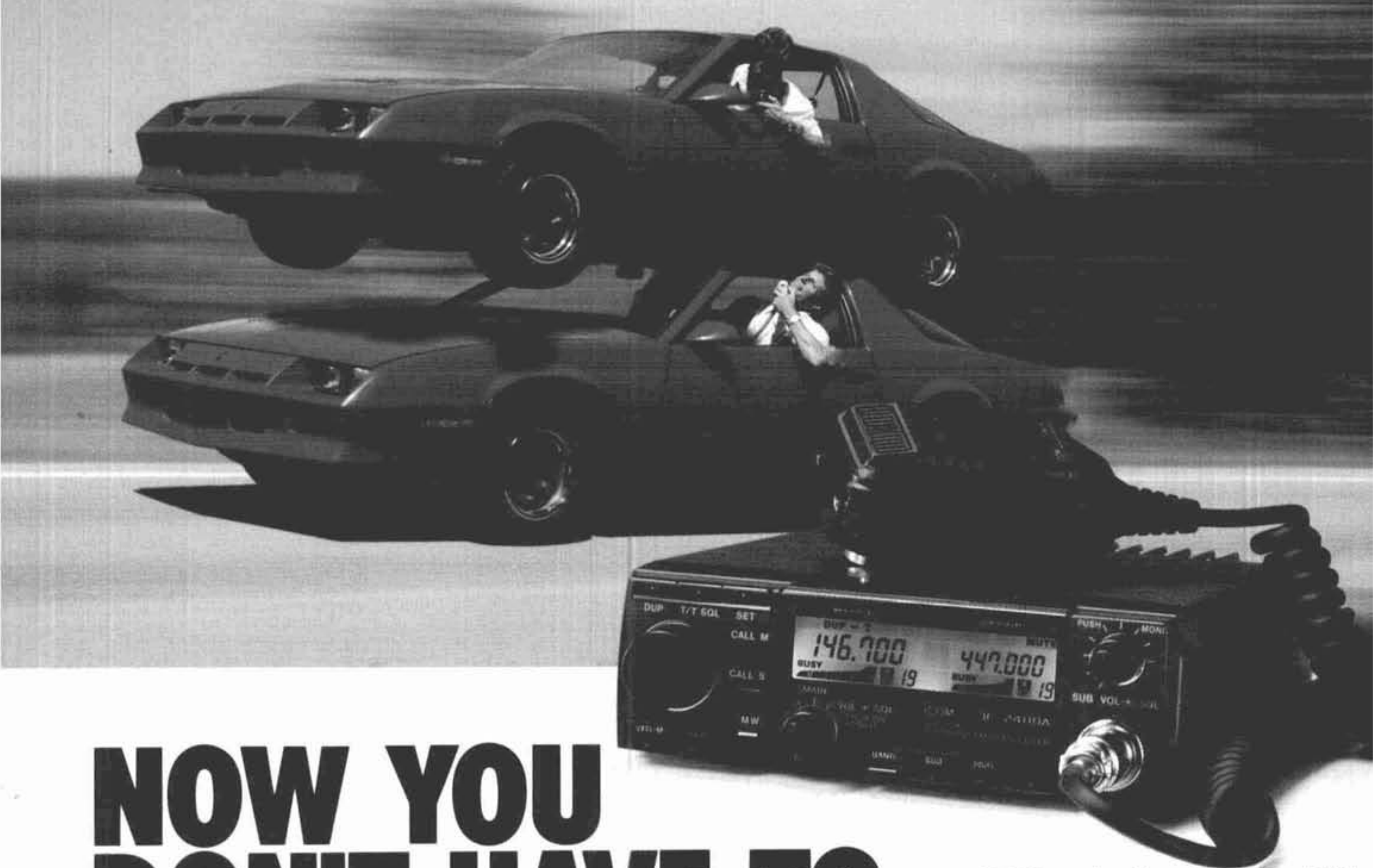
Making Printed Circuit Boards

The QRP TLC-Keyer

75-Hz Audio Filter

ICOM

IC-2400 UHF/VHF Mobile
IC-2500 UHF/1.2GHz Mobile



NOW YOU DON'T HAVE TO DOUBLE UP!

Stack today's rapidly expanding VHF/UHF action in your favor with the most advanced design yet easy-to-operate FM dual banders on the road: ICOM's IC-2400 2-meter/440MHz or IC-2500 440MHz/1.2 GHz.

Their overlapping band ranges are great for present use and future expansions, and their wide array of impressive features make your auto a double-mobile winner!

WIDEBAND COVERAGE.
The IC-2400's range of 138-174MHz RX/ 140-150MHz TX and 440-450MHz RX/TX includes NOAA weather reception plus liberal overlap for MARS/CAP operation. The innovative IC-2500 receives and transmits 440-450MHz and 1240-1300MHz.

HIGH POWER RADIOS!
The IC-2400 delivers 45 watts output on two-meters, 35 watts on 440MHz. The IC-2500 features 35 watts on 440MHz 10 watts on 1.2GHz. Both units include selectable low power for working local stations.

FULL DUPLEX OPERATION.
Both transceivers transmit on one band while simultaneously receiving on another. Both radios feature independent offsets for each band. It's like having two separate radios in one! Perfect for true telephone-style autopatching with a modern crossband repeater!

SIMULTANEOUS DUAL BAND RECEPTION.
Monitor both bands on the internal speaker or add external speakers. Each band features separate volume and squelch controls.

40 MEMORIES.
Twenty per band. Store frequencies, PL tones and TX offsets for super-convenient mobiling!

PROGRAMMABLE BAND AND MEMORY SCANNING.
You set the limits and select/lockout preferred memories. ICOM's IC-2400 and IC-2500 monitor the action. A sheer VHF/UHF delight!

Additional features include: **Priority Watch.** Monitor one channel's activity while operating on another frequency. **Two Call Channels.** One on each band for quick, single access to your favorite repeater. A **Repeater Input Monitor Switch** for rapid checks of TX offset and evaluation of direct range. Plus, an **Optional Beeper** silently monitors any selected frequency or repeater for calls with your preselected CTCSS subaudible tone.

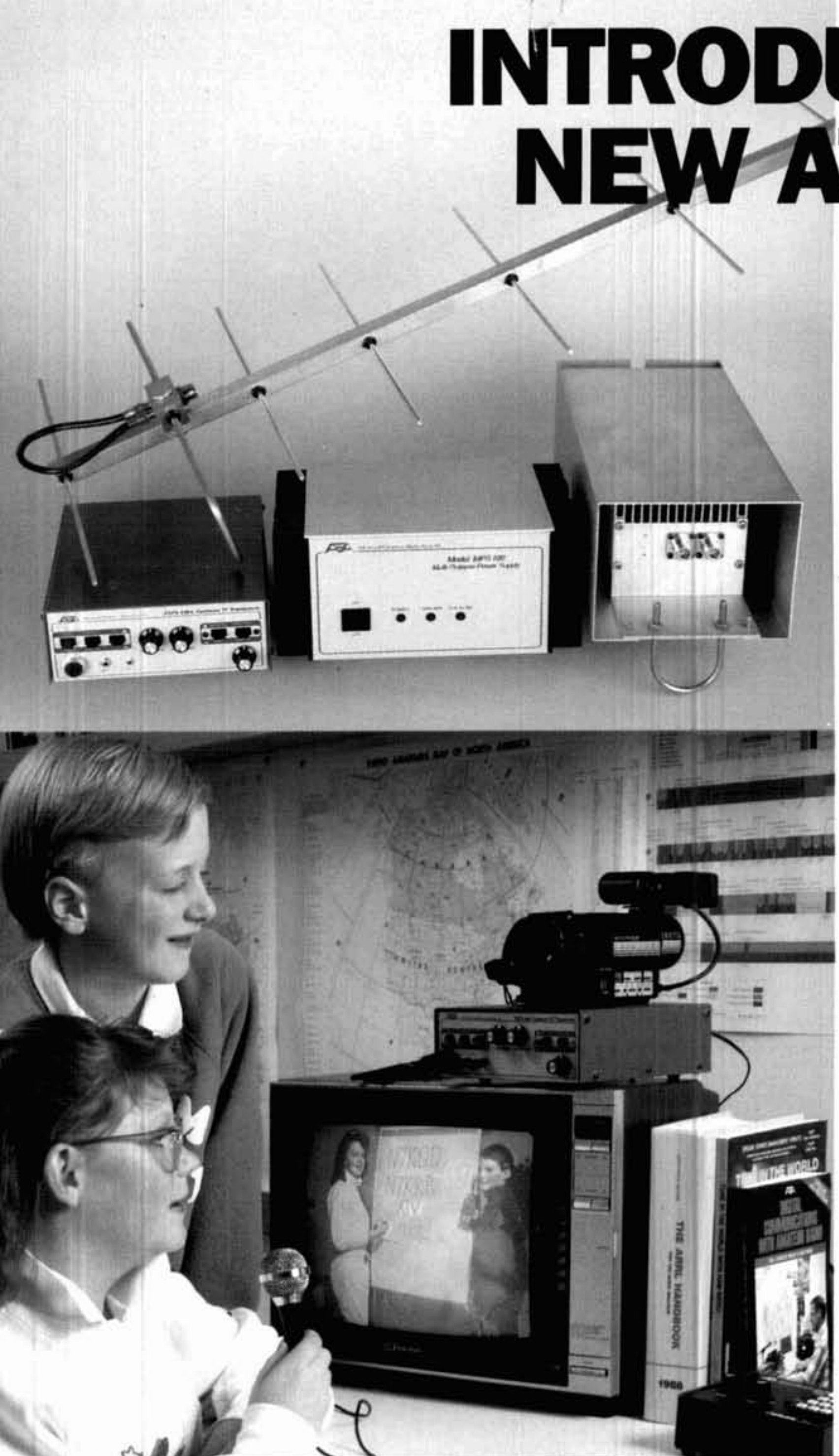
Double your bands with ICOM's new IC-2400 or IC-2500 mobiles!

ICOM America, Inc., 2380-116th Ave. N.E., Bellevue, WA 98004
Customer Service Hotline (206) 454-7619
3150 Premier Drive, Suite 126, Irving, TX 75063
1777 Phoenix Parkway, Suite 201, Atlanta, GA 30349
ICOM CANADA, A Division of ICOM America, Inc.,
3071 - #5 Road, Unit 9, Richmond, B.C. V6X 2T4 Canada

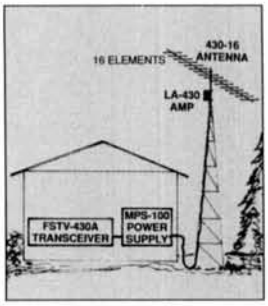
All stated specifications are subject to change without notice or obligation. All ICOM radios significantly exceed FCC regulations limiting spurious emissions. 2400/2500789

ICOM
First in Communications

INTRODUCING AEA'S NEW ATV SYSTEM



Add a new dimension to your amateur radio communications with AEA's Amateur Television (ATV) system. If you hold at least a technician-class license, you can transmit and receive live or taped audio and video Fast-Scan TV (FSTV) information that rivals broadcast quality. Now you can share more than conversation over the air with this new mode of "personal communications."



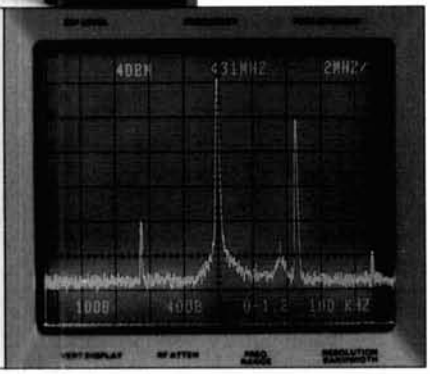
It's Easy and Inexpensive. If you have a video camera or camcorder and a standard TV set, you may already own the most expensive components of an ATV system. AEA's ATV system includes a transceiver and antenna. Simply connect the camera, TV and the antenna to the transceiver, and you're on the air LIVE with one watt P.E.P.! Your TV set will monitor your transmitted and received pictures. If you want to broadcast with more power, AEA also offers a 50 watt mast-mounted linear amplifier with power supply.

The FSTV-430A Transceiver features a low-noise UHF GaAsFET preamp with a typical noise figure of less than 1.5dB and a crystal-controlled or variable tuning down converter. Output is available on channel 3 or 4 for signal reception AND monitoring transmissions. Two frequencies can be selected from the front panel for transmission (one crystal is included). The AEA design is also optimized for superior video and audio quality without sync buzz even with weak signals. The FSTV-430A is the only transceiver you need to work ATV and it also allows you to use the same TV set to monitor your transmitted and received pictures.

The LA-430/50 Amplifier with Power Supply gives a boost to your ATV signal. It includes a 50W P.E.P. mast-mounted Linear Amplifier (**patent pending**) covering 420 to 450 MHz and a GaAsFET preamp which utilize the antenna feedline for DC power. The mast- mount eliminates the line loss between the amplifier/preamplifier and the antenna to improve both transmission and reception, and is the equivalent of a 100W amplifier in the shack with a 3dB line loss. The amplifier is housed in a weather-resistant alodized aluminum case. The MPS-100 power supply also provides a 13.6 volt output for the FSTV-430A.

What is the advantage of Vestigial Sideband (VSB)?

AEA's FSTV-430A Vestigial Sideband operation drastically reduces adjacent-channel interference. VSB requires much less bandwidth than existing double-sideband designs; it's the standard method of modulation required by the FCC for all U.S. broadcast TV stations. Similar in principle to SSB, VSB puts all of the audio energy and most of the video in ONE sideband instead of two. Using about half the spectrum space of competitive units, the FSTV-430A is the ONLY ATV unit that conserves spectrum space by using VSB. Even with AEA's LA-430/50 amplifier, one sideband is reduced more than 30dB. VSB presents an obvious advantage to the bandwidth-conscious ATV operator.



The 430-16 Antenna is a high-performance, computer-optimized yagi specifically designed for ATV operation. It features broadband frequency coverage from 420 to 440 MHz, 14.3dB gain, O-ring sealed connectors, 28 degree E plane and 32 degree H plane beam widths and 16 elements on a 10-foot boom.

See AEA's FSTV System at your local authorized AEA dealer. Put yourself in the ATV picture and join the fun!

Advanced Electronic Applications, Inc.
2006-196th St. SW/P.O. Box 2160 Lynnwood, WA 98036 206-775-7373

Prices and specifications subject to change without notice or obligation.
Dealer inquiries invited.

AEA Brings You A Better Experience.

KENWOOD

TS-950SD

"DX-clusive" HF Transceiver

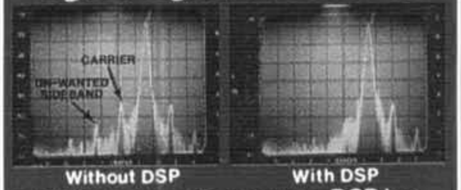
The Ultimate Signal.

The new TS-950SD is the first Amateur Radio transceiver to utilize Digital Signal Processing (DSP), a high voltage final amplifier, dual fluorescent tube digital display and digital meter with a peak-hold function.

- **Dual Frequency Receive Function.** The TS-950SD can receive two frequencies simultaneously. The sub-receiver has independent controls for frequency step size, noise blanker, and AF gain and its own digital display!
- **New! Digital AF filter.** Synchronized with SSB IF slope tuning, the digital AF filter provides sharp characteristics for optimum filter response.
- **New high voltage final amplifier.** 50 V power transistors in the 150-watt final section, results in minimum distortion and higher efficiency. Full-power key-down time exceeds one hour.
- **New! Built-in microprocessor controlled automatic antenna tuner.** The new antenna tuner is faster and you can store the settings in memory! (Manual override is also possible.)
- **Outstanding general coverage receiver performance and sensitivity.** Kenwood's Dyna-Mix™ high sensitivity direct mixing system provides from 100 kHz to 30 MHz. The Intermodulation dynamic range is 105 dB.

DSP

Digital Signal Processing



Without DSP — With DSP

- **Digital Signal Processor.** DSP is a state-of-the-art technique that maximizes your transmitted RF energy. Your signal stands out because it is much more pure than your competition! You can even tailor your transmitted CW or voice signal waveshape!
- **High performance IF filters built-in.** Select various filter combinations from the front panel. For CW: 250 and 500 Hz, 2.4 kHz for SSB, and 6 kHz for AM. Filter selections can be stored in memory!
- ***Multi-Drive Band Pass Filter* (BPF) circuitry.** Fifteen band pass filters are available in the front end to enhance performance.
- **Famous Kenwood interference reduction circuits.** SSB Slope Tuning, CW VBT (Variable Bandwidth Tuning), CW AF tune, IF notch filter, dual-mode noise blanker with level control, 4-step RF attenuator (10, 20, or 30 dB), switchable AGC circuit, and all-mode squelch.
- **Built-in TCXO for highest stability.**
- **Built-in electronic keyer circuit.**
- **100 memory channels.** Store independent transmit and receive frequencies, mode, filter data, auto-tuner data and CTCSS frequency.
- **Digital bar meter.**

Additional Features: • Built-in interface for computer control • Programmable tone encoder • Optional VS-2 voice synthesizer • Built-in heavy duty AC power supply and speaker • Adjustable VFO tuning torque • Multiple scanning functions • MC-43S hand microphone supplied

Optional Accessories
• VS-2 Voice synthesizer • SP-950 External speaker w/AF filter • SM-230 Station monitor w/pan display • SW-2100 SWR/power meter • TL-922A Linear amplifier (not for QSK)

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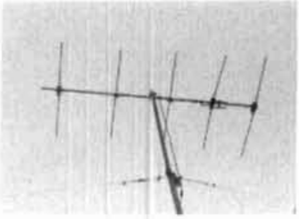
JANUARY 1990
Volume 23, Number 1

Cover photo: Marty Durham, NB1H, and Phil Alix, N1FPX

Special thanks to NY1H for letting us use his equipment.



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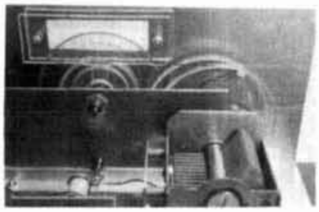

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FEATURES

DEPARTMENTS

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Backscatter

The FCC and 20-Meter Third Party Traffic

Now hold on. Let me get this straight.

Hams are using the airwaves for business communications?

Can't be. We're better'n the rest and police ourselves.

Don't we?

All the latest hubbub about phone patches on 20 meters is very interesting. For years, many of us have wondered and agonized over what constitutes "business communications." Trying to be very careful, I have always followed the rule: if there's a doubt in my mind, don't do it.

A few years back the FCC waded into a big bruhaha about 2-meter autopatches and what was and was not permissible. It always struck me as silly that I couldn't call my wife on the way home to see if anything was needed for dinner. All I'd get in return is a better dinner. There's no profit or gain for me in the call. But it was one of those questionable calls and, consequently, not on the approved list.

The FCC has now decided to get involved in the morass of 20-meter third party traffic. I have the feeling that it may be too little too late. If you haven't listened to the top end of 20 lately, you have missed some interesting conversations.

According to W5YI, Robert McNamara, chief of the FCC Special Services Division, sent a letter to many of the participants active in third party traffic. The gist of McNamara's letter is that Amateur Radio should be for experimentation purposes in the field of communications, technical advancement, and the fostering of international good will. However, he says, "It appears that as much as 15 percent of the 20-meter [Amateur] band is being claimed for such communications [phone patch traffic] by some Amateur operators and by organizations apparently organized specifically to utilize the amateur service for third party telephony communications." W5YI says that the FCC has also received letters from other countries complaining about American Amateurs and their phone patch traffic. McNamara also states that "requests to the commission to resolve the dispute are taking far too much staff time from other essential activities."

Perhaps if the FCC had shown some leadership in the first place, they wouldn't have to solve the problem now. This complaint has been voiced by many over the past ten years and is all too pertinent now. While I think we all agree that deregulation has worked to improve the overall quality of Amateur Radio, there are a number of areas that have slipped too far for even the most liberal to accept. From malicious interference, to foul language and poor operating habits, the total lack of enforcement has fostered this kind of behavior.

Self-policing only works when all parties involved agree to participate. Get one guy who refuses to go along and the system has been compromised. Unfortunately, there are too many "iconoclasts" who refuse to cooperate in a self-policing environment.

And so, you have a mess like the one we have on 20 meters. It's a shame and not in the true Amateur spirit. Hopefully, the FCC will take a strong leadership position to stop the abuses before they lead to serious damage to Amateur Radio. We have enough threats to worry about as it is without adding third part traffic violations to the primordial soup. We do not recommend a return to the restrictive policies of the FCC of forty years ago. However, the FCC is the only organization that has the power and ability to stop the abuses now, before irreparable harm is done.

It's kind of tough to extol the virtues of Amateur Radio to a friend and when you go to an on-the-air demonstration run across two bums arguing. You couldn't sell me on the basis of a demonstration like that. No sirree.

Craig Clark, NX1G

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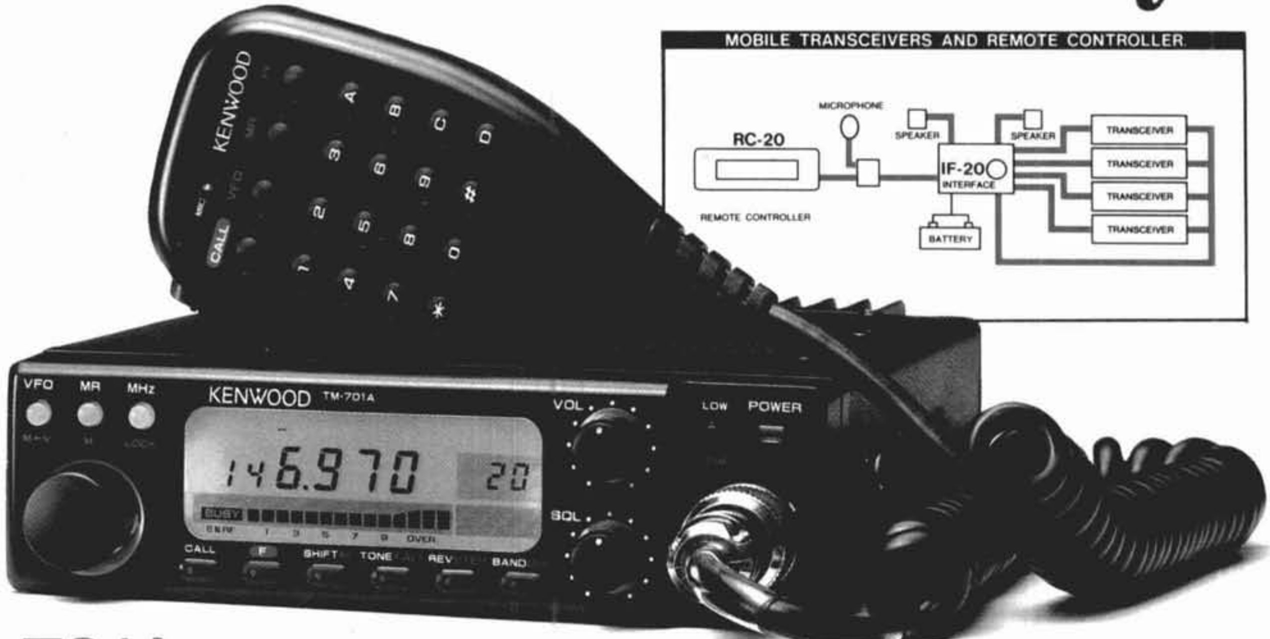
Affordable Breakthrough!

Dual Band Afford-ability!



TM-701A

Dual Bander

The TM-701A combines two radios into one compact package. You get 25 watts on 2 meters and 70cm, 20 memory channels, tone encoder built-in, multiple scanning, auto repeater offset selection on 2 meters, and a host of additional features!

- **20 multi-function memory channels.** 20 memory channels allow storage of frequency, repeater offset, CTCSS frequency, frequency step, and Tone On/Off status, CTCSS and REV, providing quick and easy access during mobile operation.
- **25W on 2m and 70cm.**
- **Selectable full duplex-cross band (Telephone style) operation.**
- **Easy-to-operate front panel layout.**
- **Multi-function DTMF mic. supplied.** Controls are provided on the microphone for CALL (Call Channel), VFO, MR (Memory Call or to change the memory channel) and a programmable function key. The programmable key can be used to control one of the following functions on the radio: MHz, T. ALT, TONE, REV, BAND, or LOW power.
- **Easy-to-operate illuminated keys.** A functionally designed control panel with individually backlit keys increases the convenience and ease of operation during night-time use.
- **Optional full-function remote controller (RC-20).** A full-function remote controller using the Kenwood bus line may be easily connected to the TM-701A and mounted in any convenient location. The new controller is capable of operating all front panel functions.
- **Built-in dual digital VFO's.**
  - **a) Frequency step selection (5, 10, 15, 20, 12.5, 25kHz)**
  - **b) Programmable VFO**
    The user friendly programmable VFOs allow the operator to select and program variable tuning ranges in 1 MHz band increments.
- **Programmable call channel function.** The call channel key allows instant recall of your most commonly used frequency data.
- **Programmable tone encoder built-in.**
- **Tone alert system—for true quiet monitoring.** When activated this function will cause a distinct beeper tone to be emitted from the transceiver for approximately 10 seconds to signal the presence of an incoming signal.
- **Easy-to-operate multi-mode scanning.**
  - **a) VFO scan**
    Band scan, Programmable band scan.
  - **b) Memory scan plus programmable memory channel lock-out**
  - **c) Dual scan**
    Dual call channel scan
    Dual memory scan
    Dual VFO scan
  - **d) Scan stop modes**
    Time operated scan (TO)
    Carrier operated scan (CO)
  - **e) Scan direction**
  - **f) Alert**
    When the AL switch is depressed memory channel 1 is scanned for activity at approximately 5 second intervals.
- **MHz switch.**
- **Lock function.**
- **Repeater reverse switch.**

Optional Accessories

- **RC-20** Full-function remote controller
- **RC-10** Multi-function remote controller
- **IF-20** Interface unit handset • **MC-44** Multi-function hand mic. • **MC-44DM** Multi-function hand mic. with auto-patch • **MC-48B** 16-key DTMF hand mic. • **MC-55** 8-pin mobile mic.
- **MC-60A/80/85** Desk-top mics. • **MA-700** Dual band (2m/70cm) mobile antenna (mount not supplied) • **SP-41** Compact mobile speaker • **SP-50B** Mobile speaker • **PS-430** Power supply • **PS-50** Heavy-duty power supply • **MB-201** Mobile mount • **PG-2N** Power cable • **PG-3B** DC line noise filter
- **PG-4H** Interface connecting cable • **PG-4J** Extension cable kit • **TSU-6** CTCSS unit

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Editor's Notes

A Preview of Coming Attractions

Every year, we at *Ham Radio* try to bring you the best of Amateur Radio. Last year we introduced a redesigned editorial package that included new graphics, two Weekender projects per month, more construction articles, and lots of ham notes. As we enter the nineties, *Ham Radio* has two new features to offer you. Here are the details...

A lot of you have written regarding the status of W1JR's "VHF/UHF World" column. After five years of writing interesting and insightful articles about the upper regions for *Ham Radio*, Joe Reisert is taking a well-deserved break. After a long search, we are pleased to announce that Bob Atkins, KA1GT, former author of the "New Frontier" column in *QST*, has agreed to share his knowledge and enthusiam with you. We'll be bringing you his new column "Microwaves" as soon as the first installment arrives. Of course, Joe is still a much valued member of the *Ham Radio* family and we hope to present an occasional piece by him in the future. In the meantime, Joe's excited that Bob will writing for all you VHF/UHFers out there!

Also new is the "*Ham Radio* Bulletin Board." The "Bulletin Board" will feature some of the more technical *letters to the editor* that we receive — letters that go into too much detail to be used in our "Comments" section. It will appear in the magazine whenever we have messages for you, or you have messages for us.

I hope you enjoy these two new features. Both are part of our continuing effort to keep *Ham Radio* fresh, exciting, and full of the most up-to-date technical information available.

Terry Northup, KA1STC

HAM RADIO READER EVALUATION

It's been over a year since we introduced our editorial redesign of *Ham Radio* Magazine. At your request we've included more short construction projects, two weekender projects each month, and loads of ham notes. HR's 25-percent increase in circulation over the last 12 months must mean that you really like what you see in the "New" *Ham Radio*!

But we're not going to stop and rest on our laurels. Here's another opportunity to let us know how you feel about Amateur Radio's #1 technical magazine. Please take a moment to fill out and return this questionnaire — a photocopy is fine. Let us know how you feel about the "New" *Ham Radio* Magazine.

1. Do you like the changes we've made to *Ham Radio*?
   Yes ______ No ______ Why or why not? ______________________
2. What else would you like to see? More technical articles ______ More projects ______
   More Weekenders ______ Other ______________________
3. Do you like the current mix of articles? Yes ______ No ______
   Why or why not ______________________
4. Do you think *Ham Radio* is: too technical ______, not technical enough ______, just right ______.
5. I like the Old ______ New ______ *Ham Radio* better. I don't really have a preference. ______
   Why? ______________________

Please return your questionnaires to *Ham Radio* Reader Evaluation, Ham Radio Magazine, Main Street, Greenville, New Hampshire 03048. Thanks!

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DX-cellence!

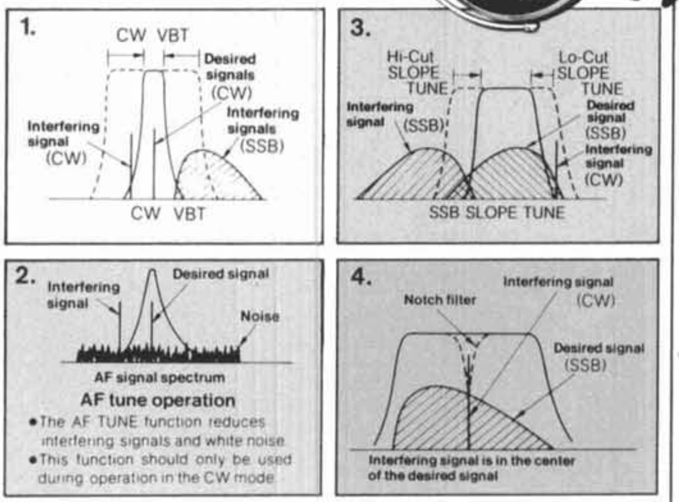
#1 Rated HF!

TS-940S

Competition class HF transceiver

TS-940S—the standard of performance by which all other transceivers are judged. Pushing the state-of-the-art in HF transceiver design and construction, no one has been able to match the TS-940S in performance, value and reliability. The product reviews glow with superlatives, and the field-proven performance shows that the TS-940S is "The Number One Rated HF Transceiver!"

- **100% duty cycle transmitter.** Kenwood specifies transmit duty cycle ***time.*** The TS-940S is guaranteed to operate at full power output for periods ***exceeding one hour.*** (14.250 MHz, CW, 110 watts.) Perfect for RTTY, SSTV, and other long-duration modes.
- **First with a full one-year limited warranty.**
- **Extremely stable phase lock-ed loop (PLL) VFO.** Reference frequency accuracy is measured in ***parts per million!***



1) CW Variable Bandwidth Tuning. Vary the passband width continuously in the CW, FSK, and AM modes, without affecting the center frequency. This effectively minimizes QRM from nearby SSB and CW signals.

2) AF Tune. Enabled with the push of a button, this CW interference fighter inserts a tunable, three pole active filter between the SSB/CW demodulator and the audio amplifier. During CW QSOs, this control can be used to reduce interfering signals and noise, and peaks audio frequency response for optimum CW performance.

3) SSB Slope Tuning. Operating in the LSB and USB modes, this front panel control allows independent, continuously variable adjustment of the high or low frequency slopes of the IF passband. The LCD sub display illustrates the filtering position.

4) IF Notch Filter. The tunable notch filter sharply attenuates interfering signals by as much as 40 dB. As shown here, the interfering signal is reduced, while the desired signal remains unaffected. The notch filter works in all modes except FM.

- **Complete all band, all mode transceiver with general coverage receiver.** Receiver covers 150 kHz-30 MHz. All modes built-in: AM, FM, CW, FSK, LSB, USB.
- **Superb, human engineered front panel layout for the DX-minded or contesting ham.** Large fluorescent tube main display with dimmer; direct keyboard input of frequency; flywheel type main tuning knob with optical encoder mechanism all combine to make the TS-940S a joy to operate.
- **One-touch frequency check (T-F SET) during split operations.**
- **Unique LCD sub display indicates VFO, graphic indication of VBT and SSB Slope tuning, and time.**
- **Simple one step mode changing with CW announcement.**
- **Other vital operating functions.** Selectable semi or full break-in CW (QSK), RIT/XIT, all mode squelch, RF attenuator, filter select switch, selectable AGC, CW variable pitch control, speech processor, and RF power output control, programmable band scan or 40 channel memory scan.

Optional accessories:
• AT-940 full range (160-10m) automatic antenna tuner • SP-940 external speaker with audio filtering • YG-455C-1 (500 Hz), YG-455CN-1 (250 Hz), YK-88C-1 (500 Hz) CW filters; YK-88A-1 (6 kHz) AM filter • VS-1 voice synthesizer • SO-1 temperature compensated crystal oscillator • MC-43S UP/DOWN hand mic. • MC-60A, MC-80, MC-85 deluxe base station mics. • PC-1A phone patch • TL-922A linear amplifier • SM-220 station monitor • BS-8 pan display • IF-232C/IF-10B computer interface.

Complete service manuals are available for all Kenwood transceivers and most accessories.
Specifications, features, and prices are subject to change without notice or obligation.

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MFJ TUNERS

Here is the finest 3 KW Tuner money can buy with roller inductor, dummy load, *new* peak reading meter, antenna switch, balun plus more ... $349.95

The MFJ-989C is not for everyone. **However,** if you do make the investment you get the finest 3 KW PEP tuner money can buy - one that will give you a lifetime of use, one that takes the fear out of high power operation and one that lets you get your SWR down to absolute minimum.

The MFJ-989C is a compact 3 KW PEP roller inductor tuner with a new **peak** reading Cross-Needle SWR/Wattmeter. The roller inductor lets you get your SWR down to absolute minimum.

With **three continuously** variable components - two massive 6 KV capacitors and a high inductance roller inductor - you get precise control over SWR **and** the widest matching range possible from 1.8-30 MHz.

MFJ-989C **$349.95**

You get a **new** lighted **peak** and average reading Cross-Needle SWR/Wattmeter with a **new** more accurate directional coupler.

You get a giant two core balun wound with teflon wire for balanced lines and a 6-position antenna switch with extra heavy switch contacts.

Its compact 10¾x4½x15 inch cabinet fits right into your station.

You get a 50 ohm 300 watt dummy load for tuning your exciter, a tilt stand for easy viewing and a 3-digit turns counter plus a spinner knob for exact inductance control. Add $10 s/h.

2-knob *Differential-T*™ Tuner

MFJ-986
$269.95

The **new** MFJ-986 Differential-T™ 2-knob Tuner uses a differential capacitor to make tuning foolproof and easier than ever. It ends constant re-tuning with broadband coverage and gives you minimum SWR at only **one** best setting. Covers 1.8-30 MHz.

The roller inductor lets you tune your SWR down to absolute minimum. 3-digits turns counter lets you quickly return to your favorite frequency.

You get MFJ's **new** peak and average reading Cross-Needle SWR/Wattmeter with a **new** directional coupler for more accurate readings over a wider frequency range. It reads forward/reflected power in 200/50 and 2000/500 watt ranges. Meter lamp uses 12 VDC or 110 VAC with MFJ-1312, $12.95.

A **new** current balun for balanced lines reduces feedline radiation and forces equal currents into antenna halves that are not perfectly balanced for a more concentrated, stronger signal. Add $10 s/h.

MFJ's *Fastest Selling* Tuner

MFJ-941D
$109.95

The MFJ-941D is MFJ's fastest selling 300 watt PEP antenna tuner. Why? Because it has more features than tuners costing much more and it matches everything continuously from 1.8-30 MHz.

It matches dipoles, vees, verticals, mobile whips, random wires, banlanced and coax lines.

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With MFJ's **deluxe** 300 watt PEP tuner you get an MFJ tuner that has earned a reputation for being able to match just about anything - one that is highly perfected and has years of **proven** reliability.

MFJ's *Mobile* Tuner

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Don't leave home without this **mobile** tuner! Have an uninterrupted trip as the MFJ-945C **extends your antenna bandwidth** and eliminates the need to stop, go out and adjust your mobile whip.

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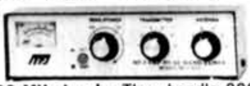
Small 8x2x6 inches uses little room. **SWR/ Wattmeter and convenient placement of controls make tuning fast and easy while in motion.** 300 watts PEP output, efficient airwound inductor, 1000 volt capacitors. Mobile mount, MFJ-20, $3.00.

144/220 MHz VHF Tuners

MFJ-921 **$69.95**



MFJ's new VHF tuners cover both 2 Meters and the 220 MHz bands. They handle 300 watts PEP and match a wide range of impedances for coax fed antennas. SWR/Wattmeter. 8x2½x3 in. **MFJ-920, $49.95.** No meter. 4½x2½x3 inches.

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Comments

QSL cards available

Dear HR

The American Amateur Radio Club of Korea has in hand 55 pounds of QSL cards, some as much as 10 years old. These were recently released to KARL by the Postal Department. If you were (or know someone who was) a United States Forces Korea "HL9" during the past 10 years, a SASE to: American Amateur Radio Club of Korea, P.O. Box 153, APO San Francisco, California 96206, will get your cards. Don't forget to include your HL9 callsign and the dates it was valid.

Charles H. Kelley, W5SPK/HL9CK, PSC Box 5349, APO San Francisco, California 96366-0006.

Balance of Modes

Dear HR

Donald Sinex is right ("Comments," September). Morse code is no longer an indispensable skill for ham radio operating, and the inability to master it should not disqualify a person from becoming a ham. Code virtuosity — like typing speed — is not an indication of general intelligence.

Code stands or falls as a technical requirement. But license exams still overemphasize code even though other modes are predominant. This has led hams to view code as a fraternity initiation. "I did it, so you're going to have to do it too!"

We don't need fraternity initiations. CW is no longer the only mode we have and our license exams should reflect a *fair* balance of modes, instead of being 75 percent Morse.

Care to argue? See you on 21.060.

Michael A. Covington, N4TMI, Athens Georgia

New FCC rules

Dear HR

I just read the new September 1989 FCC part 97 rules for ham radio. It states on page 22 that "repeaters can be limited to certain user stations" when in a ancillary capacity, such as a parade or special function.

In checking the 1989 ARRL repeater directory for the 440-MHz band, I found 293 "closed to the licensed public" repeaters in the Southern California (Los Angeles) area. I could find only three "open to the public" repeaters. That means 99 percent of the Southern Californi repeaters are not available to the licensed public!

I feel we should notify the public to use the 440 repeaters, or possibly the 440 repeater band in Southern California, as a "test location" for the new "code-free" licensed public!

W. Douglass, K6BAZ, Glendale, California

True believer

Dear HR

Congratulations on your editorial in the September 1989 issue of *Ham Radio*. You have presented a balanced, concise viewpoint which is also well written.

While I was not especially keen on your magazine, you are making a believer out of me! Recent issues have been very informative, and I now look forward each month to receiving my copy.

Keep up the good work.

Marvin J. Fein, Newport Beach, California

Celebrity info request

Dear HR

I am researching a book on the life, times, and activities of Arthur Godfrey. In addition to his broadcasting, he was very active in many other areas: Amateur Radio, aviation, military service, stage shows, horsemanship, ecology, etc. I understand Mr. Godfrey had a very early, unusual callsign. Can anyone tell me what it was?

I may be reached at (201) 386-1920. Thank you for any ideas or reminiscences you or others may be able to share with me.

Lee R. Munsick, Whippany, New Jersey

Godfrey's callsign was K4LIB. Ed.

Article stirs memories

Dear HR

It has been a long time since I've enjoyed an article more than the one in the November issue on the early Hallicrafters' receivers. It was well done in every respect. I commend the author for writing it and you for publishing it. It's an example of the kind of "balance" we're seeing in the "new" *Ham Radio*.

My own affinity for Hallicrafters' products began in a similar fashion. I started my ham career just after World War II with the much-maligned, but eminently affordable, S-38. It surely offered very little in electronic sophistication, but because it covered 10 meters, it opened a new door on life for me! Those first years after the war found 10 meters wide open, often till well after dark, with hams all over the globe getting back on the air and signals rolling in from the far-flung corners. I was just an SWL back then, but what joy that little S-38 brought me.

After a year or so, I decided it was time to "trade up." My next receiver

(continued on page 76)

COMPUTER AIDED DESIGN
OF PRINTED CIRCUIT BOARDS

By Bryan P. Bergeron, NU1N, 30 Gardner Road, Apt. 1G, Brookline, Massachusetts 02146

Construction has always been one of the challenges of Amateur Radio. Before there were transistors and integrated circuits, the basic building blocks for most projects included a few tube sockets, a metal chassis, a handful of insulated terminals, and some wire, along with a few tubes, capacitors, resistors, and inductors. Today, the printed circuit board is used universally in electronic construction. The neatness and miniaturization made possible by etched pc boards, coupled with the additional benefits of low lead inductance, good physical stability, and repeatability, make it an ideal construction medium for group projects. With the aid of a personal computer and printer, you can design pc board etching patterns for use with the photographic circuit board preparation process.

Photographic reproduction

Photographic reproduction is the most efficient and error free means of transferring a layout from a printed page to a circuit board. Many journal articles and reference books feature pc board layouts. Photographic reproduction starts with the creation of a negative from the circuit layout artwork. A negative is usually created by copying, with a plain paper copier, the circuit board artwork onto transparent sheets used for overhead projections. This negative is pressed against a specially prepared photosensitive copper-clad board and exposed to ultraviolet (UV) light to deactivate the etchant resist on the exposed part of the board. You can use inexpensive UV exposure lights[1] or sunlight to expose the board. After removing the exposed copper with a standard etching solution, you can drill the board and solder the components into place.

One method of creating circuit board artwork is to transfer rub-on resist patterns to a white, nonporous surface. Once designed, the resist pattern can be used with a plain paper copier to create the required photographic negative. This method of circuit board design has some limitations. First, minor changes in artwork may require that you scrap the original design (and the press-on materials). Second, it's difficult to determine component placement, because you don't have a perfboard-like template to work with. Third, once a pattern is developed, it can't be used within another circuit board design easily. A computer-based drawing tool and a good quality dot matrix or laser printer are more efficient means of creating reusable circuit board artwork.

Computer hardware

You can use any computer capable of driving a dot matrix or laser printer (including the IBM PC and clones, Commodore, Amiga, and Macintosh) to generate circuit board artwork. Although a high resolution video display and a mouse, joystick, or other pointing device can make the task of creating circuit board artwork more enjoyable, the equipment you use is much less important than the quality of the printer output and the software tools available.

Output devices

The quality of your pc board artwork is to a large degree dependent on the quality of the printer or plotter used to print the tracing. A clean, sharp original provides the basis for a crisp circuit board tracing. A good quality laser printer, like the LaserWriter (Apple Computer) for the Macintosh and the LaserJet (Hewlett-Packard) for IBM PC and compatibles, produces the best output. Even the smallest details of a tracing design can be reproduced clearly at 300 dots per inch (DPI). One of the advantages of using a laser printer is that you can create the photographic negative in one step, by loading the plain paper tray with heat-resistant transparency film. Film suitable for use in a plain paper copier will work.* On the down side, laser printers are expensive; prices fall in the $1000 to $3000 range.

The dot matrix printer is suitable for reproducing moderately complex circuit board tracings. The quality and design of your printer defines the limits of tracing density and complexity. Because most dot matrix printers for home use have resolution of near 100 DPI, the output won't be as clear, the curves won't be as smooth, and the optical density of the printer output won't be as great as compared with the output available from a laser printer. Unevenness in the optical density of dot matrix printer output, caused by variations in the printer ribbon, can be minimized with a new ribbon. The process of copying the artwork to transparency film will also minimize variations in the optical density. Another way to reduce these variations is to prepare an enlarged version of your circuit and shoot it down to size. This method is popular with professionals who have access to lithographic equipment. You can use a reducing copier in the same way; however, there's a tradeoff involved. There will be some loss of quality with an office copier — especially if it's not well maintained. You'll need to calibrate out an "indeterminate" reproduction ratio.

Plotters can also be used to create a hard copy of circuit board artwork. While comparable in price to low-end laser printers, small plotters offer little if any advantage over a laser printer. But plotters do excel in the ability they give you to handle circuit board tracing designs larger than those that can be accommodated by the standard paper sizes supported by most laser printers.

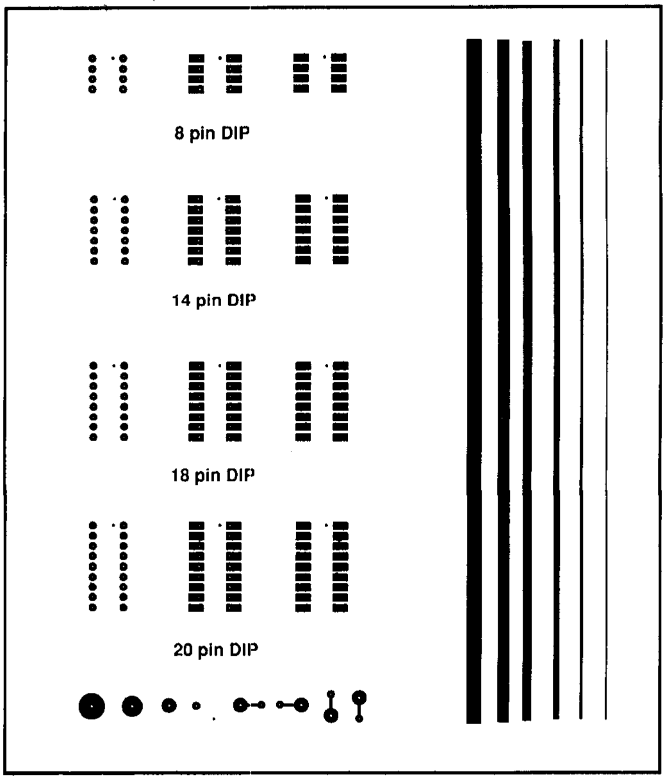
Software

Although programs are available that will compute automatically the trace patterns required to connect a given group of components in a multilevel board (e.g., HiWire for the PC from Wintek Corporation), the price of these programs can equal or exceed that of a good HF or VHF transceiver. A more economical alternative is to use one of the popular drawing programs to design the trace patterns. Once drawn to scale, a circuit board pattern can be sent to a printer to create the photo resist pattern.

There are two basic types of drawing programs available for most microcomputers. The first, typified by MicroSoft Paintbrush (MicroSoft Corp.) for the IBM PC and MacPaint (Claris Corp.) for the Apple Macintosh, can produce free-form graphics with great variability in shading, color, and contour. These "bitmap" editors produce graphic documents in a manner analogous to using wet paint on a canvas. Once individual graphics have been created and combined, there's no easy way to recover the individual elements. Free-form bitmap editors, while great for drawing lifelike scenes of people and places, lack many of the features needed to support the design of pc board traces.

The second type of drawing programs, object-oriented graphics editors, produce documents composed of separate reusable objects. Even if it's combined with a line or other graphic object, a circle remains a circle — just as if you were working with cardboard cutouts. Object-oriented graphic programs — typified by MacDraw (Claris Corp.), Cricket Graph (Cricket Software), and SuperPaint (Silicon Beach Software) for the Apple Macintosh, and Windows "DRAW!" (Micrografx, Inc.), Freelance Plus (Lotus Development Corp.), and AutoCAD (AutoDesk, Inc.) for the IBM PC — are ideally suited to creating pc board patterns.* Objects can be grouped into other objects, and these new objects can be moved or copied to other areas on the working document. For example, a group of suitably arranged circles or rectangles can be grouped into IC tracings. The ability to save predefined objects in a library makes for quick and easy circuit board design (see **Figure 1**).

FIGURE 1



A subset of a library of foil pattern objects constructed in an object-oriented graphics editor (MacDraw). This example illustrates foil patterns for 8 to 20 pin integrated circuits (left), component and connector patterns (bottom), and interconnecting tracings of various widths (right). Objects from this and other libraries are fashioned into a circuit board by copying and pasting the patterns onto a worksheet (see *Figure* 3).

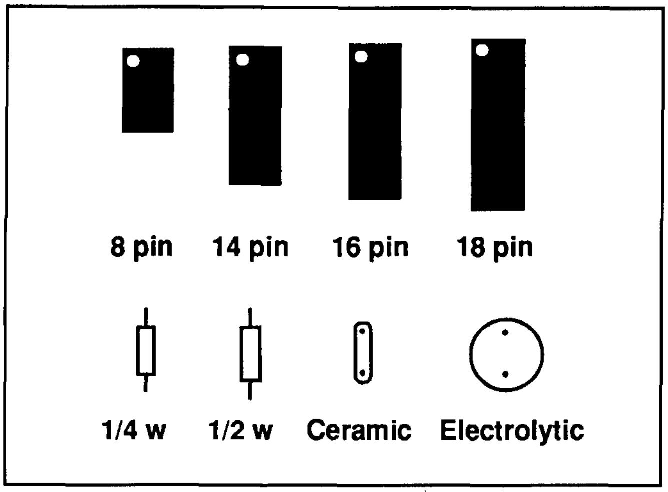
An example system

The system I use to draw printed circuit board artwork is based on the Apple Macintosh MacDraw software and the Apple LaserWriter printer. Like the better object-oriented drafting programs available for the Amiga, IBM PC, or Commodore 64, MacDraw supports the concepts of objects, object groups, and independent layers. As discussed earlier, objects can be grouped together to form other

*Try TEC Film, available from The Meadowlake Corporation, Box 497, Northport, New York 11768.

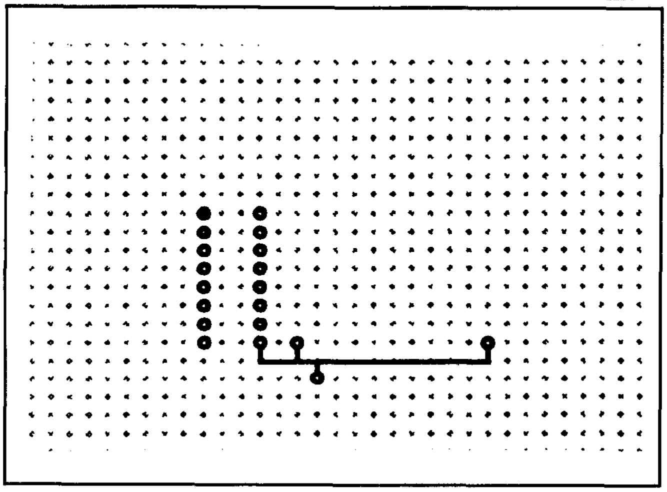
*These programs and others are available from most computer stores and software dealers.

FIGURE 2



Examples from a component library constructed in an object-oriented drawing program (MacDraw). Standard integrated circuit (top), resistor (left, bottom), and capacitor (right, bottom) bodies can be arranged and rearranged on a worksheet until the physical layout of the circuit board is adequate. Component objects are not only useful in illustrating circuit component layout, but they can be used to determine the minimum distance between circuit board tracings.

FIGURE 3



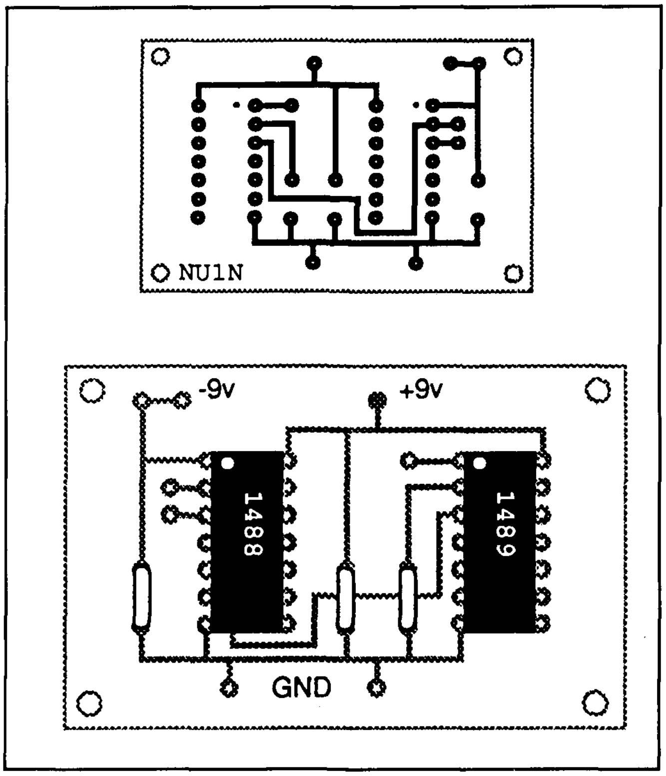
The worksheet, manipulated as a layer by the object-oriented graphics program. Much like the layout paper sold by the Vector Company, the computer-based worksheet serves as a template for the layout of a circuit board. In this illustration, the foil pattern for a 16-pin IC has been added, as well as a few connection points to pin 8 of the IC.

objects, which can be copied easily and moved to working documents (see **Figures** 1 and 2).

Figure 3 illustrates the layers concept. The background layer, which serves as both a guide and a template, is composed of a matrix of dots with a spacing and size identical to that of standard perfboard. Graphic objects (see **Figure 1**) can be copied and placed over the simulated perfboard layer to create a circuit board pattern. Layers can be hidden from view and printed selectively. For example, the perfboard guide in **Figure 3** can be hidden in the final printed output (see **Figure 4**, top). Other layers can be added to the printed output (see **Figure 4**, bottom) to show component placement.

Figure 4 also illustrates some of the powerful functions associated with object-oriented graphics programs — the ability to scale, flip, rotate, or invert objects easily. The top picture in **Figure 4** is actual size as viewed from the foil side; the bottom picture is viewed from the component side at 200-percent actual size.

FIGURE 4



The completed, actual size circuit board tracing design (top), along with the component side design at 200 percent actual size (bottom). Notice that the worksheet pattern does not appear in the final output. This board, *together with three 0.1 µF capacitors* and the two ICs indicated, provides for bi-directional TTL to RS-232 conversion.

Conclusion

I've used the system described here to develop circuit board patterns for projects as small as the one illustrated in **Figure 4**, and for boards containing more than a dozen integrated circuits. In general, I've found that the time savings afforded by the computerized approach is directly proportional to the complexity of the project. Massive alterations in a tracing pattern can be made in a matter of minutes instead of hours. If your club is interested in promoting construction projects, you should seriously consider borrowing or acquiring a system like the one described above. You'll never want to work with tape and rub-on resist patterns again.

REFERENCES

1. L. Hala and P. Hala, "UV Exposure Light," *Modern Electronics*, March 1989, page 28-34.

Introducing the only compact HT designed for you—Heath's new 2-meter and 450 MHz Micro-Deluxe handheld transceivers.

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75-HZ WIDE
AUDIO FILTER

IC header-type construction makes this easy to build

By Albert A. Roehm, W2OBJ, 22 Brookdale Road, Cranford, New Jersey 07016

I recently worked on developing a tactile pad for the hearing impaired. The project required an evaluation of several different kinds of audio filters. I explored Gaussian versus Butterworth filters, envelope detection, time delay circuits to absorb noise pulses, and carrier-activated limiters. Eventually, I decided that simpler was better, and used a bandpass amplifier and comparator to drive some digital circuits. Later, I extracted and repackaged the filter portion of the project as an effective audio filter for some of the local hams. Why not add this filter to your receiving setup? The parts are readily available and the IC header-type construction makes it easy to complete the project in an evening or two.

Circuit description

Designers of good receivers have always tried to obtain the ultimate in selectivity. The migration from single-tuned L-C circuits, to cascaded IF stages, to crystal and mechanical filters gradually approached the desired rectangular, or 1:1, shape factor. But it was necessary to balance the losses of the selective circuits against the danger of instability that resulted when too much gain was used to overcome these losses. The designers also had to be careful to avoid ringing in passive or active audio filters, especially where the response curve contained a sharp peak.

Figure 1 is the circuit diagram of my 75-Hz filter. The 741 integrated circuit used in the first stage is wired as a dual feedback bandpass amplifier with a Q of 10 and a gain of 4.[1] Normally, you'd need a multistage filter, with each stage limited to a Q of 4 or 5 to reduce ringing. However, the higher value of Q is possible here because only one stage is used. The result is a sharper, improved shape factor. R1 is a variable resistor for adjusting the center frequency of the filter to match the offset frequency of the receiver (typically in the 700 to 800-Hz range). If you intend to use the filter with only one receiver or transceiver, you can locate the frequency control internally to conserve panel space.

The second stage is a comparator whose output is low if the signal applied to pin 5 from the bandpass amplifier is lower than the value of the bias set on pin 4. The output voltage on pin 2 switches rapidly to the high state when the positive peak of the signal voltage exceeds the bias by a few millivolts. **Figure 2** illustrates the net bandpass characteristics of these two stages. The characteristics are those of an excellent CW filter. The flat top in the passband guards against ringing because pin 2 remains at a constant high level, even though the output of the bandpass amplifier varies above the bias setting. You get a shape factor of 1:1 because of the sharp change in output voltage when the signal goes above or drops below the bias set on pin 4 of the comparator. R2 varies the bias (threshold) level of the comparator, which in turn determines the bandwidth of the filter. Mount this control on the panel for operating convenience.

Another op amp is used for adjusting the comparator's bias. I selected an LM-339 because it requires a single polarity supply voltage and contains four op amps in its 14-pin IC package. This means that the second op amp (plus two spares) is already available. Its input is connected to the first op amp to sense the same audio signal and threshold setting (points X and Y in **Figure 1**). The output switches a light-emitting diode (LED) on and off electronically to indicate the threshold setting. The LED goes off when the background noise is biased out. It will then light as the code elements are received. Being able to see the received signal should be an aid when you're copying code.

The output of the comparator is connected to R3, which acts as a volume control for the filter. You adjust this control only once, so it can be located internally to save panel space. The wiper arm of R3 is coupled capacitively to one end of R4, which serves as a fader control. The other end of R4 is coupled back to the audio signal coming from the receiver. This arrangement lets you switch smoothly between unfiltered and filtered audio, or a blend of both. Locate this control on the front panel for easy access.

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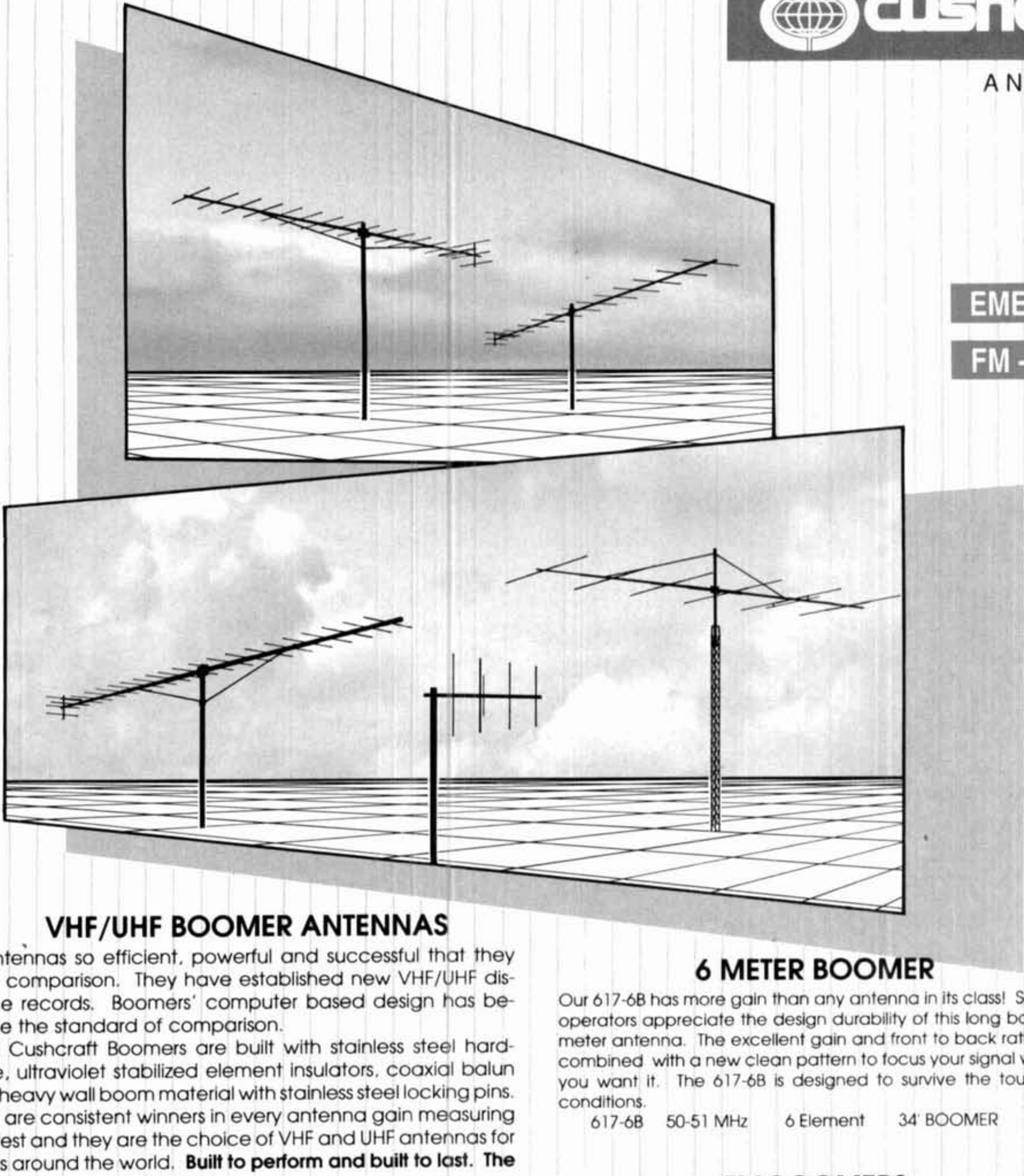

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124WB	144-148 MHz	4 Element	4' BOOMER
215WB	144-148 MHz	15 Element	15' BOOMER
230WB	144-148 MHz	2x15 Element	BOOMER
224WB	220-225 MHz	4 Element	3' BOOMER
225WB	220-225 MHz	15 Element	10' BOOMER

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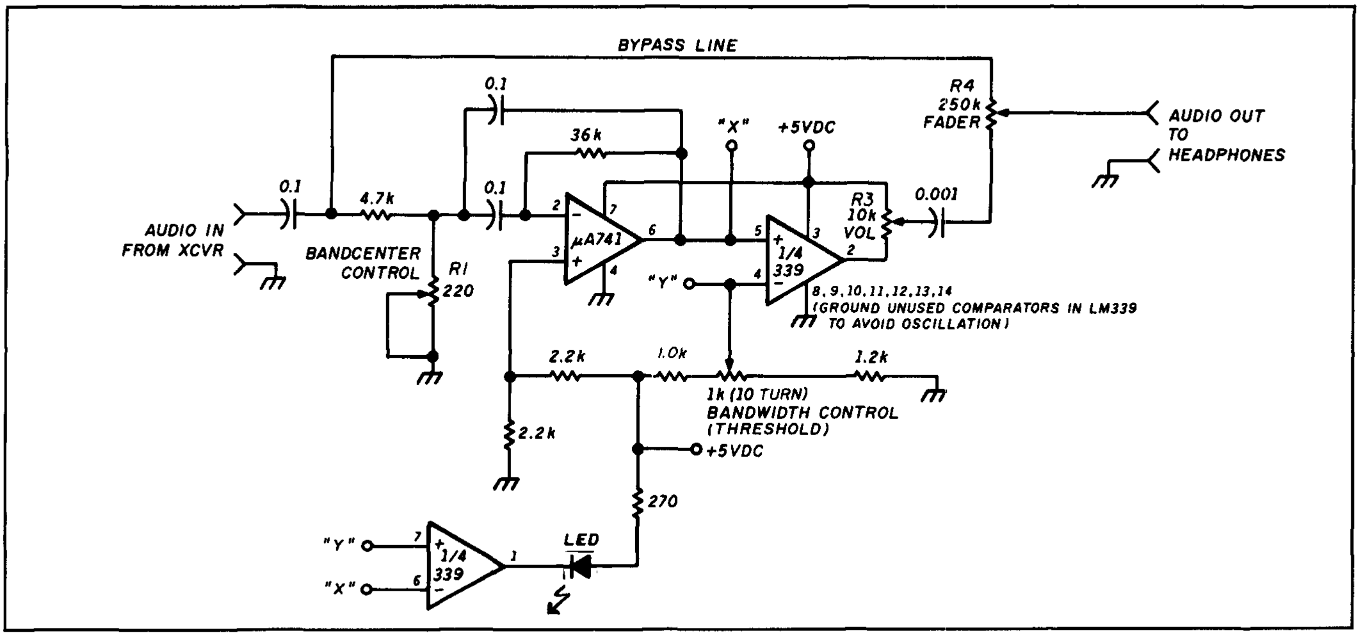
FIGURE 1



Schematic diagram of the complete 75-Hz bandwidth audio filter.

PARTS LIST

Recommended power supply:
Datel AC/DC regulated power adapter model PA-5/500.

Recommended cabinet:
Radio Shack no. 270-251.

All resistors 1/4-watt carbon composition or film types. All pots use linear tapers. All capacitors 25-volt disc ceramic types. Use shielded cables for power supply and audio input leads to avoid RFI.

Design of bandpass filter[1]

Figure 3 shows how an operational amplifier can be wired as an effective bandpass filter. Solving three simple equations determines circuit values:

$$Q = (R3) \times \pi \times f_c \times C \quad or \quad R3 = \frac{Q}{\pi \times f_c \times C} \qquad (1)$$

$$Gain = A = \frac{R3}{2 \times R1} \quad or \quad R1 = \frac{R3}{2 \times A} \qquad (2)$$

$$R2 = \frac{Q}{(2 \times Q^2 - A) \times 2 \times \pi \times f_c \times C} \qquad (3)$$

where: $C1 = C2 = C$
f_c = *center frequency*

$$Q = \frac{f_c}{3_{dB}\ BW} \qquad BW = bandwidth = \frac{f_c}{Q} \qquad (4)$$

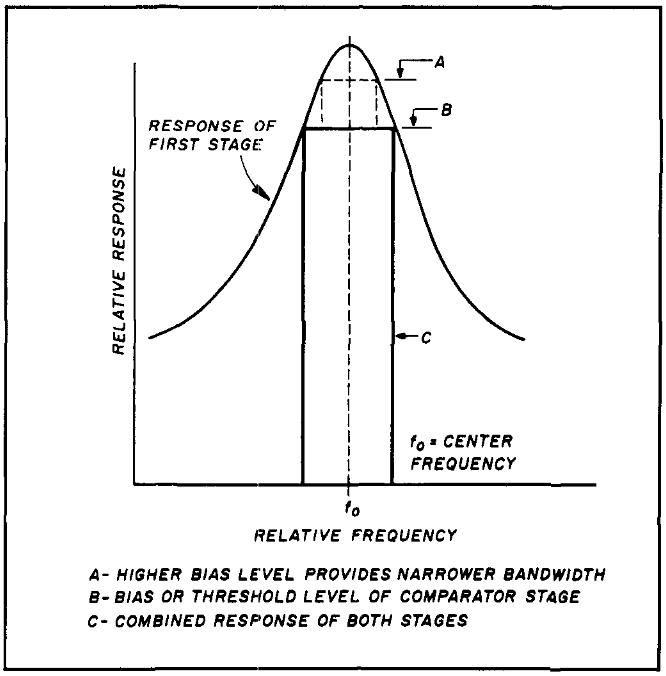
For: $f_c = 750\ Hz$
$A = 4$
$Q = 10$
Try: $C = 0.1 \mu F$

Then,

$$R3 = \frac{Q}{\pi \times f_c \times C} = \frac{10}{3.14 \times 750 \times 0.1 \times 10^{-6}} \qquad (5)$$

$$= 42{,}441.3\ ohms$$

FIGURE 2



Illustrated response of the first two stages showing bandwidth adjustability and selectivity.

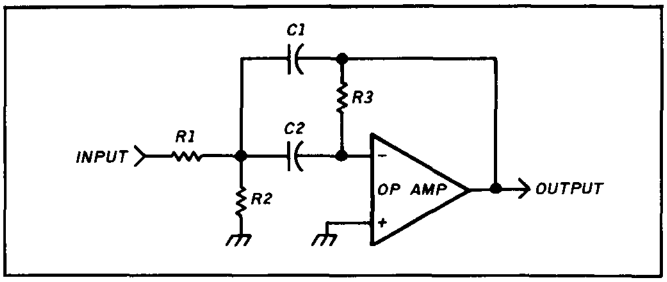
$$R1 = \frac{R3}{2 \times A} = \frac{42{,}441.3}{2 \times 4} = 5{,}305.2 \text{ ohms} \quad (6)$$

$$R2 = \frac{Q}{(2 \times Q^2 - A) \times 2 \times \pi \times f_c \times C} \quad (7)$$

$$= \frac{10}{(2 \times 10^2 - 4) \times 2 \times 3.14 \times 750 \times 0.1 \times 10^{-6}} = 108.3 \text{ ohms}$$

$$3_{dB}BW = \frac{f_c}{Q} = \frac{750}{10} = 75 \text{ Hz} \quad (8)$$

FIGURE 3



Basic schematic of an op amp (741) wired as an effective bandpass filter.

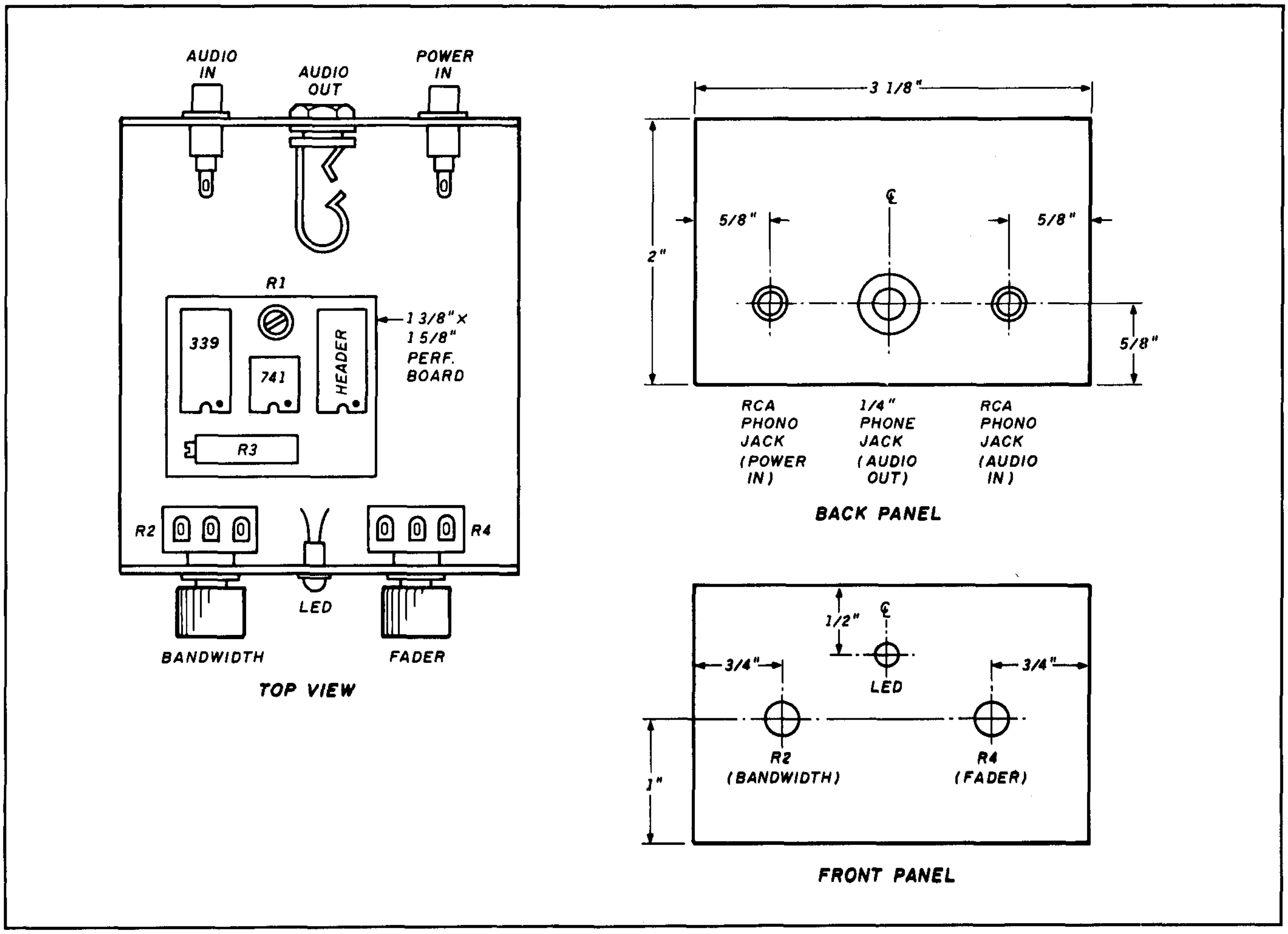
Because actual capacitor and resistor values tend to be on the high side of their tolerance ranges, select standard value resistors *below* the calculated values. For example, use 4.7 k for R1 and 36 k for R3. Variable resistor R2 can be any convenient value — like 200 ohms, or higher. A recalculation for 0.15-μF capacitors yields 3.3 k for R1, 100 ohms for R2, and 27 k for R3.

Construction notes

You can build the circuit in a variety of ways. There's nothing critical about the wiring. Point-to-point or pc board techniqes are proven methods; however, this project is ideally suited to a combination of both. All the fixed value resistors and capacitors can be soldered to a single 16-pin DIP header which plugs into a standard IC socket. Jumper wires from the socket to the panel-mounted components and active ICs complete the job.

Figure 4 shows the suggested arrangement of a 1-3/8 × 1-5/8 inch piece of perfboard, along with the parts layout on the front and rear panels. This layout is for use in a 3-1/4 inch wide × 2-inch high × 4-inch deep metal cabinet, like Radio Shack's catalog no. 270-251. The layout in **Figure 4** requires an external source of power. Take power from existing equipment or use a small wall-mounted power pack.

FIGURE 4



Mounting details and dimensions for the filter enclosure.

108

FIGURE 5

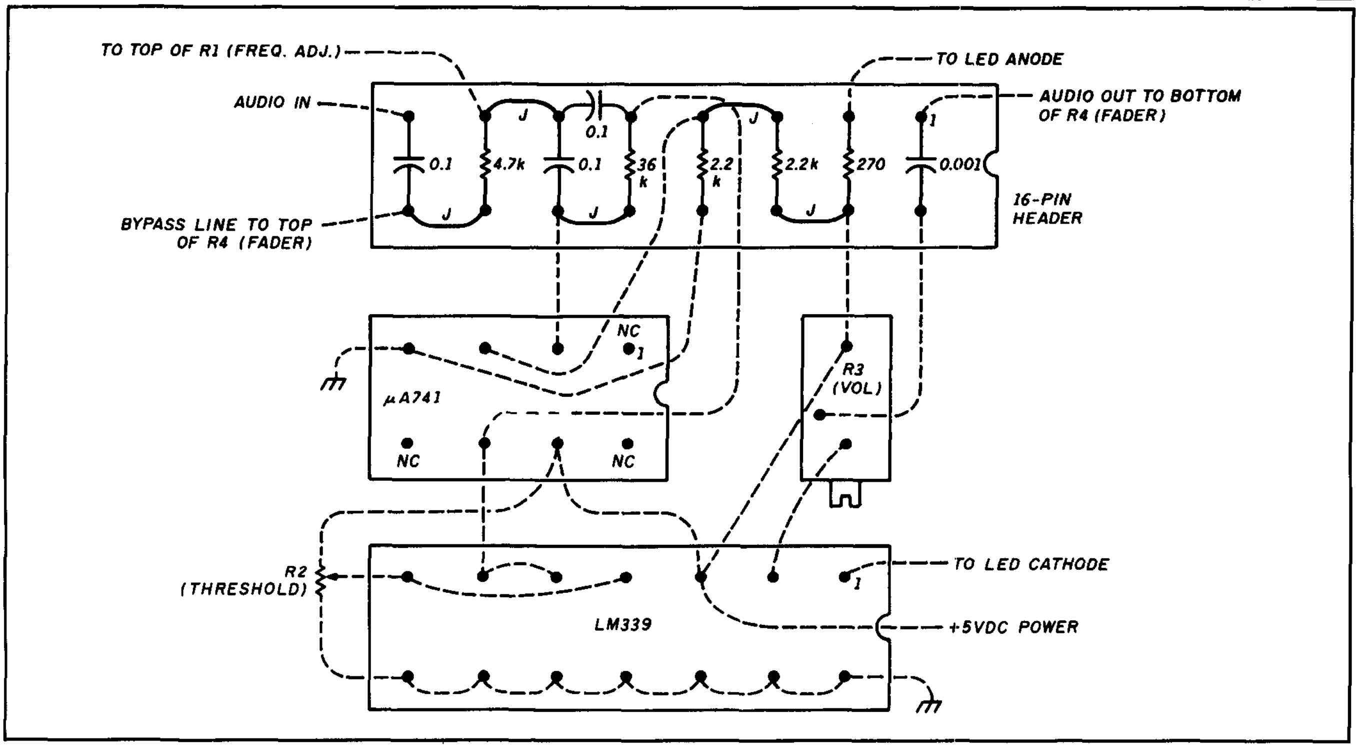


Diagram of parts placement and jumper connections for use with the DIP header type construction. Enlarged top view of header wiring and active ICs is shown. Heavy lines marked "J" are jumpers on header.

Figure 5 shows one arrangement for mounting parts on the IC header. The jumpers indicated by the heavy solid lines are also part of the header wiring. R2 can be any convenient value over 1 k. If you use 5 k or more, the 1-k and 1.2-k resistors shown connected to R2 in **Figure 1** can be eliminated.

Adjustment and operation

Adjustment of the four variable resistors is simple and straightforward. R1's setting determines the center frequency of the bandpass amplifier. If you plan to use the filter with a single receiver or several pieces of equipment with the same offset frequency (CW beat note), R1 is a "set and forget" control. Tuck it away inside the cabinet to conserve panel space. The same applies to R3, which is used to adjust the volume of the filter's output to match that of the receiver. R2 and R4, however, should always be located on the front panel. R2 determines the switching threshold of the comparator stage, and its setting is influenced somewhat by the strength of the received audio. **Figure 2** shows how the setting of the threshold level in relation to the response curve of the bandpass amplifier determines overall bandwidth. Note that the filter's selectivity narrows as the threshold is set closer to the peak of the curve. I recommend that you use a multiturn potentiometer, although a conventional control with about 330 degrees of rotation is satisfactory.

R4 acts as a fader control, but you can replace it with an SPDT switch. Unfiltered audio appears at the output of R4 when the wiper arm is pointing toward the bypass line. This position is handy for general tuning purposes. It's advantageous to use a variable control, rather than the switch arrangement, because you can move the wiper away from the full bypass position in smaller increments. In this mode of operation the narrower bandwidth still permits casual receiver tuning, but adds sufficient resistance to the bypass line to force some audio to enter the filter and activate the LED. Moving the wiper to the other end of R4 provides fully filtered audio at the output jack. In this position, the quality of the audio note changes from the original smooth sounding sine wave to a highly clipped note reminiscent of the CW limiters in old vacuum tube receivers. The resulting sound approaches that of a square wave and, in my opinion, produces a CW note that's easier to copy.

Adjust R1 using a steady carrier picked up by the receiver. You can use a crystal calibrator to supply the carrier. Tune the receiver for maximum deflection of the S-meter and leave it undisturbed while you make the rest of the adjustments. With the receiver audio level set no higher than needed for detection by the filter, and both R1 and R2 set fully counterclockwise (maximum bandwidth), the LED should be on. Carefully turn R2 clockwise until the LED goes off. Adjust R1 until the LED comes on again, and note the knob position. Continue turning R1 *in the same direction* until the LED goes off; note the knob position again. Return R1 to the setting midway between the transition points and turn R2 clockwise slightly to extinguish the LED. Reduce the filter bandwidth progressively using R2 and adjust frequency control R1, while maintaining minimum necessary excitation from the receiver. Eventually, you'll reach an adjustment of R1 which matches the filter's center frequency exactly to the offset frequency of the receiver. *Once optimized, R1's setting shouldn't be disturbed* during normal filter operation.

This filter is very easy to use. Just plug it into your headphone jack and turn up the receiver's volume control until the LED blinks in unison with the incoming code elements. Keep the fader control aimed toward the bypass line for maximum bandwidth. As I mentioned earlier, this position is best for general tuning purposes — including listening to phone QSOs. Moving the fader slightly away from the broadest position reduces the bandwidth enough to filter out background noise and cut phone QRM. Turning the fader control to the sharpest position lets you copy CW signals in the noise, or through heavy interference. The filter's sharp skirts will amaze you. A signal tuned to the edge of the passband simply disappears.

Acknowledgments

Part of this filter's circuitry was adapted from an article written by David Jagerman, KC2FR.[2] I'd also like to thank Jack Thompson, W2OPE for his valuable assistance in building the first prototype. hr

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1. Don E. Hildreth, W6NRW, "Graphic Filter Design," Figure 2, *Ham Radio*, April 1984, page 41.
2. David Jagerman, KC2FR, "The KC2FR QRM Fighter, *QST*, July 1982, page 28.

TV TO 2-METER ANTENNA CONVERSION

By Karen D. McIntyre, N4FQO, 3711 Gayle Avenue, Omaha, Nebraska 68123

As a very new ham, licensed for just a month, I found the idea of building a 2-meter antenna rather intimidating. However, my XYM (Ex-Young-Man) said that if I wanted one, it was up to me to build it. Thus challenged, I set to work.

I had originally planned a simple three-element beam, but because I find it impossible to keep anything simple, the antenna grew to five elements before I was out of the planning stage. It's an amazingly simple antenna to build — even for a rookie. All you need is three free hours, a scavenged TV antenna, some stainless steel hardware (nuts, bolts, flat and lockwashers, and two solder lugs), 7 feet of RG-58/U coax, a PL-259 coax connector, and a few strips of flat metal or wire (for the beta match).

This is also an inexpensive antenna to build, though the actual cost will depend on your scavenging ability. In my case, it only cost me $3.00 for some hardware I couldn't find in my husband's junkboxes. I garnered my TV antenna by climbing up on our shed and unbolting an unused antenna abandoned by the previous owners. My husband realized he had created a monster when I dragged it into the dining room to begin work on my creation! The fruits of my labor are shown in **Photo A**.

Selecting the antenna

You can use almost any TV antenna of the Yagi or log-periodic type, provided that it's in fair-to-good condition. Insulate the driven element from the boom. Don't use a folded dipole without a matching transformer.

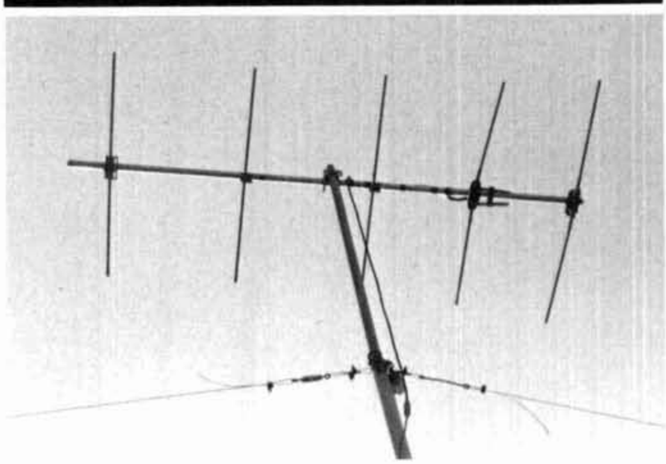
Make sure the TV antenna you choose has at least 71″ of boom. Any excess length may be either left alone or cut off; it makes no difference in the performance of your antenna. You'll need to salvage five elements of about 40″ each for the elements of your 2-meter antenna.

Disassembling the antenna

Once you've rounded up the TV antenna, the next step is to take it apart. Before you start taking the elements off the beam, look at **Figure 1**. It shows you the finished lengths of the elements and their spacing on the antenna. If possible, leave the first element (the longest one) of your TV antenna in place. This becomes the reflector of your antenna. Simply cut off the ends of the element to obtain the desired length (39″ tip to tip). It doesn't matter if the element is attached to the boom with a metal bracket; all the elements except the driven element are grounded to the boom, anyway.

Now remove the remaining elements from the TV antenna. Save all the brackets and hardware that you can and reuse it where possible during reassembly. You may have to drill out rivets to disassemble the TV antenna. Be careful not to damage the brackets when you do this, as they are hard to find and quite expensive.

PHOTO A



Completed 2-meter antenna. (Dimensions shown are for 146.50 MHz.)

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INSIDE VIEW — RS-12A

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SPECIAL FEATURES

- SOLID STATE ELECTRONICALLY REGULATED
- FOLD-BACK CURRENT LIMITING Protects Power Supply from excessive current & continuous shorted output
- CROWBAR OVER VOLTAGE PROTECTION on all Models **except RS-3A, RS-4A, RS-5A.**
- MAINTAIN REGULATION & LOW RIPPLE at low line input Voltage
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- THREE CONDUCTOR POWER CORD
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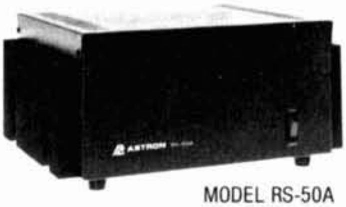
PERFORMANCE SPECIFICATIONS

- INPUT VOLTAGE: 105-125 VAC
- OUTPUT VOLTAGE: 13.8 VDC ± 0.05 volts (Internally Adjustable: 11-15 VDC)
- RIPPLE Less than 5mv peak to peak (full load & low line)
- **Also available with 220 VAC input voltage**

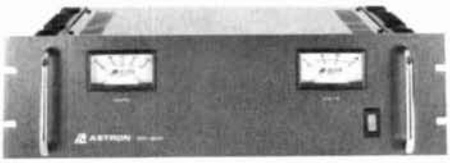


MODEL RS-50A

MODEL RS-50M

MODEL VS-50M

RM SERIES



MODEL RM-35M

19" × 5¼ RACK MOUNT POWER SUPPLIES

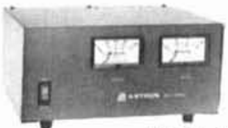
MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
RM-12A	9	12	5¼ × 19 × 8¼	16
RM-35A	25	35	5¼ × 19 × 12½	38
RM-50A	37	50	5¼ × 19 × 12½	50
• Separate Volt and Amp Meters				
RM-12M	9	12	5¼ × 19 × 8¼	16
RM-35M	25	35	5¼ × 19 × 12½	38
RM-50M	37	50	5¼ × 19 × 12½	50

RS-A SERIES

MODEL RS-7A

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
RS-3A	2.5	3	3 × 4¾ × 5¾	4
RS-4A	3	4	3¾ × 6½ × 9	5
RS-5A	4	5	3½ × 6⅛ × 7¼	7
RS-7A	5	7	3¾ × 6½ × 9	9
RS-7B	5	7	4 × 7½ × 10¾	10
RS-10A	7.5	10	4 × 7½ × 10¾	11
RS-12A	9	12	4½ × 8 × 9	13
RS-12B	9	12	4 × 7½ × 10¾	13
RS-20A	16	20	5 × 9 × 10½	18
RS-35A	25	35	5 × 11 × 11	27
RS-50A	37	50	6 × 13¾ × 11	46

RS-M SERIES



MODEL RS-35M

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
• Switchable volt and Amp meter				
RS-12M	9	12	4½ × 8 × 9	13
• Separate volt and Amp meters				
RS-20M	16	20	5 × 9 × 10½	18
RS-35M	25	35	5 × 11 × 11	27
RS-50M	37	50	6 × 13¾ × 11	46

VS-M AND VRM-M SERIES

MODEL VS-35M

- Separate Volt and Amp Meters • Output Voltage adjustable from 2-15 volts • Current limit adjustable from 1.5 amps to Full Load

MODEL	Continuous Duty (Amps) @13.8VDC	@10VDC	@5VDC	ICS* (Amps) @13.8V	Size (IN) H × W × D	Shipping Wt. (lbs.)
VS-12M	9	5	2	12	4½ × 8 × 9	13
VS-20M	16	9	4	20	5 × 9 × 10½	20
VS-35M	25	15	7	35	5 × 11 × 11	29
VS-50M	37	22	10	50	6 × 13¾ × 11	46
• Variable rack mount power supplies						
VRM-35M	25	15	7	35	5¼ × 19 × 12½	38
VRM-50M	37	22	10	50	5¼ × 19 × 12½	50

RS-S SERIES

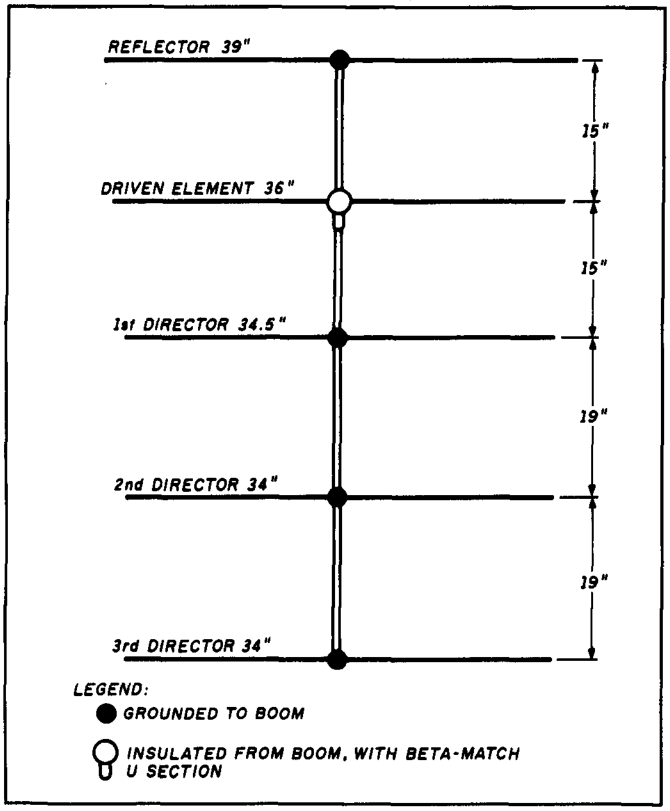
MODEL RS-12S

- Built in speaker

MODEL	Continuous Duty (Amps)	ICS* Amps	Size (IN) H × W × D	Shipping Wt. (lbs.)
RS-7S	5	7	4 × 7½ × 10¾	10
RS-10S	7.5	10	4 × 7½ × 10¾	12
RS-12S	9	12	4½ × 8 × 9	13
RS-20S	16	20	5 × 9 × 10½	18

*ICS—Intermittent Communication Service (50% Duty Cycle 5min. on 5 min. off)

FIGURE 1



Driven element details.

Assembling the antenna

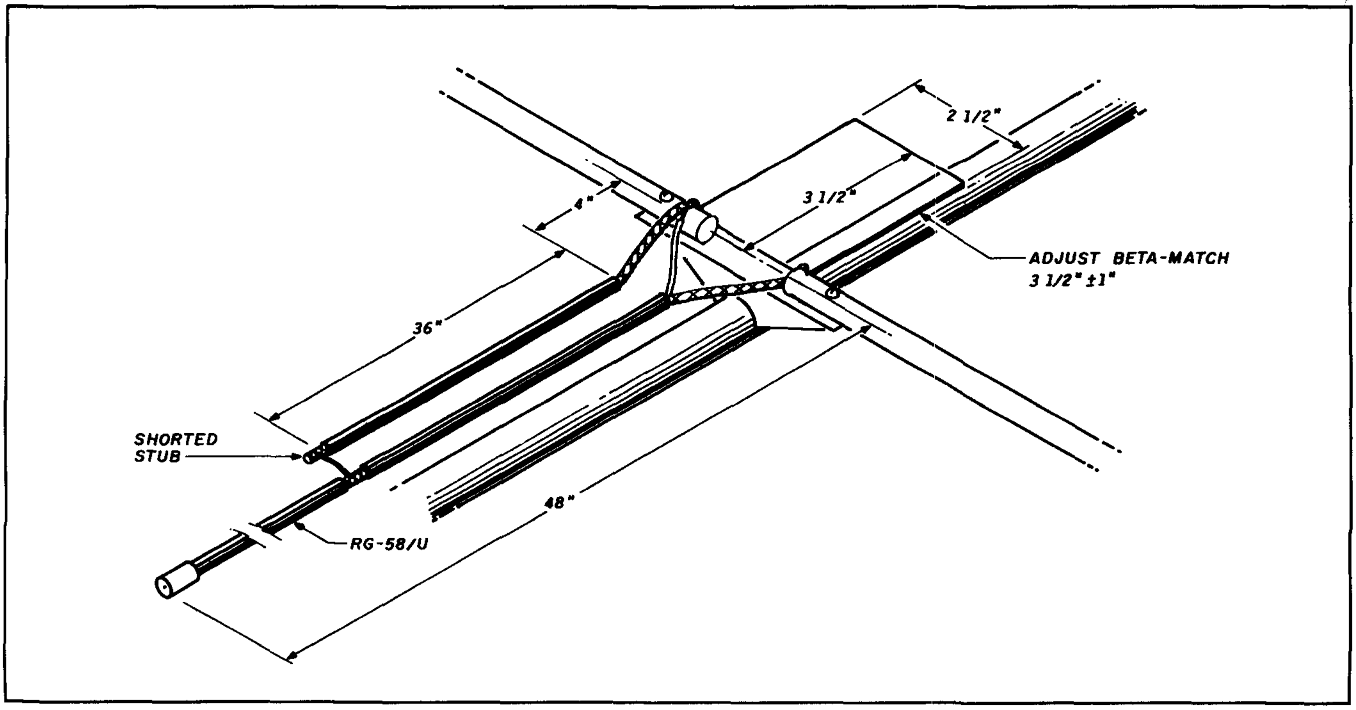
You now have a pile of salvaged elements and hardware, and a boom with one element attached. So far, so good. You're ready to put everything back together. If possible, use stainless steel hardware when reassembling your antenna; it's much more wear and corrosion resistant.

The next element, the driven element, must be insulated from the boom as it is "hot." The TV antenna I used had plastic brackets attaching three of the elements, so I simply used one of those. If your antenna doesn't have any plastic brackets, rummage in the junkbox or make one out of a piece of plastic or Lucite™. Measure 15" along the boom from the center of the reflector and drill a hole through the boom. Attach the plastic bracket to the boom, and any two element pieces to the bracket, with long stainless steel bolts, nuts, and lockwashers. Include two no. 10 stainless steel solder lugs when you affix the driven element, and tighten this piece just a bit for now. The solder lugs are used for connecting the coax line later. The beta match will also be attached at this point. Now cut this element to measure 36" total, tip to tip.

The last three elements — the first, second, and third directors — are virtually identical. Refer to **Figure 1** for spacing and element lengths. Simply drill a hole through the boom and mount a piece of element with stainless steel hardware and scavenged metal brackets. Then trim the elements to the correct lengths.

I think a few words are called for here regarding the accuracy of your measurements. Relax! Precision to the second and third decimal points isn't necessary, though the formulas in most antenna handbooks would seem to indicate

FIGURE 2



Two-meter antenna made from salvaged TV antenna, assembled and ready to roll.

otherwise. Stay as close as you can to the recommended lengths, but remember that a slight variance of 1/8" or so here or there isn't going to ruin your antenna. After I had cut and attached all the elements, I discovered that my old and frayed tape measure gave a slightly different reading each time I measured the same piece of metal. My husband, responding to the wails of distress emanating from the dining room, assured this panic-stricken rookie that everything would be okay — but I didn't really believe him at this point.

Matching network

The last order of business is the construction of the beta match and coaxial balun shown in **Figure 2**. The beta match is nothing more than a U-shaped conductor bridging the gap across the driven element. I used some flat pieces of metal 1/2" wide by 1/8" thick scavenged from the TV antenna and secured in a U shape 2-1/2" wide by 3-1/2" long. However you make the beta match, be sure that you can adjust its length (from 2-1/2" to 4-1/2" overall) for the best VSWR.

Now construct the coaxial balun as shown in **Figure 2**. Attach a PL-259 connector to one end of a 4' length of RG-58/U coax. At the other end of this 4' length of coax, separate about 4" of shield and center conductor. Measure back 36" from the point where the shield and center conductor divide, and expose about an inch of the shield by removing the outer insulation all the way around the coax. Cut another 36" piece of coax; solder one end of this to the exposed shield of the feedline and the other end to the center conductor (yes, center conductor!) of the feedline. Cover all solder joints, braid, and the center conductor with tape or heatshrink tubing to keep moisture out and to keep the sun from cracking the exposed center insulation. Attach this completed feedline to the solder lugs on the driven element, tighten the hardware, and tape the cable securely to the boom. I know this sounds like one big short circuit, but it works!

Adjusting the antenna

Now it's time to test your craftsmanship. Attach the feedline from your station to the PL-259 connector on the antenna feedline and check the VSWR. Through some blessed combination of skill and beginner's luck, my antenna came up at 1.2:1 VSWR at 146.97 MHz with very distinct front-to-back ratio the first time I tried it. (My XYM wanted to tinker with it, but I threatened him with bodily harm!) If you're not as fortunate, use the following steps to adjust the antenna:

- Adjust the driven element length for the lowest VSWR at your preferred operating frequency.
- Adjust the length of the U-shaped beta match until the VSWR at this frequency is minimum. You should have no trouble bringing it below 1.5:1.
- If you are a purist, repeat the two steps above, as there may be some iteration.

Summary

Mount your antenna any way you prefer. Now fire up the rig and have some fun! This antenna gives excellent performance, is lightweight, rugged, and has survived three Navy moves. It was a great confidence-building project for a rookie ham. ■

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MAKING
PRINTED CIRCUIT BOARDS

Don't give in to perfboard just yet!

By Dave Mascaro, WA3JUF, RD 1 Box 467, Ottsville, Pennsylvania 18942

There are many ways to produce your own printed circuit boards. Small boards for DC switching circuits are easy to make because neither the size nor the shape of the copper foil traces is critical. Boards containing many digital ICs are considerably harder to lay out and etch. There are also some double-sided digital board designs with plated-through holes. These types of boards aren't reproducible and you're better off buying them from the source.

Many articles have been published on the use of stencils and rubyliths in conjunction with sensitized pc boards and light tables. These techniques are good for the more complicated boards or for making multiple boards. The process involves making a positive or negative artwork, exposing and developing the light sensitive board, and then etching the board. Most homebrewers don't have access to light tables, developing solutions, and darkroom facilities. I use light sensitive methods for many of my pc boards — mostly for digital IC boards or multiple boards of the same design. What follows are some pc board techniques you can use instead of these facilities.

There are ways to produce RF microstrip and small DC pc boards in minutes without light tables, some without the etching process. Basically, there are four methods. Each method has its own variations, depending on the board material.

- X-ACTO™ knife method
- X-ACTO etch method
- Drafting tape method
- Dremmel method

These methods involve the use of an X-ACTO knife and other procedures that require safety glasses or goggles. The tip of an X-ACTO blade can snap off when used to cut copper foil. I purposely snap off a very small portion of each new blade before starting. This way I'm sure that the small blade tip will end up in the trash can and not on my workbench.

X-ACTO knife method

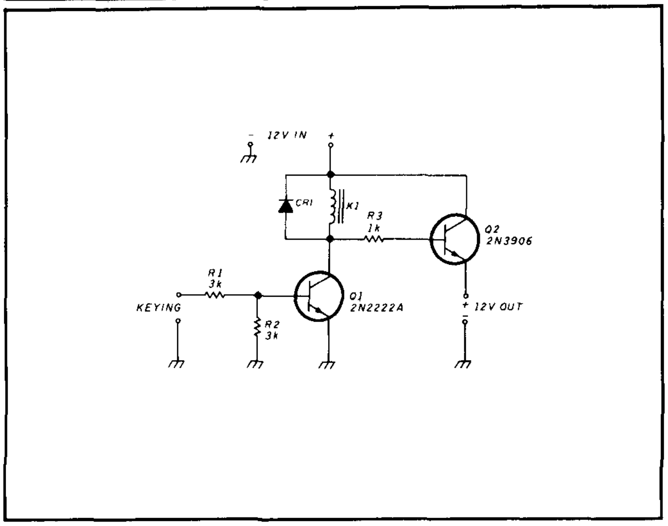
This type of pc board construction can be used on standard G-10 fiber glass board or Teflon™ dielectric boards. It involves cutting away strips of copper, leaving isolated pads to which components are soldered. This is a *non-etch* process for making pc boards quickly. A working project board can be completed in a quarter of the time it takes to make just the pc board using light sensitive methods. A pencil soldering iron with a pointed tip is required.

Figure 1 shows a small DC switching circuit to be made on G-10 board. Parts placement isn't critical on a simple non-RF board, and the parts layout can follow the schematic directly. Islands of copper are needed at all junctions of the individual components. Ground connections are common using the main copper foil portion of the board.

Figure 2 shows the pc board layout for the circuit in **Figure 1**. Using a pencil, draw small rectangular pads on the copper foil for each component connection. Draw a second outline slightly larger than the first. This small strip of copper around each pad will be removed later. You can draw symbols for each component on the board to make layout easier and ensure correct spacing for leads.

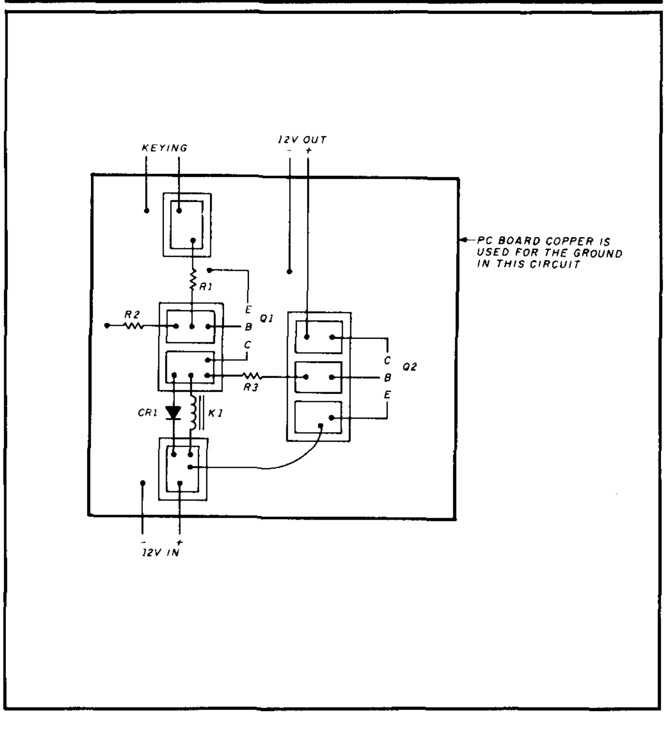
After drawing all the pads, mark and drill component mounting holes. Now, while wearing safety glasses, use the X-ACTO knife to cut along the pencil lines. Use a straight edge if you wish. Heat up the small strips of copper by dragging the tip of your soldering iron back and forth along the strip. The copper foil will pull away from the fiber glass board easily. You can remove very narrow strips with the soldering iron tip. Make the strips just wide enough to isolate the

FIGURE 1



Simple DC switching circuit.

FIGURE 2



Board layout showing pads made by removing copper strips around each square using X-ACTO knife methods. A "score knife" could also be used to cut away the copper, leaving the isolated pads.

pads. Wider foil strips can be tinned with solder first, then removed using the X-ACTO knife along with the soldering tip. After all the pads are isolated from ground, use steel wool to smooth the board and remove any oxidation that would hinder soldering the components in place.

You can remove copper to make mounting pads in another way — with a "score" knife. Roofing and siding people use this type of knife to cut aluminum siding. The blade makes a "V" cut in the aluminum, making it easy to bend and break. The blade will also cut a V-shaped groove in the fiber glass pc board. Using this knife is sometimes much easier than using an X-ACTO knife because you need to make only one cut. Dragging the knife along a straight edge allows you to remove long strips of copper for long rectangular pads. With this knife and a straight edge, you can cut pads with 0.1-inch spacing to accomodate ICs, computer-type connectors, or header plugs. I made a board with seven ICs, two LED readouts, and three header plugs using the score knife. Making pads with IC spacing using this knife, in conjunction with some wire wrapping, is a simple way to make an otherwise complicated pc board. After cutting the board to the proper layout, drill component and IC holes and use steel wool to smooth out the knife cuts.

You can use a double-sided pc board (copper foil on both sides) on larger boards with many grounding points. On double-sided boards, the non-etched or non-patterned side of the board is referred to as the ground plane side. All grounds are connected to the ground plane side of the board by holes drilled for each ground lead. Isolate the non-ground leads on the ground plane side of the board by clearing the holes with an oversized drill bit. Drill and clear all non-ground holes first to eliminate the confusion of which holes get cleared.

The X-ACTO knife method can also be used on Teflon pc boards for very basic microstrip designs. **Figure 3** shows a simple RF amplifier. A pc board for the amplifier with a 50-ohm microstrip is shown in **Figure 4**. This board can be produced using the X-ACTO knife method because all lines are straight. Basically, you need remove only two strips of copper. A working amplifier of this type can be completed in 15 minutes using X-ACTO etch.

The copper on a Teflon pc board won't peel when heated with a soldering iron as it does on G-10 board. Peel off the copper using the knife and good needle nose pliers. After drawing the design on the board with a pencil, cut along the lines with the knife. Cut just deep enough to go through the copper foil. Now use the X-ACTO knife and needle nose pliers to pull up the foil strips. After doing a few boards this way, you'll learn to remove the foil without cutting into the Teflon dielectric. Use other techniques for more complicated boards.

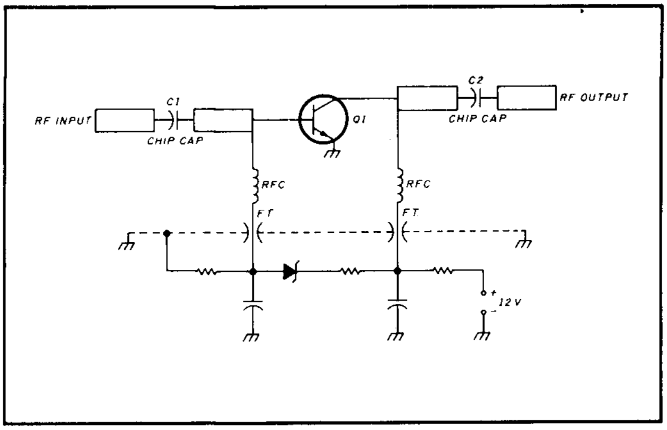
An X-ACTO knife is all you need to make microstrip-type boards on Epsilam 10-type board material (dielectric constant of 10). You can cut the foil with the knife and peel it off with a small pair of needle nose pliers. It's easy to remove the copper foil from this type of board material.

X-ACTO etch method

This process is used for making microstrip-type pc boards. The technique takes little time, doesn't require photo-type artwork, and eliminates the exposure/developing processes. With X-ACTO etch, you prepare your pc board for etching by cutting "clear tape resist" to the desired pattern with an X-ACTO knife. You can purchase clear tape on a 4-inch wide roll at most stationery stores. Although light sensitive methods would normally be used for producing multiple boards, I often use X-ACTO etch because it's faster. It takes less time to X-ACTO etch two or three boards than it does to use light sensitive methods. Making the rubylith artwork for light sensitive methods can be very time consuming.

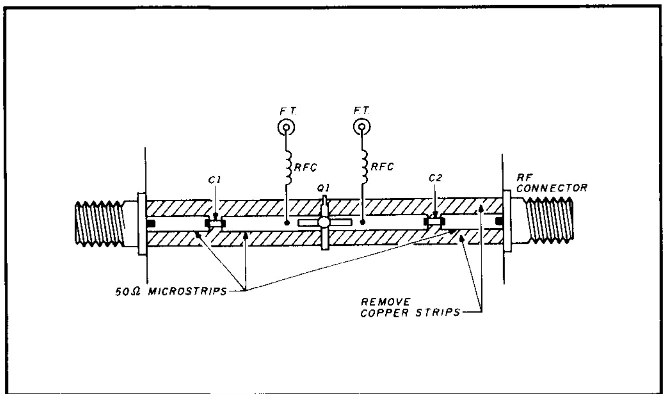
Select a pc board of the proper size. You must use double-sided board for all microstrip designs. Draw the desired pattern on the board with a pencil and straight edge. You can use a dial caliper to accurately lay out a

FIGURE 3



RF amplifier using 50-ohm microstrip.

FIGURE 4



Layout of RF amplifier showing two strips of copper to be removed with an X-ACTO knife to produce a microstrip pc board. Cut away copper to mount DC blocking chip caps C1 and C2.

design from full scale artwork in a magazine. Most microstrip designs have trimmer capacitors for optimization, anyway.

Cover both sides of the board with clear tape. Cut the tape along the penciled lines, using a straight edge as needed. Remove the tape where the copper is to be etched. The remaining tape will serve as the resist for etching the board. Press the resist tape firmly to the board to reduce the "under etching" effects of the ferric chloride. You can add any additional pads to the board later with pieces of tape. Etch the board and remove the resist tape. Clean the board with steel wool and trim to size if necessary.

Another variation of X-ACTO etch involves using a photocopy of the full-scale artwork as a pattern from which to cut the tape resist. Attach the board to the reverse side of the photocopy with tape. Cut the resist tape with your knife, following the artwork copy. You may find this technique difficult to use on some designs because, depending on the number of cuts, the artwork copy will fall apart before the last cuts are made. The last few cuts can usually be made by taking measurements with a dial caliper. After the tape pattern is cut, continue by using the procedures mentioned earlier.

Drafting tape method

You can make many DC switching and small IC projects on single-sided pc boards with this technique. Drafting supplies for making light table artworks are used as the actual resist for etching a board. Drafting tapes are available in many different widths. "Donuts" and other pad shapes are used to mark drill holes. Transistor and IC patterns are also available. Use clear tape to make your own special patterns. Then use these patterns in conjunction with drafting tapes to create circuit resist patterns on the copper side of the board.

Press the patterns and tape lines to the board firmly. Some under etching will occur, but this isn't a problem on DC-type boards. Making the lines a little wider initially will help. Now etch the board, remove the resist tape, and clean the board wih steel wool.

Dremmel method

A dremmel tool or small drill press can be used to cut away the copper foil to produce small pads of copper on G-10 fiber glass board. Instead of using the X-ACTO knife and soldering iron, use a small dremmel bit to cut isolating pads on the board. You can do this freehand on boards that don't require a neat appearance.

I use small dental drills in a drill press to cut some of my boards. The worktable is raised up close to the drill bit and set so the bit cuts only through the copper foil. Mark the copper side of the board with a pencil. Move the pc board along the worktable, following the penciled lines. A straight edge clamped to the worktable acts as a guide, letting you make straight cuts on the pc board.

Etching boards

You can etch boards in several ways. The easiest method is to use a spray etching tank. If you don't have access to a tank, the method that follows can be used for basement or garage etching. Conventional methods involving plastic trays with agitating motors and heat lamps work too.

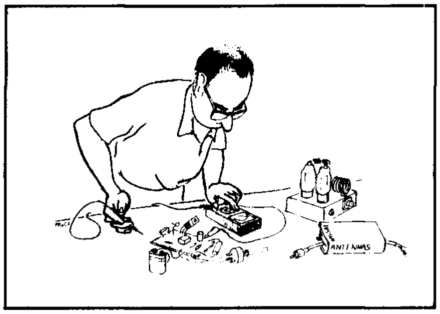
Place the board to be etched in a Tupperware® or other sealed plastic container with sufficient etching solution. Ferric chloride works best at higher temperatures. The etching solution should be less than half the volume of the container to allow for air expansion. Put the plastic container in a bucket of hot water and agitate until the board is etched.

Another etching container that works well is the ceramic "crock pot." I got the idea of using the crock pot from Phil, WA3NUF. Pour about 1 inch of ferric chloride into the pot. Put your board in the pot and replace the cover. Set on the low heat position. Your board will be done in 30 minutes. You can etch several small boards at the same time, providing they aren't stacked on top of each other. The ferric chloride fumes stay in the pot; this is an advantage over using a plastic tray for etching. This type of etching can be used for all resist methods. Even in the high heat position, the clear tape resist works just fine.

Conclusion

I hope these methods will encourage you to build projects requiring a pc board. A double-sided board with plated-through holes is nice, but isn't always necessary. Next time you think about a perfboard project, try it on a pc board using the X-ACTO knife method. I think you'll find it's easier.

Ham Radio Techniques



Bill Orr, W6SAI

ANTENNA GAIN

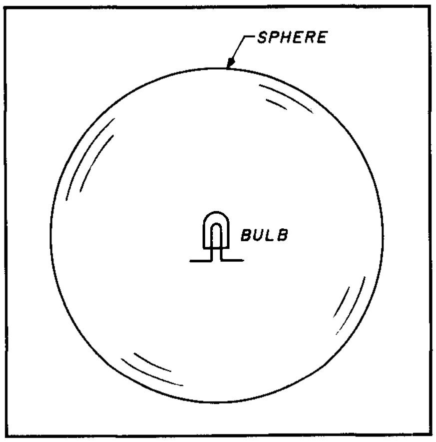
Antenna gain is nice. Those who have it are louder on the air than those who don't. It's as simple as that. Antenna gain costs money and takes up space. Antenna gain, much like "music power" in a stereo amplifier, is a concept that brought joy to the believers in the hard sell technique. Antenna gain advertisements touted bigger and better gain figures that stretched the imagination and glazed the eyes of the innocent.

A decade or so ago, the "gain wars" between antenna manufacturers grew so intense that the gain figures given in antenna advertisements were no longer accepted in some Amateur magazines. Things have calmed down now, and sophisticated hams have a pretty good idea of the gain available from various antennas. They also know the expressions that define the gain.

Expressing antenna gain reference in dBi and dBd

For the record, accepted expressions of antenna gain reference either an isotropic radiator or a comparison dipole. The isotropic radiator is a theoretical antenna that radiates equally well in all directions. This concept can be illustrated by a tiny light bulb placed at the center of a large sphere. The bulb illuminates the interior of the sphere equally at all points (**Figure 1**). Antenna gain in decibels referenced to an isotropic radiator is expressed as dBi.

FIGURE 1



An isotropic radiator is simulated by a tiny light bulb placed at the center of a large sphere. The bulb illuminates the interior of the sphere equally at all points.

A real-life antenna has some degree of directivity and, if placed in the center of a large sphere, illuminates certain portions better than others. That is, the antenna radiates energy better in certain directions. The simple dipole has maximum radiation at right angles to the wire and minimum radiation off the ends. Antenna gain in decibels referenced to a dipole is expressed as dBd.

If the same amount of energy is radiated by the dipole as by the isotropic radiator, the energy in the direction of maximum radiation of the dipole is about 2.14 dB greater than that of the isotropic antenna. So it can be said that a dipole has a power gain of 2.14 dB in the direction of the main lobes over an isotropic radiator.

All of this supposes that the isotropic radiator and dipole are in free space. What happens when an antenna is placed in proximity to the earth?

The effect of the earth on antenna gain

The best way to visualize the antenna near earth is to cut the sphere of measurement in half horizontally and substitute a conducting metal plate for the missing portion (**Figure 2**). Now, only half of the original sphere is illuminated. The other half is represented by the ground plate. Assume a horizontal half-wave dipole is placed at the center point of the sphere. The direct and reflected waves are in phase, or additive. Because the same amount of power is radiated in half the volume, the field is doubled — or increased by 3 dB. In addition, if the ground plane is smooth and a perfect conductor, ground reflection adds another 3 dB. Thus, a dipole in a "near earth" situation can have up to 6-dB gain over the antenna in free space.[1,2]

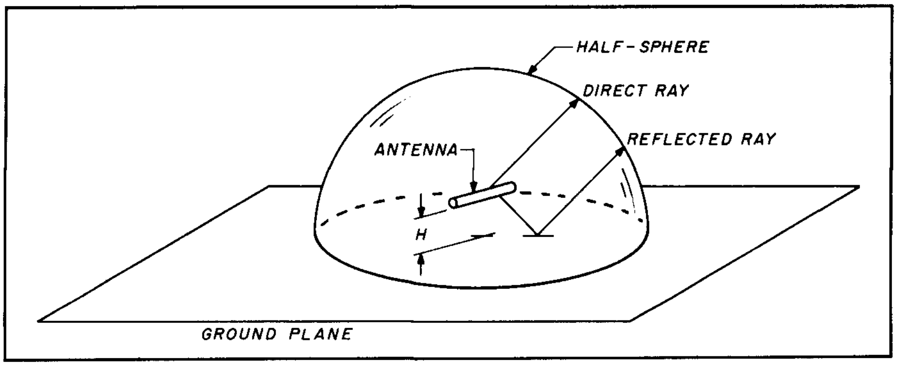
Note that I said "up to." Maximum ground reflection gain occurs in line with the direction of maximum radiation. Cancellation of gain occurs at other angles above the horizon. Limiting cases are either 6 dB greater than the free space value, or zero. The result is the well-known radiation pattern shown in **Figure 3**.

The reflection gain figure can be less than the theoretical value if ground conductivity is poor. Ground conductivity studies have been made since the early days of broadcasting, and the values in the United States are well known.[3] Conductivity is expressed in siemens (or millisiemens) per meter. The dielectric constant is also given (see **Table 1** in **Reference 3**).

There's a computer program* available that lets you examine reflection gain as a function of ground conductivity (**Figure 4**). In an area of high ground conductivity, the reflection gain for a dipole is better than 6 dB over the free space value. As ground conductivity and dielectric constant decrease, the reflection gain decreases. In the

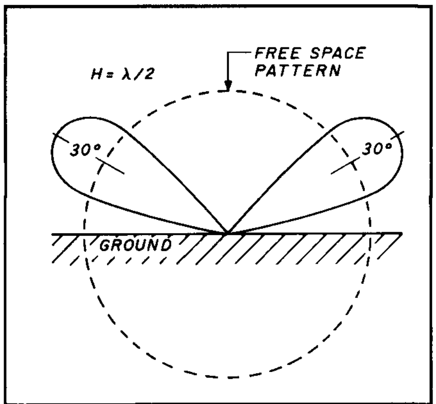
*MN Antenna Analysis, Brian Beezley, K6STI, 507-1/2 Taylor, Vista, California 92084.

FIGURE 2



The effect of ground is simulated by placing the antenna over ground plane. Because the same amount of power is radiated in half the sphere volume, the radiated field is doubled. Ground reflection depends upon ground conductivity and can increase the field by up to 3 dB in line with maximum radiation.

FIGURE 3



Ground modifies the free space pattern. This shows a half-wave dipole 1/2 wavelength above ground. Six dB gain is added when antenna is above perfect ground, as compared with free space.

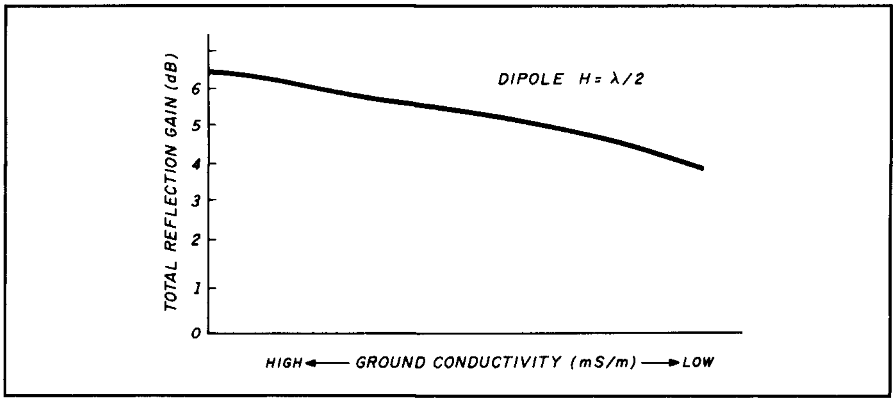
example shown, the dipole loses nearly 3 dB in reflection gain when going from an area of high ground reflection to an area of poor reflection.

Enter the computer

The conventional dBi and dBd gain figures are well known, but the picture has been clouded recently by computer-derived antenna programs that automatically add up to 6-dB ground reflection gain to the results — depending on the value of ground conductivity you enter into the program. This is producing eye-popping gain figures for even rather simple antennas. A casual observer might jump to the tantalizing conclusion that a dipole is indeed a "gain" antenna. After all, it has up to 6 dB of ground reflection gain, doesn't it?

Thus, there are four valid ways of referencing antenna gain: (1) in free space, referenced to an isotropic radiator; (2) in free space, referenced to a dipole; (3) in proximity to the earth, referenced to an isotropic radiator. (4) in proximity to the earth, referenced to a dipole.

FIGURE 4



As ground conductivity decreases, ground reflection gain also decreases.

Comparing apples and oranges

Everything seems simple enough, up to this point. But the possibility exists that some antenna manufacturers will claim inflated gain figures. The opportunity to tout reflection gain can be irresistible. All's well if everyone uses the same ruler for gain comparison. I've noticed, however, that one antenna manufacturer has latched onto the ground reflection concept and is boasting antenna gain figures based on earth proximity, referenced to an isotropic radiator. His data sheet doesn't mention any definition of the gain reference.

More and more computer-designed antennas are being publicized, and it's common to see antenna gain figures based upon earth reflection.[4] Once the concept of reflection gain and ground conductivity are well known, and antenna gain figures are properly referenced, the computer-derived gain figures fall into their proper perspective.

Halyard replacement

I have a bi-square loop antenna[5] supported by a halyard passing over a pulley that hangs from a yardarm near the top of my tower. The rope was quite frayed and I wanted to replace it before it broke. I knew that if it did break, it would run through the pulley, and I would have to climb the tower and hang by my heels to get a replacement rope through. Because fear sets in if I go more than 10 feet above the ground, this was an unpleasant thought!

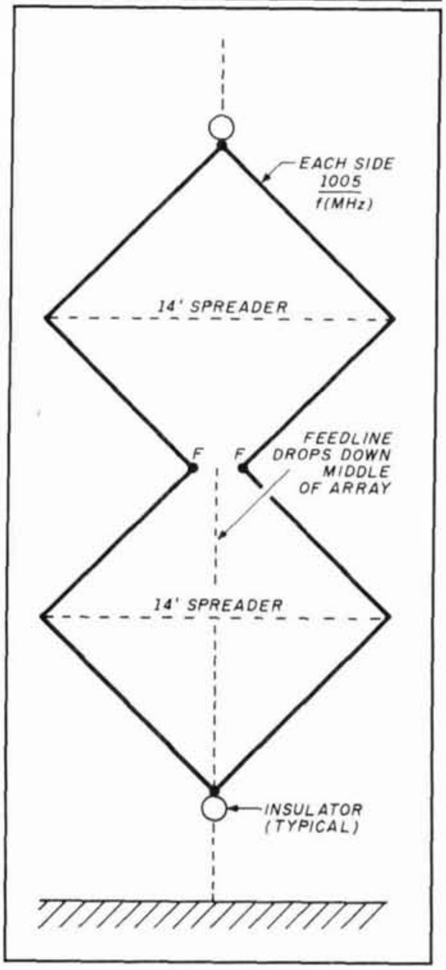
How was I going to get a replacement rope through the pulley from ground level? That was the puzzle. I couldn't splice the new rope to the old and pull it through the eye of the pulley. There was no room for that! I had forgotten long ago the tricky knots that earned me a Scout merit badge. Finally, I had a brainstorm! I could use heatshrink tubing to splice the rope ends together! I placed the end of the old rope in one end of a foot-long section of heatshrink tubing; the new rope went in the other end. I used safety matches to shrink the tubing. The two ropes were firmly connected and the splice slid easily through the pulley! Q.E.D.

The dual quad loop antenna

A single, vertical quad loop makes an effective antenna. It has the radiation pattern of a dipole and provides an additional gain of approximately 1.2 dB. The quad loop has a very broad band response and a feedpoint impedance of about 120 ohms. Place two of these loops in phase and feed them at the common point, and you have Jeff O'Connell's, K4BLT, dual quad loop antenna.

Jeff's antenna is cut for the 12-meter band. It's suspended from a branch of a pine tree (**Figure 5**). Two oak spreaders 1-1/4 inch square and 14 feet long form the diamonds. The pattern is bidirectional and the gain is estimated to be about 3.5 dBd. Polarization is horizontal.

FIGURE 5



Antenna is fed at F-F with coax line. Line is wound into four-turn RF choke at feedpoint.

The antenna is fed at the center with a coax line. The feedpoint impedance is very close to 50 ohms. The line is wound into an RF choke at the feedpoint. The choke consists of four turns of coax 5 inches in diameter. This helps keep RF off the outer shield. Bring the line down the middle of the array, as shown.

The K4COF dragonfly effect

Phil Elrod, K4COF, reports a puzzling effect he noticed on a dipole antenna when he was stationed in Japan. He says that he saw dragonflies sitting on the antenna, all facing in the same direction. Each time the transmitter was keyed, the dragonflies would instantly leap off the antenna and hover in the air. When the transmitter was unkeyed, the insects would return to the wire! He said the dipole was fed directly with coax; no balun was used. The hopping insects were mainly on the dipole half connected to the center conductor of the coax!

It occurs to me that dragonflies might be good, cheap indicators of antenna balance. They might even be more effective than an SWR meter! However, there aren't many dragonflies in northern California. How about hummingbirds or killer bees? Do you suppose Phil is pulling my leg?

The "Dead Band" Quiz

K4COF also supplies this month's quiz. (He doesn't supply the answer because he doesn't know it!) The question is: At 4:00 and 8:00 o'clock the clock's minute and hour hands form a 120-degree angle. Is there a time at which the hour, minute, and second hands form three simultaneous 120-degree angles? If you know the solution, and can prove it, drop me a note at Box 7508, Menlo Park, California 94025. Phil will get his answer when he reads this column.

Coming next month: results of the "snowplow" quiz! hr

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COPPER PIPE TRANSMISSION LINES

"Plumber's delight" antenna feed system

By Ernie Franke, WA2EWT, 10484 138th Street N., Largo, Florida 34644 and Judd Sheets, WA4BUS, 6926 10th Avenue N., St. Petersburg, Florida 33710

Copper pipe offers a mysterious attraction to the VHF/UHF enthusiast. When he comes across a large diameter piece of tubing in a scrap yard, he has a compelling desire to store it away in anticipation of building a cavity.

The tables in this article show the impedances obtainable when using copper pipe from a plumbing store. You may find them helpful in determining how to use these pipes to form coaxial TEM structures. Copper pipe has been used for coaxial transmission lines,[1] antenna power dividers,[2] coaxial filters,[3] cavity duplexers,[4,5] and baluns.[6] By considering the best impedance for achieving the lowest loss, you can design these structures for the highest Q and minimum loss.

The design of a transmission line or a coaxial cavity is set by the maximum allowable inside diameter of the outer conductor (D), as shown in **Figure 1**. Once you have this dimension, calculate the impedance using the outer-to-inner conductor D/d diameter ratio. The characteristic impedance (Z) of a coaxial line is given by:

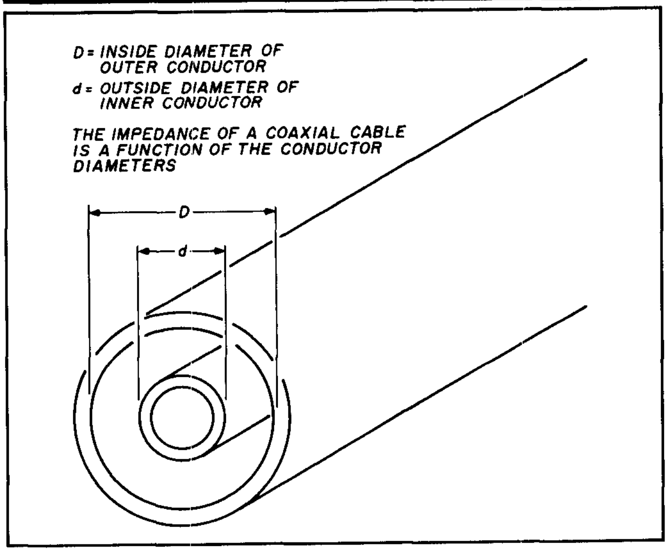
$$Z = (138/\sqrt{\epsilon_r}) \log (D/d) \qquad \textbf{(1)}$$

where ϵ_r is the relative dielectric constant and d is the inner conductor outside diameter (OD), given in the same unit of measure as the outer conductor. The relative dielectric constant for air is extremely close to 1. The impedances for various tubing diameter ratios for copper pipe are shown in **Table 1**. We've listed various combinations of inner and outer conductors to provide a wide impedance selection for any given outer diameter. Impedance selection is especially useful for impedance matching. An impedance-matching section is used frequently in an antenna-phasing harness to match the transmission line impedance to each antenna in an array. The simplest matching section is a quarter-wave transmission line (commonly referred to as a Q matching section), with an impedance equal to the square root of the product of the source and load impedances:

$$Z = Z_S \cdot Z_L \qquad \textbf{(2)}$$

Copper tubing is classified in accordance with the wall thickness, which is based on the required service — as shown in **Table 2**. Household plumbing codes usually require type L pipe. For heating systems, where the same water is recirculated through baseboard heaters, thinner wall type M pipe is acceptable. The outside diameter (OD) of copper tubing is always 1/8″ greater than the nominal size. For instance, the chart in **Table 1** shows that 1/4″ tubing has an OD of 3/8″ and

FIGURE 1



Anatomy of a transmission line. D = inside diameter of outer conductor; d = outside diameter of inner conductor. The impedance of a coaxial cable is a function of the conductor diameters.

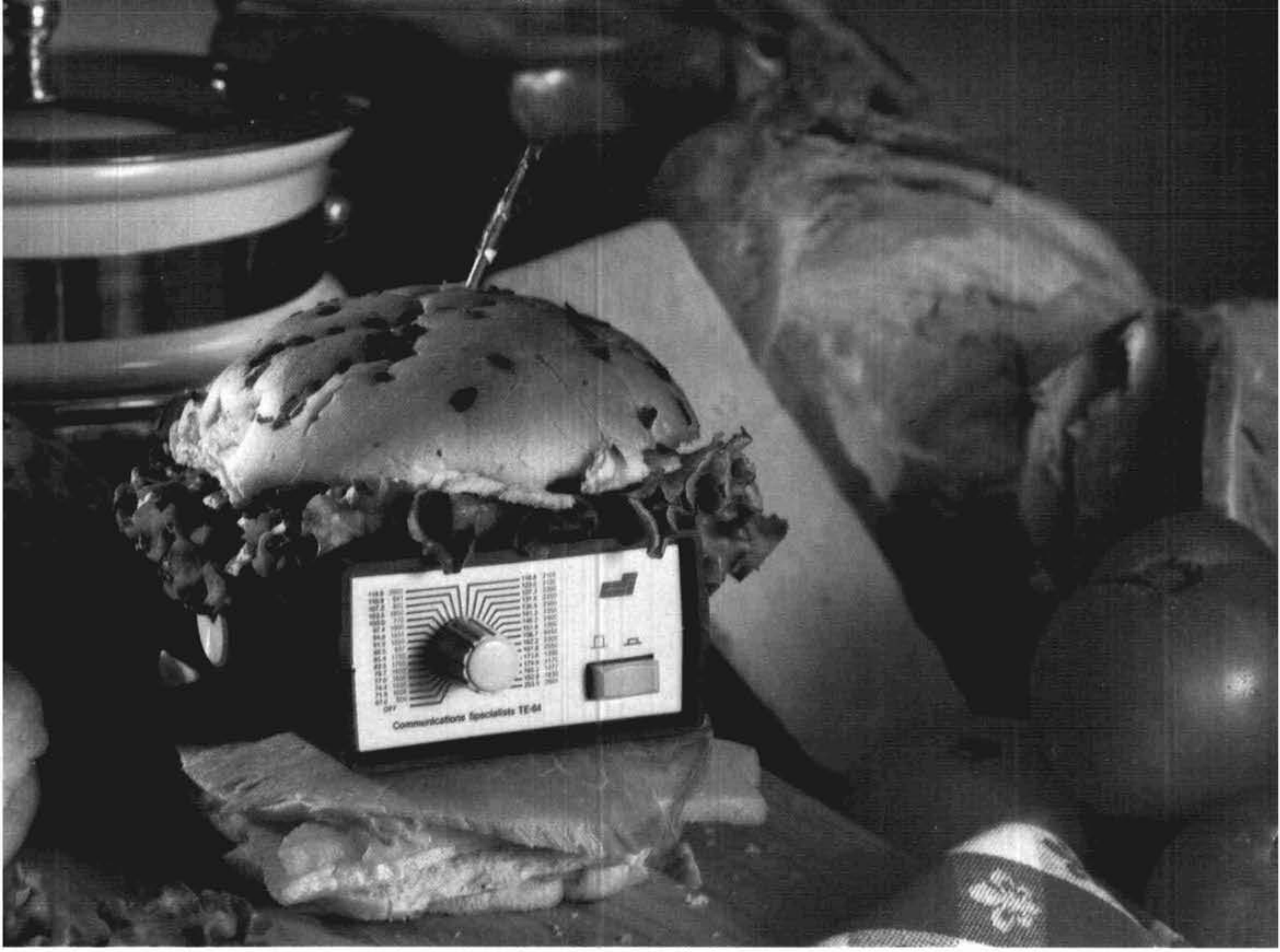


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TABLE 1

INNER CONDUCTOR (COPPER)

OUTER CONDUCTOR (COPPER)

		Size	1/4"	3/8"	1/2"	5/8"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"
Size	Type	ID\OD	0.375	0.500	0.625	0.750	0.875	1.125	1.375	1.625	2.125	2.625
3/4"	K	0.745	41.1	23.9	10.5	-	-	-	-	-	-	-
	L	0.785	44.3	27.0	13.7	2.7	-	-	-	-	-	-
1"	K	0.995	58.5	41.2	27.9	16.9	7.7	-	-	-	-	-
	L	1.025	60.3	43.0	29.7	18.7	9.5	-	-	-	-	-
1-1/4"	K	1.245	71.9	54.7	41.3	30.4	21.1	6.1	-	-	-	-
	L	1.265	72.9	55.6	42.3	31.3	22.1	7.0	-	-	-	-
	M	1.291	74.1	56.8	43.5	32.6	23.3	8.3	-	-	-	-
	DWV	1.295	74.3	57.0	43.7	32.7	23.5	8.4	-	-	-	-
1-1/2"	K	1.481	82.3	65.1	51.7	40.8	31.5	16.5	4.5	-	-	-
	L	1.505	83.3	66.0	52.7	41.7	32.5	17.4	5.4	-	-	-
	M	1.527	84.2	66.9	53.5	42.6	33.4	18.3	6.3	-	-	-
	DWV	1.541	84.7	67.5	54.1	43.2	33.9	18.9	6.8	-	-	-
2"	K	1.959	99.1	81.8	68.5	57.5	48.3	33.2	21.2	11.2	-	-
	L	1.985	99.9	82.6	82.6	58.3	49.1	34.0	22.0	12.0	-	-
	M	2.009	100.6	83.3	70.0	59.1	49.8	34.8	22.7	12.7	-	-
	DWV	2.041	101.5	84.3	70.9	60.0	50.8	35.7	23.7	13.7	-	-
2-1/2"	K	2.435	112.1	94.9	81.5	70.6	61.3	46.3	34.3	24.2	8.2	-
	L	2.465	112.8	95.6	82.2	71.3	62.1	47.0	35.0	25.0	8.9	-
	M	2.495	113.6	96.3	83.0	72.0	62.8	47.7	35.7	25.7	9.6	-
3"	K	2.907	122.7	105.5	92.1	81.2	72.0	56.9	44.9	34.9	18.8	6.1
	L	2.945	123.5	106.3	92.9	82.0	72.7	57.7	45.7	35.6	19.6	6.9
	M	2.981	124.2	107.0	93.6	82.7	73.5	58.4	46.4	36.4	20.3	7.6
	DWV	3.035	125.3	108.1	94.7	83.8	74.5	59.5	47.5	37.4	21.4	8.7
4"	K	3.857	139.7	122.4	109.1	98.1	88.9	73.8	61.8	51.8	35.7	23.1
	L	3.905	140.4	123.2	109.8	98.9	89.7	74.6	62.6	52.6	36.5	23.8
	M	3.935	140.9	123.6	110.3	99.3	90.1	75.0	63.0	53.0	36.9	24.3
	DWV	4.009	142.0	124.8	111.4	100.5	91.2	76.2	64.1	54.1	38.0	25.4
5"	K	4.805	152.9	135.6	122.2	111.3	102.1	87.0	75.0	65.0	48.9	36.2
	L	4.875	153.7	136.5	123.1	112.2	102.9	87.9	75.9	65.8	49.8	37.1
	M	4.907	154.1	136.9	123.5	112.6	103.3	88.3	76.3	66.2	50.2	37.5
6"	K	5.741	163.5	146.3	132.9	122.0	112.7	97.7	85.7	75.6	59.6	46.9
	L	5.845	164.6	147.4	134.0	123.1	113.8	98.8	86.7	76.7	60.6	48.0
	M	5.881	165.0	147.7	134.4	123.4	114.2	99.1	87.1	77.1	61.0	48.3
	DWV	5.959	165.8	148.5	135.1	124.2	115.0	100.0	87.9	77.9	61.8	49.1

Characteristic impedance of rigid air line using large copper pipe. (Impedance values given in ohms.)

TABLE 2

Copper tubing classified by wall thickness and required service.

Type	Wall thickness	Service
K	Heaviest wall	Underground
L	Medium wall	General plumbing and heating
M	Thin wall	Sanitary drainage and heating
DWV	Thinnest wall	Drainage, waste, vent

2-1/2″ tubing has an OD of 2-5/8″. The outside diameter of copper tubing must always be constant for any type within a nominal pipe size (in spite of wall thickness variations), so that solder fittings will be common to each type of tubing.

When you use copper pipe with less than 1″ outside diameter, it's desirable to use brass tubing for the inner conductor. Look for it in local hobby shops. The values of impedance are shown in **Table 3**.

As the outside diameter of a coaxial line is increased, the attenuation decreases. There is, however, a limit to the allowable pipe size that can be used for the outer conductor. The minimum attenuation point[7] of a coaxial transmission line occurs at an outer-to-inner conductor diameter D/d ratio of 3.591, which is 76.6 ohms for an air line. Because the attentu-

TABLE 3

INNER CONDUCTOR (BRASS)

OUTER CONDUCTOR

		Size	3/32"	5/32"	7/32"	1/4"	9/32"	5/16"	11/32"	3/8"	13/32"	7/16"	15/32"	1/2"	17/32"	9/16"	19/32"	5/8"
Size	Type	ID\OD	0.094	0.156	0.219	0.250	0.281	0.313	0.344	0.375	0.406	0.438	0.469	0.500	0.531	0.563	0.594	0.625
5/32"	B	0.125	17.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/32"	B	0.189	42.0	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/4"	B	0.221	51.4	20.9	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
9/32"	B	0.253	59.5	29.0	8.6	-0.7	-	-	-	-	-	-	-	-	-	-	-	-
5/16"	B	0.285	66.6	36.1	15.8	7.8	0.8	-	-	-	-	-	-	-	-	-	-	-
11/32"	B	0.321	73.8	43.2	22.9	15.0	8.0	1.5	-	-	-	-	-	-	-	-	-	-
3/8"	B	0.347	78.4	47.9	27.6	19.6	12.6	6.2	0.5	-	-	-	-	-	-	-	-	-
13/32"	B	0.377	83.4	52.9	32.6	24.6	17.6	11.1	5.5	0.3	-	-	-	-	-	-	-	-
7/16"	B	0.408	88.1	57.6	37.3	29.4	22.3	15.9	10.2	5.1	0.3	-	-	-	-	-	-	-
15/32"	B	0.442	92.9	62.4	42.1	34.2	27.1	20.7	15.0	9.9	5.1	0.5	-	-	-	-	-	-
1/2"	B	0.471	96.7	66.2	45.9	38.0	31.0	24.5	18.8	13.7	8.9	4.4	0.3	-	-	-	-	-
17/32"	B	0.503	100.7	70.2	49.8	41.9	34.9	28.4	22.8	17.6	12.8	8.3	4.2	-	-	-	-	-
9/16"	B	0.536	104.5	74.0	53.6	45.7	38.7	32.2	26.6	21.4	16.6	12.1	8.0	4.2	0.6	-	-	-
19/32"	B	0.565	107.7	77.1	56.8	48.9	41.9	35.4	29.7	24.6	1.8	15.3	11.2	7.3	3.7	0.2	-	-
5/8"	B	0.598	110.9	80.5	60.2	52.3	45.3	38.8	33.1	28.0	23.2	18.7	14.6	10.7	7.1	3.6	0.4	-
3/4"	K	0.745	124.1	93.7	73.4	65.4	58.4	52.0	46.3	41.1	36.4	31.8	27.7	23.9	20.3	16.8	13.6	10.5
	L	0.785	127.2	96.8	76.5	68.6	61.6	55.1	49.4	44.3	39.5	35.0	30.9	27.0	23.4	20.0	16.7	13.7
1"	K	0.995	141.4	111.0	90.7	82.8	75.8	69.3	63.7	58.5	53.7	49.2	45.1	41.2	37.6	34.2	30.9	27.9
	L	1.025	143.2	112.8	92.5	84.6	77.6	71.1	65.4	60.3	55.5	51.0	46.9	43.0	39.4	36.0	32.7	29.6
1-1/4"	K	1.245	154.8	124.5	104.2	96.2	89.2	82.7	77.1	71.9	67.2	62.6	58.5	54.7	51.1	47.6	44.4	41.3
	L	1.265	155.8	125.4	105.1	97.2	90.2	83.7	78.0	72.9	68.1	63.6	59.5	55.6	52.0	48.6	45.3	42.3
	M	1.291	157.0	126.7	106.3	98.4	91.4	84.9	79.3	74.1	69.3	64.8	60.7	56.8	53.2	49.8	46.5	43.5
	DWV	1.295	157.2	126.8	106.5	98.6	91.6	85.1	79.4	74.3	69.5	65.0	60.9	57.0	53.4	50.0	46.7	43.7
1-1/2"	K	1.481	165.2	134.9	114.6	106.6	99.6	93.2	87.5	82.3	77.6	73.0	68.9	65.1	61.4	58.0	54.8	51.7
	L	1.505	166.2	135.8	115.5	107.6	100.6	94.1	88.5	83.3	78.5	74.0	69.9	66.0	62.4	59.0	55.7	52.7
	M	1.527	167.1	136.7	116.4	108.5	101.4	95.0	89.3	84.3	79.4	74.8	70.7	66.9	63.3	59.8	56.6	53.5
	DWV	1.541	167.6	137.3	116.9	109.0	102.0	95.5	89.9	84.7	79.9	75.4	71.3	67.5	63.9	60.4	57.2	54.1

B = Brass K, L, M, DWV = Copper

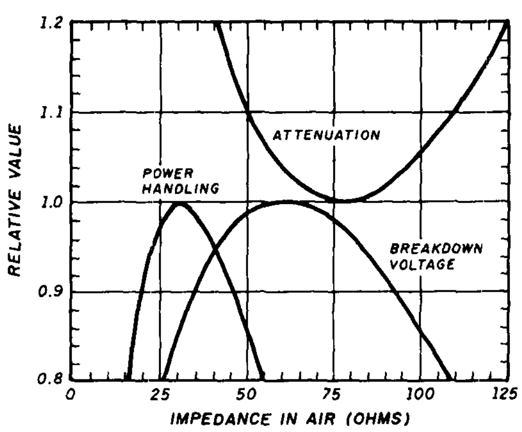
Characteristic impedance of rigid line using brass center conductor tubing. (Impedance values given in ohms.)

ation function is a broad one (see **Figure 2**), the attenutation goes up by a factor of only 1/2 percent at D/d ratios of 3.2 (Z=69.7 ohms) and 4.1 (Z≈84.6 ohms). Thus the conductor diameter ratios need not be exact. The relative attentuation increases by only 5 percent at widely varying *D/d* ratios of 2.6 (Z=57.3 ohms) and 5.2 (Z=98.8 ohms). The best impedances of several criteria for coaxial line are given in **Table 4**, where the minimum attentuation and maximum power are shown for copper pipe using air as a dielectric.

After consulting these impedance tables, you can quickly sort through your junkbox for the pipe diameter closest to optimum. For example, the 2-meter cavity duplexers constructed by John Bilodeau[4] and duplicated by Stewart Gurske[5] used 4" type DWV copper drain pipe with a 1-3/8" OD copper tube (a 1-1/4" size copper pipe has an outside diameter of 1-3/8") as the center conductor. Dave Baxter[8] constructed a single cavity filter for his 2-meter repeater receiver using the same conductor ratio. The cavity's Q could be improved with the identical 4" pipe by simply dropping down to a 1" nominal diameter copper pipe for the center conductor. According to **Table 1**, the characteristic impedance using a 1" copper pipe center conductor is 76 ohms. This is approximately the minimum attenuation point for a coaxial structure. The impedance of a coaxial line with a 1-1/4" center conductor is approximately 64 ohms. The relative loss for an impedance of 64 ohms is about 2 percent higher than that of the theoretical optimum value of 76.6 ohms. The unloaded Q of a copper quarter-wave coaxial cavity, designed for an optimum impedance of 76 ohms, is approximated as:

$$Q_u \cong 74D\sqrt{f} \quad \textbf{(3)}$$

FIGURE 2



The attenuation, breakdown voltage, and power handling capability for rigid lines is a function of the D/d ratio.

TABLE 4

Optimized air line copper transmission line parameters.

Cable parameter	Conductor ratio (D/d)	Characteristic impedance
Minimum attenuation	3.591	76.6 ohm
Maximum voltage	2.718	59.9 ohm
Maximum power	1.649	30.0 ohm

TABLE 5

Relative conductivity of commonly available material.

Metal	Relative Conductivity
Silver	1.03
Copper	1.00
Gold	0.84
Aluminum	0.78
Brass	0.48

TABLE 6

Commercial rigid air line copper transmission line dimensions (in inches).

Nominal rigid cable size	Inner conductor OD	Inner conductor ID	Outer conductor OD	Outer conductor ID
7/8 inch (50 ohm)	0.341	0.291	0.875	0.785
1-5/8 inch (50 ohm)	0.664	0.588	1.625	1.527
3-1/8 inch (50 ohm)	1.315	1.231	3.125	3.027
6-1/8 inch (50 ohm)	2.600	2.520	6.125	5.981
6-1/8 inch (75 ohm)	1.711	1.631	6.125	5.981

where D is the inside diameter of the outer conductor in inches and f is the operating frequency in megahertz. If you use other materials, the unloaded Q will vary in direct proportion to the relative resistivity of the metal, as shown in **Table 5**. Therefore, a brass coaxial cavity will have about one-half the Q of a similar copper cavity. A silver-plated cavity will show a 3 percent increase in unloaded Q.

Large, rigid coaxial transmission lines used for high-power radio and television stations are generally designed with 50-ohm air line. You must pressurize the lines slightly with dry air or nitrogen to prevent moisture condensation. This impedance is a compromise value between power handling capability, voltage breakdown, and attenuation. The attenuation is about 10 percent higher than that of a transmission line with a minimum attenuation impedance of 76.6 ohms. Verify this by checking radio/TV transmitter rigid air line catalogs for 6-1/8″ commercial transmission line, where the line is fabricated for both 50 and 75 ohms. **Table 6** lists the sizes of the copper pipe used in these installations in case you want to duplicate a high-power, low-loss installation. The 7/8″ commercial air line uses common 3/4″ type L copper tubing for the other conductor; the 1-5/8″ rigid line uses 1-1/2″ type M copper tubing. hr

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SIMPLE EEPROM PROGRAMMER

By George Swindell, Jr., WA2IHE, 538 Griscom Drive, Deptford, New Jersey 08096

Anyone who deals with computerized equipment will, sooner or later, come up against Read Only Memory (ROM) ICs. Nowadays, Electrically-Erasable Programmable Read-Only Memory (EEPROM) is replacing the older Ultra Violet-Erasable Programable Read-Only Memory (EPROM) and many of the new ICs are "drop-in compatible" with older types. For example, the 2Kx8 2816 used here matches the popular 2716 EPROM pin for pin. Except during programming, the 2816 needs only a single 5-volt supply.

The EEPROM is a significant improvement over the ultra violet-erasable device. First, it can be erased quickly without an expensive UV source (or waiting for a long, sunny day, hi). Second, single bytes can be erased selectively without disturbing the rest of the ROM's contents.

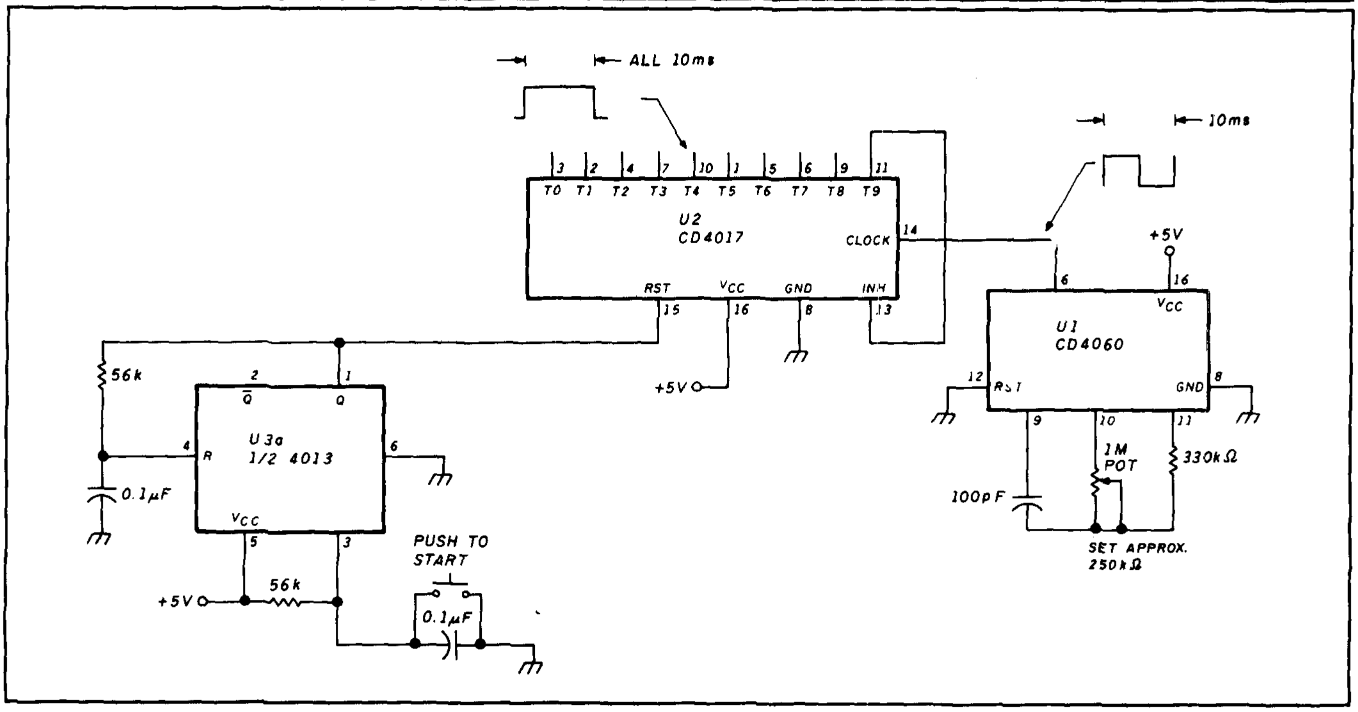
This EEPROM programmer lets you do both erasing and simple, manual programming. It's described as a "stand-alone" device assembled on a prototyping block, but it can just as easily be incorporated into your equipment using the EEPROM. As shown here, the programmer can't be computer driven or operated automatically. You can add these features, but it will cost more in terms of both time and money.

The electrical characteristics for programming show only two *critical parameters*. The programming voltage (V_{pp}) write pulse duration must be between 9 and 15 ms, and the V_{pp} rise time must be between 0.45 and 0.75 ms. Because all other timing parameters are given as minima expressed in nanoseconds or microseconds, I timed everything around the V_{pp} pulse width of 10 ms to keep things simple.

How it works

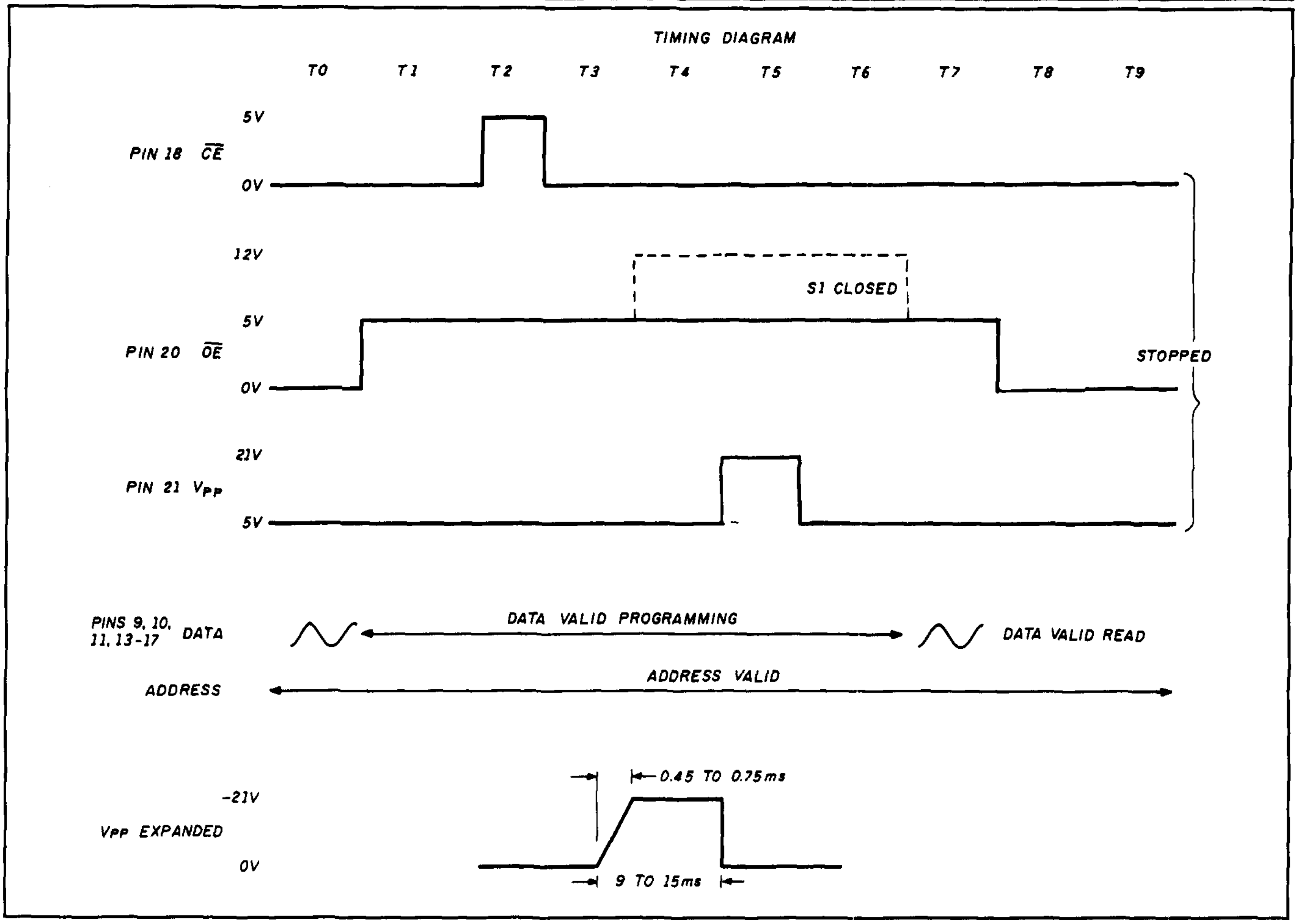
The 4060 oscillator/pulse generator (*U1*) in **Figure 1** is an oscillator/divider combination. The 1-meg pot adjusts the oscillator frequency to 12.8 kHz. This is divided by 128 to

FIGURE 1



Oscillator/pulse generator.

FIGURE 2



Timing diagram.

give a 100-Hz output at pin 6, pulsing the input of pin 14 of the CD4017 (U2), a decade counter which produces sequential 10-ms pulses from the 100-Hz clock input. The pulses appear in order from T0 to T9. When output T9 goes high it activates inhibit, pin 13, stopping all activity. When you press the START switch it resets the 4017, causing T9 to go low and the program to run from T0 to T9 again. Flip-flop U3A is a debounce circuit.

Flip-flop U3B has already been reset when the counter arrives at T9, causing the outputs of the 4503 analog multiplexer/demultiplexers (U4 and U5) to float. The inputs to the 4049 hex inverting buffers (U6 and U7) from the EEPROM socket cause the LEDs to display the value of data being read from the EEPROM. Refer to the timing diagram in **Figure 2**. When you push START, T0 goes high for 10 ms and then goes low. Next, T1 goes high and sets flip flops U3B and U8B causing the value of the data thumbwheel switches (shown in **Figure 3**) to be applied to the I/O pins of the EEPROM. Also, $\overline{OE}$ (**Figure 4**) pin 20 goes to 5 volts. T2 then applies a 10-ms pulse to pin 18 of the EEPROM. T4 sets flip-flop U8A to apply a 12-volt pulse to pin 20. This pulse is used for chip erase. Leave the 26-volt switch S1 open for a byte erase and the pulse will remain at 5 volts, as indicated by the solid section of the timing diagram in **Figure 2**, EEPROM $\overline{OE}$. The LM317 voltage regulator (U10) normally supplies 5 volts to the V_{pp} pin. The 1 and 4.4-k resistors are in parallel because T5 is still low. The bottom of the 1-k resistor is effectively at ground. When T5 goes high, LM317 voltage regulator U10 is allowed to rise to 21 volts. The time constant of the 1-k resistor and 0.02-μF capacitor produces a rise time of about 0.6 ms, which should improve device reliability. After T5 the process reverses itself, and the circuit comes to a stop at T9. The address pins are connected directly to the thumbwheel switches in **Figure 5** and you must enter the correct address before any byte erase/write takes place. The resistors at the bottom of the data and address switches terminate the CMOS inputs of IC 4503 and the address pins A0 to A10.

Power supply

I didn't build a power supply for this project. I have several 1 to 15-volt regulated supplies with floating outputs. I connected two of them in series to obtain 26 volts. The current drain is very small, around 20 mA maximum. The 5-volt supply uses about 200 mA.

Adjustments

Temporarily disconnect pin 11 of the 4017 and ground pin 13. This causes the counter to run constantly. Apply

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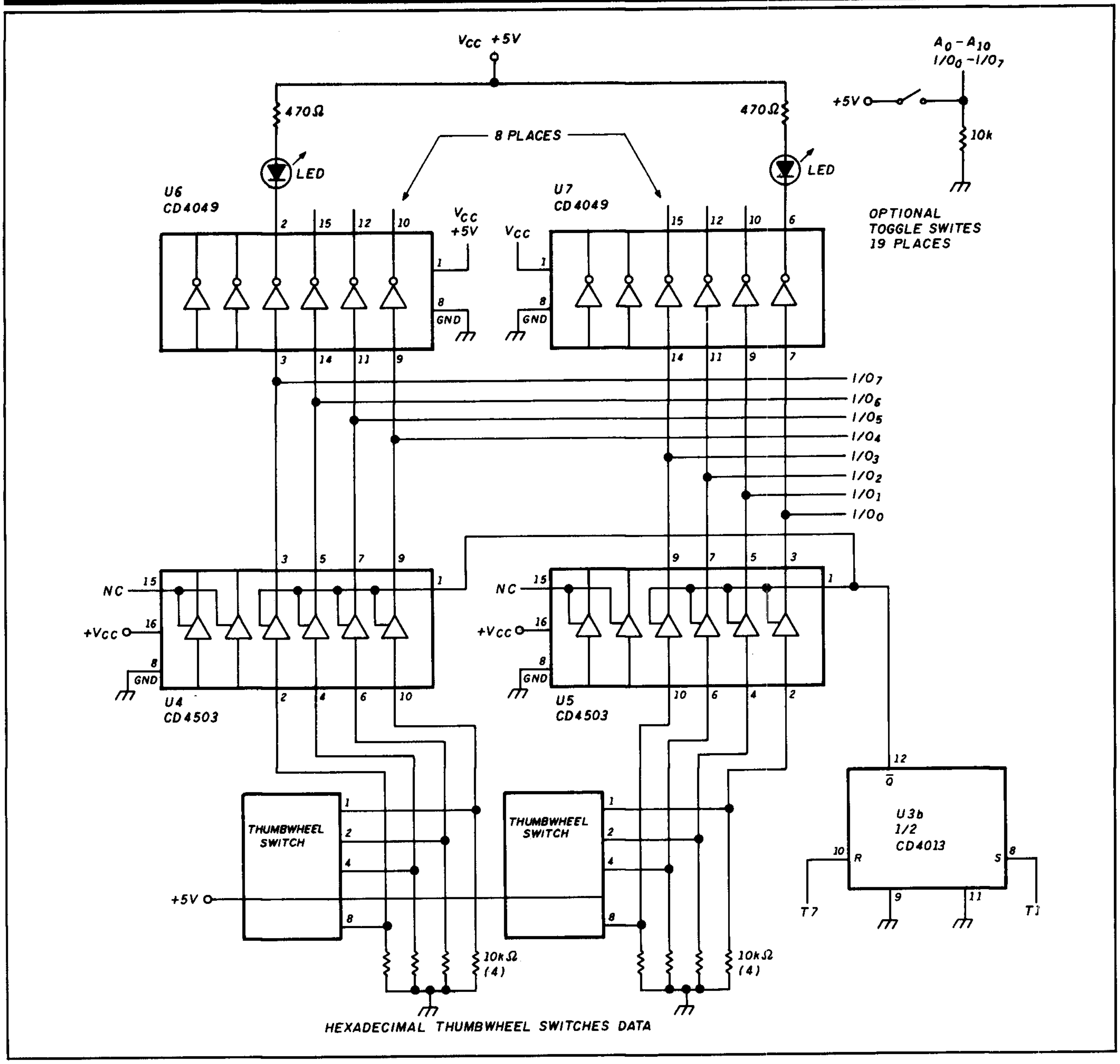
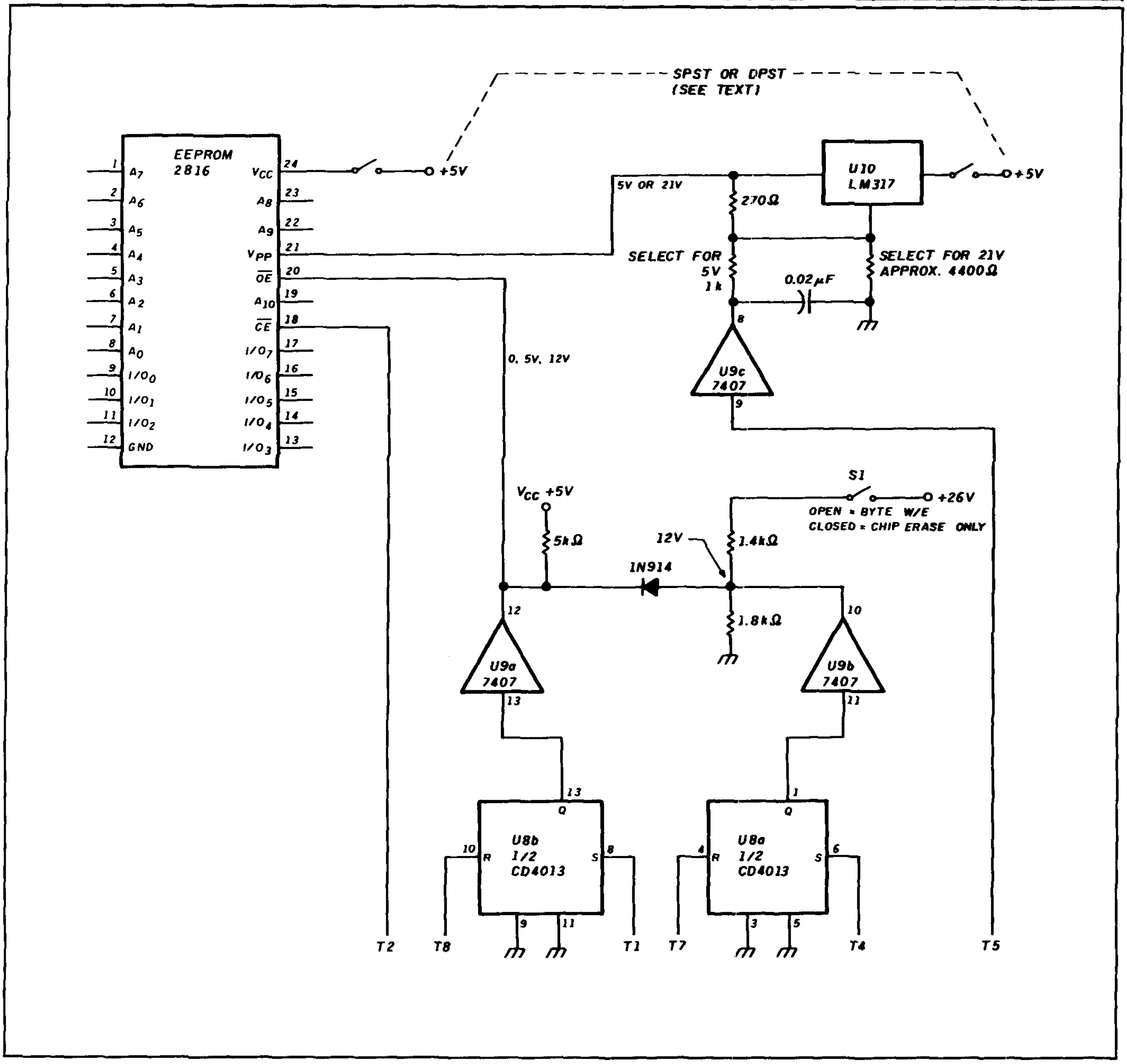
FIGURE 3



Data setup and readout.

power to all circuits with the EEPROM removed from its socket. Using a scope, sync on T0 (U2 pin 3) and adjust the 1-meg pot on IC 4060 for a pulse width of 10 ms. Keep sync on T0 and adjust the scope sweep speed for 10 ms/cm. T0 to T9 are now each represented by centimeters across the screen. Refer to the timing diagram and observe $\overline{CE}$, pin 18 of the EEPROM socket. The pulse should be at T2. $\overline{OE}$ pin 20 should appear as a 5-volt pulse. Closing S1 causes a 9 to 15-volt pulse to be superimposed on the 5-volt pulse as indicated by the dotted lines. The 1.4 and 1.8-k resistors establish this voltage. V_{pp} pin 21 should start out at 5 volts (adjust the 1-k resistor if necessary). The pulse then goes to 21 volts. Adjust the 4.4-k resistor for 21 volts ±1 volt. Next, expand the trace speed to x10 and observe the rise time of the 21-volt pulse; it should be between 0.45 and 0.75 ms. Adjust the 0.02-μF capacitor if necessary. The pulse should be between 9 and 15 ms long, so go back and tweek the 1-meg pot if necessary. Now return to normal sweep. Check the I/O pins by observing the waveforms. If you touch the probe tip you should see a 60-cycle hum, indicating that the outputs of IC 4503 are floating. The solid line from T1 to T7 should be either low or high depending on the setting of the data switches. Next, check each address pin to see if you're getting good highs and lows. Remove the ground on IC 4017 pin 13 and reconnect pin 11; the counter should stop. Push START; one cycle should pass

FIGURE 4



Programming control.

and stop at T9. If two or more cycles pass, you may have to adjust the debounce flip-flop for a longer time constant.

Using the circuit

This circuit can power up at any point from T0 to T9, applying unwanted pulses. To prevent this, I've placed a toggle switch to inhibit the EEPROM's V_{CC} 5-volt and 26-volt, which inhibits V_{PP}. First insert the 2816 into its socket and turn on the main power to the rest of the ICs. Push START once or twice to reset all flip-flops. If you're using an SPST switch, apply 5-volt V_{CC} power first — then apply the 26-volt power. If you have a DPST switch, both V_{CC} and V_{PP} will be applied simultaneously. Power down in the reverse order when removing the 2816 from its socket.

The EEPROM should be in read mode after power up. A new EEPROM should show all highs (LEDs lit) for the erased condition. The LEDs and LED drivers can be eliminated if you don't mind touching each I/O pin with a VOM to determine the logic level. Place the address switches at 000 or any desired address. If the data byte you're looking at has been erased already (all highs), enter the value of data you want at that address and push START. The LEDs should show the same value entered on your data switches because you're reading the 2816 at T9. If data is already present and you want to change it, first erase that location by writing all "1"s (FF_H), then enter the correct data and push START again. To erase the entire 2K of memory, close S1 and push START. The entire chip will be erased. I've

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2252G	220-225	25	250	.7	14	13.6	36	UHF
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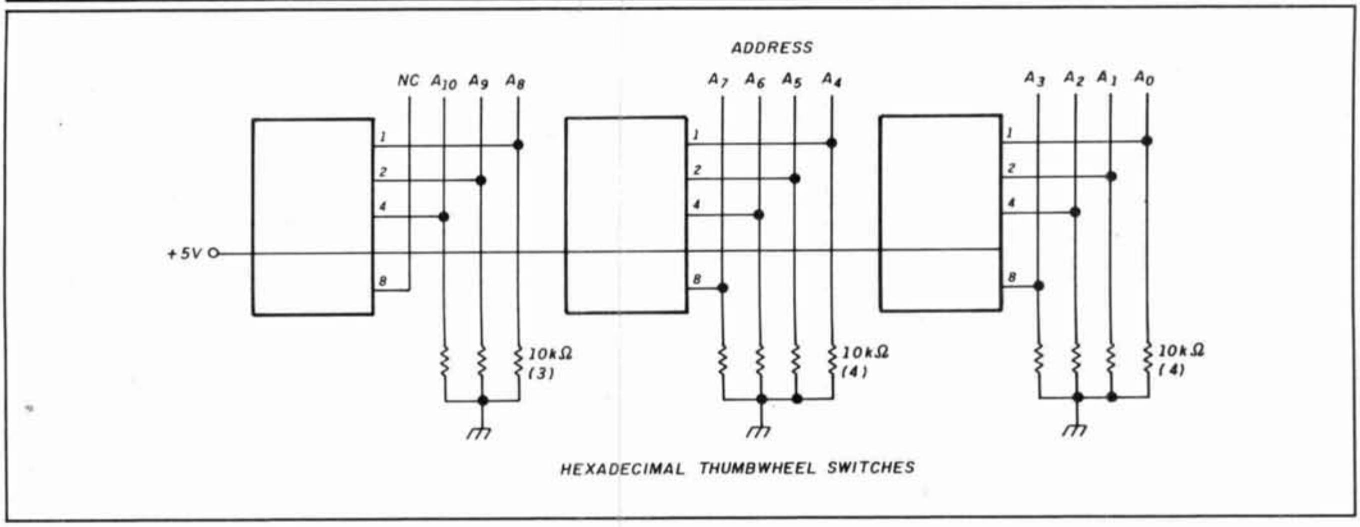
FIGURE 5



Address selection.

found that the address and data settings aren't important when you're doing a chip erase using the SEEQ device. However, another 2816 by EXEL requires the data value FF for a chip erase as well as a byte erase. I suggest you obtain data sheets for any EEPROMs you buy to determine if there are any special procedures to follow.

Conclusion

I built the programmer on a protoboard so I could change the circuitry to accommodate other PROMs. You may want to try using the EEPROM to decode binary values into seven-segment readouts including the characters A to F. Circuits with the 2716 UV EPROM can be modified using the 2816. You can program eight outputs with varying pulse widths to control other circuits by hooking a binary counter up to the address pins. I used three EEPROMs with their addresses in parallel for a total of 24 control lines. Those 24 lines let me program a single chip microcomputer with its own UV EPROM. I have since replaced the EEPROMs with a single chip microcomputer which programs other PROMs. You can purchase all of the ICs used in this project from Jameco, 1355 Shoreway Road, Belmont, California 94007. hr

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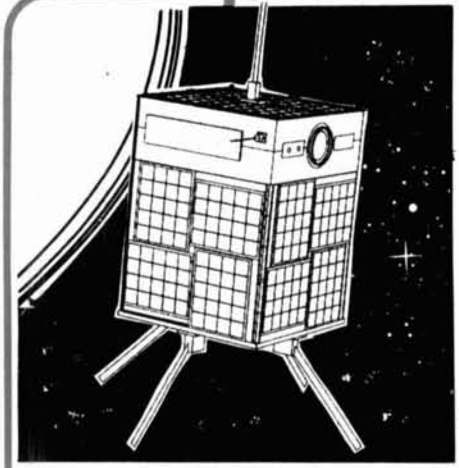

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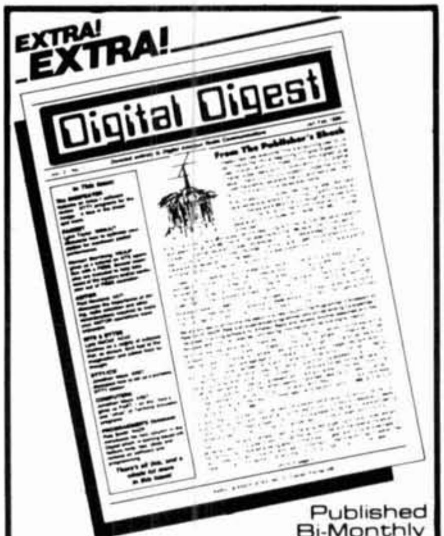

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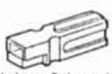

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NEAR LINEAR TUNING WITH DUAL ECCENTRIC PULLEYS

Straight line variable caps cover a large tuning range

By John Pivnichny, N2DCH, 3824 Pembrooke Lane, Vestal, New York 13850

Extraordinarily linear tuning is possible with ordinary variable capacitors if you use some new techniques. As my earlier articles[1,2] point out, all modern Amateur transceivers have very linear frequency dials. Unless they use a digital PLL technique, commercial products use precision, specially made, gear-driven variable capacitors not available to the homebrewer. This article describes a dual eccentric pulley approach, which allows common straight line capacitance variables to be used over fairly large frequency ratios.

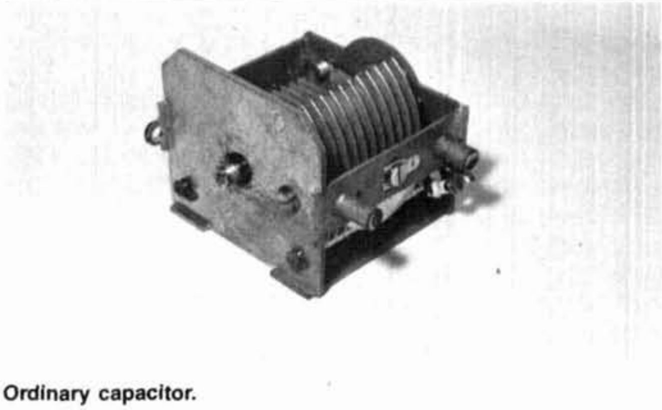
Variable capacitors

Ordinary variable capacitors have semicircular rotor plates and uniform change in capacitance as the shaft is rotated through 180 degrees from full mesh to completely open (see **Photo A**). This is known as a straight line capacitance variable. When used as the main tuning element, it produces a frequency change that compresses the scale at the high frequency end.

Shape of rotor plates

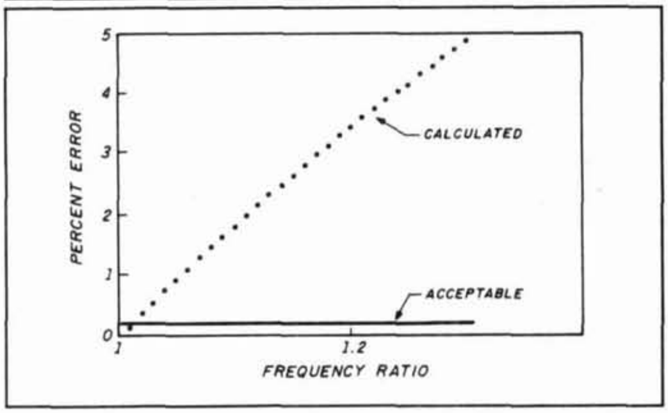
If the capacitor rotor plates are specially shaped, this dial compression can be spread out. In general, the radius of the rotor plates must be reduced at the minimum capacitance end so that each degree of rotation causes less capacitance change. With correctly shaped rotor plates, an equally spaced linear frequency scale results. The plates are referred to as "straight line frequency variables." Capacitors constructed this way are usually not available or very expensive. One exception is the WWII surplus capacitor described in **Reference 2** and shown in **Photo B**.

PHOTO A



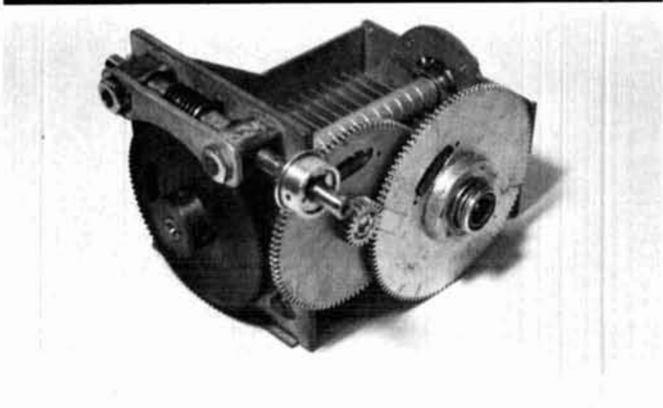
Ordinary capacitor.

FIGURE 1



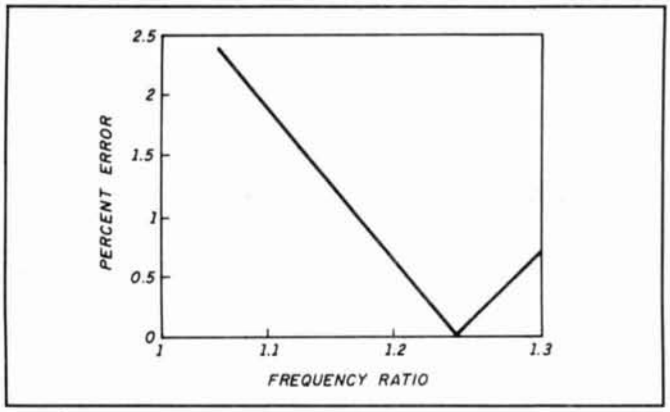
Percent error for straight line capacitance variable.

PHOTO B



World War II capacitor.

FIGURE 2



Percent error for special World War II capacitor.

Worst-case dial error

Equations in the appendix of **Reference 1** show how to calculate the degree of error a linear dial will have when a straight line capacitance variable is used. The frequency at the dial center will be low if the end points are set exactly. Note that the worst-case error can be reduced to one-half by setting the frequency at both ends of the dial high by one-half the center dial error. This error is shown in the graph in **Figure 1**, plotted as a percentage of full-range error for various frequency tuning ratios. The range is defined as high frequency minus low frequency, and the errors have been reduced to one-half.

The curve is very steep; the error is unsatisfactory for all but very low tuning ratios and narrow ranges. I consider an error of ±1 kHz in a 500-kHz range satisfactory and an error much beyond that as excessive. For example, the area below the dotted line in **Figure 1** represents the acceptable region.

Low satisfactory tuning ratios force you to select fairly high frequencies to cover a reasonable range. In **Reference 1** I chose 11.5 to 11.75 MHz to cover a 250-kHz range with a ±2-kHz worst-case error. That let me receive 3.5 to 3.75 MHz with an IF of 8 MHz.

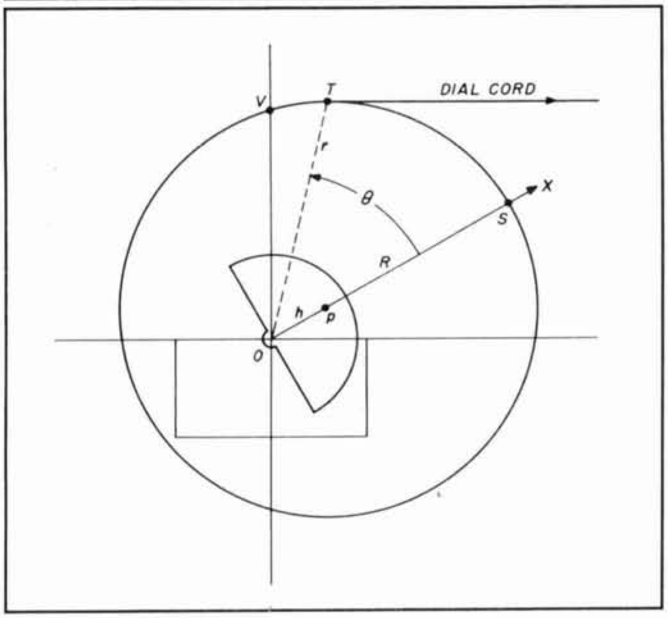
Comparison with the curve of **Figure 2** for the specially constructed WWII capacitor[2] shows that very low errors are possible for a 1.25:1 frequency ratio. Such capacitors are usable for a single ratio. However, the technique described here can be used for many frequency ratios.

Eccentric pulleys

One way to reduce the capacitance change at the high frequency end is to mount an off-center (eccentric) pulley on the shaft and drive it with dial cord. The mounting must be made so the cord winds or unwinds with a maximum radius when the capacitor is at the high frequency or low capacitance end. Check the conceptual sketch in **Figure 3** for details.

If this pulley were just the right shape, you'd have the same effect you'd have if the capacitor plates were cut to exactly the right shape for linear frequency response. Such a pulley would be very difficult to make. On the other hand, circular pulleys are easy to make from Plexiglas™ as described in **Reference 1**. Note, however, that the shaft mounting hole will be off center — you can't use it in the initial turning, filing, and sanding of the rough cut pulley when it's mounted in an electric drill.

FIGURE 3



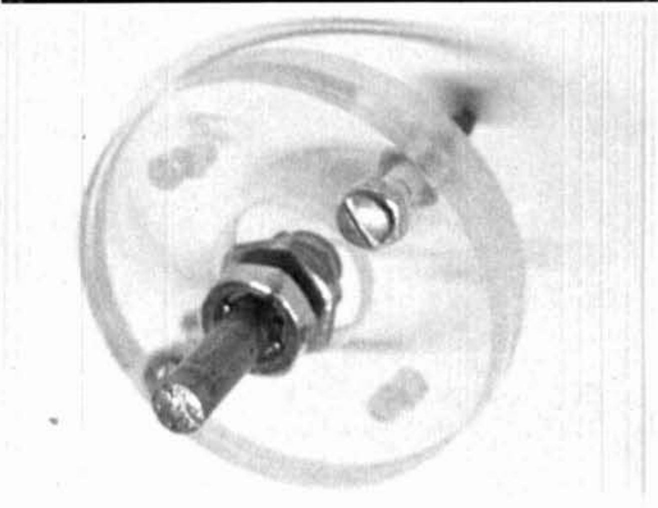
Eccentric pulley.

Instead, the rough cut pulley is mounted on center to a mandrel with machine screws as shown in **Photo C**. The off-center shaft hole is drilled after the pulley has been completed and removed from the electric drill. I realize that you may wonder how far off an eccentrically mounted circular pulley arrangement will be, and if it will be close enough to the right shape for a linear frequency scale.

Theory

Figure 3 shows a pulley with center P and radius PS of length R. It's mounted on a variable capacitor at point O, which is length h off center. The capacitor and pulley rotate around point O. A dial cord pulls horizontally on the pulley. Note that distance r from tangent point T to center O changes as the pulley rotates through angle θ from 0 degrees (plates fully unmeshed) to 180 degrees (plates fully meshed).

PHOTO C



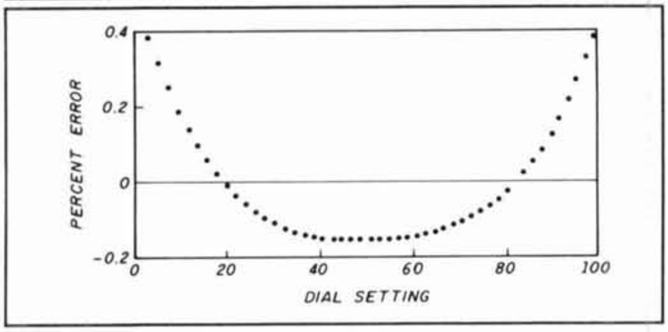
Mandrel.

TABLE 1

Typical calculations for h = 0.5, R = 1, and external capacitance $C_{ext} = C_{max} - C_{min}$.

θ (degrees)	Length TS (inches)	Frequency F (kHz)
0	0	0.1
1.8	0.04711	0.09950
3.6	0.09419	0.09901
5.4	0.14121	0.09853
7.2	0.18815	0.09806
9.0	0.23498	0.09759
10.8	0.28169	0.09713
12.6	0.32825	0.09667
↓	↓	↓
180	3.1416	0.07071

FIGURE 4



Best fit deviation of calculated frequency from true straight line.

Because the distance r changes, the amount of capacitor rotation produced by a given increment of dial cord movement also changes. This is the desired effect. Note that the point of tangency T will coincide with the vertical y axis at $\theta = 0$ degrees and $\theta = 180$ degrees. For other angles in between it moves slightly to the right as shown. The difference in distances OT and OV will be small and are ignored in this analysis. Mathematically, length r is given for any angle θ by the following equation:

$$r = h \left[\cos\theta + \sqrt{\frac{R}{h}^{2} - \sin^2\theta} \right] \quad (1)$$

This formula is derived in the article's appendix. The appendix begins with a formula from an old high-school math textbook.[3] It's not necessary to understand the details of these equations to use this technique in Amateur construction. I've reduced the math to graphical easy-to-use results.

Finding perimeter distance TS

As the dial cord is pulled to the right, it unwinds from the pulley. The unwound length is perimeter distance TS. Assume the dial cord is pulled an equal amount for each increment of change in the main tuning knob and dial. This is what happens with the usual dial and tuning knob arrangement, where the dial is driven by an on-center pulley of approximate radius R/2. That is, the dial rotates through 360 degrees for a 180-degree rotation of the capacitor pulley. If you know distance TS for each angle θ, you'll know the capacitance change for each increment the dial cord is pulled, or (in effect) each increment of dial rotation.

The method for finding distance TS using numerical integration follows. I calculated the distance r from **Equation 1** by taking 100 increments of θ from 0 degrees to 180 degrees for a preselected offset h. The perimeter distance traveled through a 1.8-degree increment of θ is equal to:

$$s = 2\pi r \cdot \frac{1}{360} \quad (2)$$

Each small increment s will be slightly shorter than the previous one. Add these increments of length from 0 to θ degrees for each angle θ. I now have a table of values of length TS for all 100 values of θ. I repeat the process for each offset value h. One such table is shown in the first two columns of **Table 1** (for h = 0.5 R). I recommend that you use a personal computer for these calculations.

With the arrangement shown in **Figure 3**, the capacitance at $\theta = 0$ is equal to the variable capacitor's minimum value C_{min} plus any fixed external capacitance. Call the total:

$$C_o = C_{min} + C_{ext} \quad (3)$$

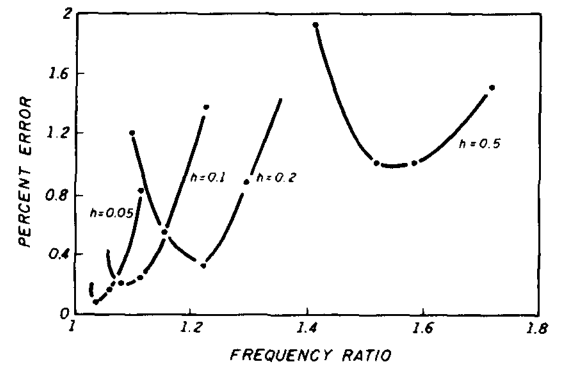
As the capacitor rotates to angle θ degrees, its capacitance increases to the following:

$$CAP = (C_{max} - C_{min}) \times \frac{\theta}{180} \quad (4)$$

The frequency, however, is given as follows:

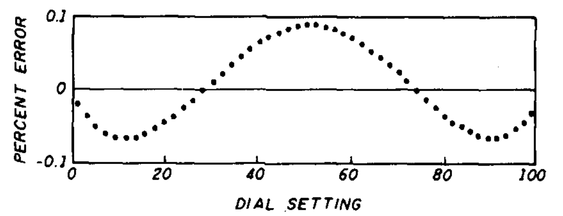
$$F = \frac{1}{2\pi\sqrt{L(C_o + CAP)}} \quad (5)$$

FIGURE 5



Percent error as a function of frequency ratio for four offset values h. This is the main result of the calculations.

FIGURE 6



Deviation with external capacitance set for minimum error.

Select a value for C_o (a value of external capacitance). Calculate CAP from **Equation 4** and f from **Equation 5** for each of the 100 values of θ in the table. Include these numbers as a third column in the table.

Frequency linearity

For a particular value of pulley offset h and a particular value of external capacitance C_{ext}, you now have 100 values of dial position TS and 100 corresponding frequencies. You may wonder about the linearity of the resulting frequency if you're using a linear dial like one made from a circular protractor (suggested in **Reference 1**). This question is best answered by drawing a best-fit straight line through the points on a graph of frequency F versus dial position TS. The deviations of the points calculated from this best-fit straight line give the error. A graph of these deviations is shown in **Figure 4**. I prefer to divide the error by the frequency range covered and call this the percent error. Then I plot percent error versus frequency ratio f_{max}/f_{min}.

For each offset value h, you can try a range of fixed external capacitance to see which gives the lowest percent error. Note that frequency range covered, and therefore the frequency ratio, will be different for each value of external capacitance.

Frequency ratios

These data points are plotted in **Figure 5** for values of offset: h = 0.05, 0.1, 0.2, and 0.5. Note that there's a range of values for each h value where the percentage error is quite low. To the left and right the error gradually increases. For larger offsets h, the minimum occurs at larger frequency ratios.

This is to be expected, because a larger frequency ratio requires a larger difference in the capacitance changes at the dial ends than a low ratio does. Larger offsets h produce larger differences in the distance r at the C_{max} and C_{min} ends.

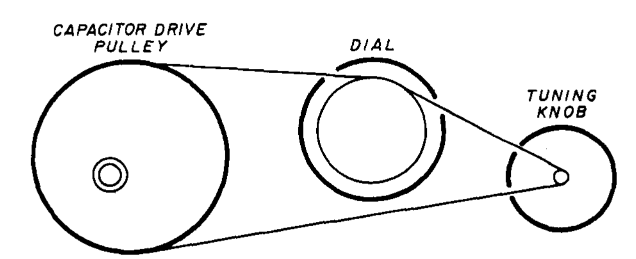
Also note that the minimum percentage error is larger with larger values of h. This is undoubtedly because an off-center circle isn't exactly the right shape for a linear frequency scale. The variation from the correct shape becomes greater at larger frequency ratios.

Nevertheless, quite acceptable percentage errors are produced with the easy-to-build, circular, off-center mounted pulleys. As I mentioned earlier, I consider an error of 0.2 percent, or 1 kHz, in a 500-kHz frequency range dial very acceptable. This is about the limit at which I can set such a dial by eye, if I'm very careful.

Figure 6 shows another plot of frequency differences from a best-fit straight line with an external capacitance set for an error near the minimum. I've included this to illustrate the type of error you would normally experience because you'd usually select a deviation h and external capacitance C_o for a minimum error.

Figure 5 is the key operating result of all this theory. You can use it to optimize any off-center tuning design. You can also see what effect small differences in mechanical dimensions or external capacitances will have. In general, because the curves are so flat near the minima, minor construction differences won't have much consequence. Small percentage errors are readily achievable as the next section will show.

FIGURE 7



Impossible arrangement.

Practical verification

I built an operating model to verify these results. A note on the overall dial stringing is necessary here. Any off-center pulley like the one shown in **Figure 3** requires that the dial cord be returned to the pulley at the same (varying) rate it is removed. Otherwise the cord will become too loose or too tight. The simple sketch in **Figure 7** won't work with this off-center pulley.

Resolve the problem by using a second off-center pulley, offset in the opposite direction. **Figure 8** shows an offset which has been greatly exaggerated. As the main tuning

(continued on page 60)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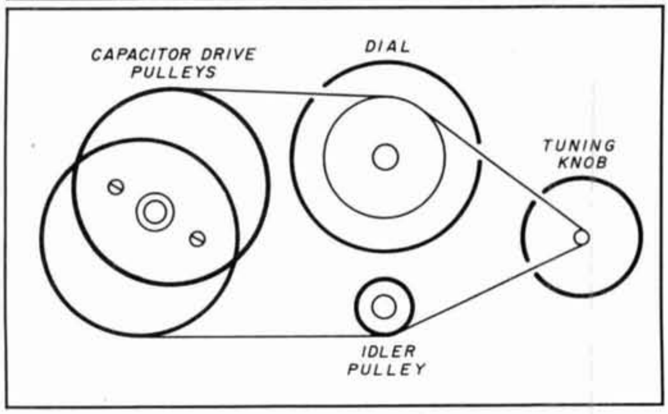
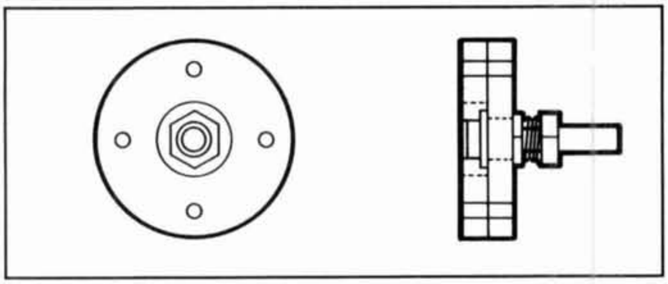
(continued from page 56)

FIGURE 8



Dual eccentric pulley arrangement.

FIGURE 9



Mandrel for pulley construction.

knob is rotated clockwise, the top dial cord comes off the off-center pulley and an equal amount is picked up by the other pulley from the bottom cord. You need a small idler pulley to keep the bottom cord horizontal (approximately). This is the arrangement I selected and built. It's shown in **Photos D, E,** and **F** and operates very smoothly.

Pulley details

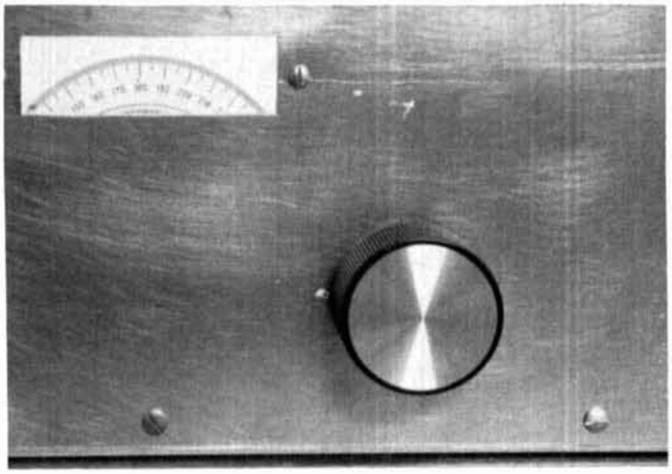
I completed the pulley construction using the method in **Reference** 1. I also built the mandrel shown in **Figure 9** and **Photo C** using the same techniques. This mandrel holds the large pulleys on center when each is mounted temporarily to the mandrel with four machine screws. After a large pulley is shaped and the groove is cut, it's removed from the mandrel and its mounting hole is drilled off center. My large pulleys have a diameter of 3-1/2 inches. The mounting hole was drilled 0.175 inches off center for h = 0.1.

You can do this easily by marking the off-center location with an awl, drilling it with a small 1/16-inch or smaller drill, and increasing the hole diameter with gradually increasing bit sizes. The final one should be 3/8 inch. The second large pulley has its mounting hole cut for 3/4 inch with a hole-cutting attachment, like the one shown in **Reference 1**. This larger size lets you mount the locking shaft securely. The two pulleys are held together with machine screws. Check the photographs for details.

Pulley sizes

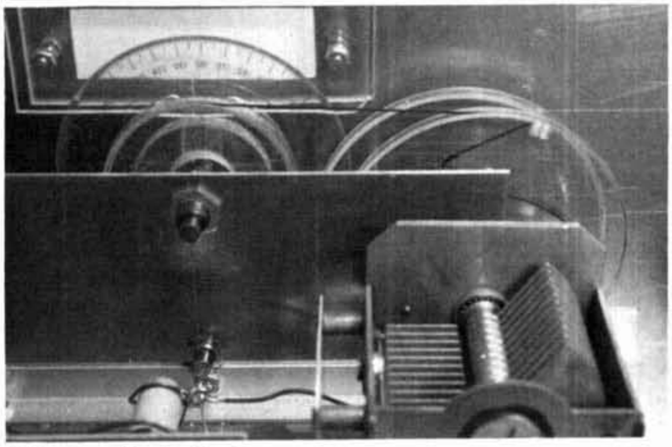
I mounted an aluminum front panel and subpanel on an aluminum bottom plate following the sketches in **Reference** 1. In this case the dimensions were as follows:
Dial pulley diameter: 2-1/4 inches.
Dial pulley centered 2-5/8 inches above base plate.

PHOTO D



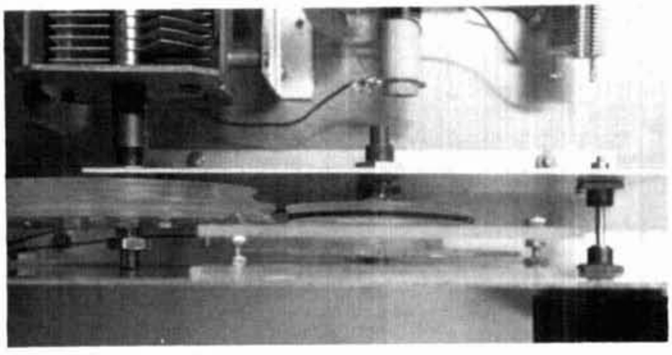
Dial assembly, front view.

PHOTO E



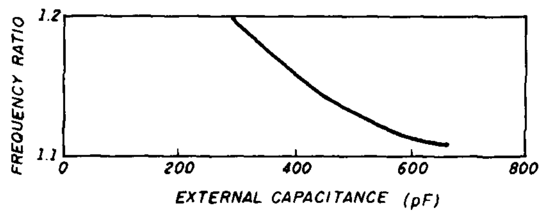
Dial assembly, back view.

PHOTO F



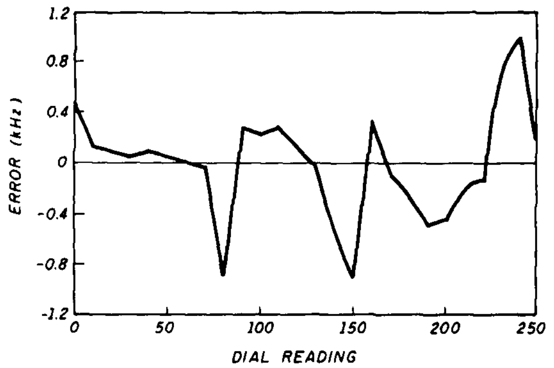
Dial assembly, top view.

FIGURE 10



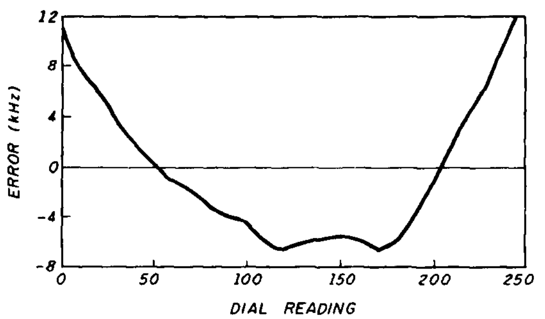
Frequency ratios for various external capacitors.

FIGURE 11



Deviation of measured frequencies with 600-pF external capacitance (2.0 to 2.2 MHz).

FIGURE 12



Deviation of measured frequencies (2.8 to 3.4 MHz; 220 pF external).

Capacitor pulley centered 2 inches above base plate.
Idler pulley diameter: 3/4 inch.
Idler pulley centered 11/16 inch above base plate.

I cut the shafts to length, and once all were operating smoothly I strung the dial cord as shown in **Figure 8**. You should use a small spring at one end to keep the dial cord under tension. The arrangement is shown in **Photos D** (front view), **E** (back view), and **F** (top view).

TABLE 2

Measured results for 5.5 to 6.0-MHz range.

dial	Frequency (kHz)	dial	Frequency (kHz)
0	5500	260	5760
20	5519	280	5780
40	5539	300	5801
60	5559	320	5820
80	5579	340	5839
100	5600	360	5859
120	5620	380	5880
140	5640	400	5899
160	5660	420	5920
180	5680	440	5940
200	5700	460	5961
220	5720	480	5981
240	5741	500	6000

The circuit

It's important to use a high quality capacitor. For my setup, I used the ARC5 oscillator capacitor[1] shown in **Photo A**. **Photo E** has the details. I also used the CA3028 circuit with emitter follower buffer of **Reference 1**. I tried several values of fixed capacitor to establish the value needed for a 1.1:1 frequency ratio. The graph in **Figure 10** shows the measured results. About 600 pF is right for the dial with its h = 0.1.

Frequency readings

With the pulley directions just given, a 250-degree rotation of the circular protractor dial gives slightly less than 180 degrees of capacitor rotation. I took readings every 10 degrees from 0 to 250, then plotted and curve fit them to a straight line. **Figure 11** shows the results. The less than 0.8-kHz error for a 2 to 2.2-MHz range agrees with the calculated results shown in **Figure 5**.

Another check with 220-pF external capacitors is shown in **Figure 12**. The resulting 1-percent error also agrees with **Figure 5**.

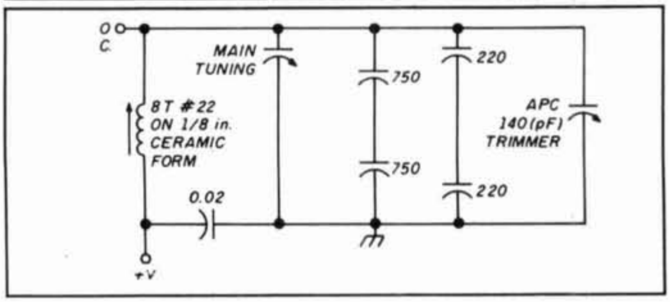
Finally, I decided to see how well this off-center apparatus can cover the 5.5 to 6-MHz range. This is the 500-kHz range used in my Kenwood transceiver. I replaced the protractor labeling with a paper disc of new labels from 0 to 500, covering the 0 to 250 degrees on the original labels. I left the outer degree lines visible and indicated 2-kHz markings. Then I mounted an external 140-pF APC trimmer capacitor next to the oscillator coil and changed the fixed capacitors as shown in **Figure 13**.

After adjusting the inductor for 5.500 MHz at the low end and the trimmer for 6.000 MHz at the high end, I took frequency counter readings for every 20-kHz position of the dial. **Table 2** shows my results. A 1-kHz maximum error across the dial is acceptable, in my opinion.

Conclusion

I find it practical to perform near linear tuning using dual eccentric pulleys, and know of no other way to get this kind of linearity out of a straight line capacitance variable. The technique appears to be new, probably because the math required for analysis is quite involved. But by using the main result of **Figure 5**, you can build practical tuners easily in your home workshop.

FIGURE 13



External capacitors for 5.5 to 6.0-MHz range.

Appendix

To derive **Equation 1**, start with the general equation of a circle:

$$x^2 + y^2 + Ax + By + C = 0 \quad \textbf{(6)}$$

This is given in polar coordinate form by Currier[3] on page 291:

$$r^2 + r(A \cos\theta + B \sin\theta) + C = 0 \quad \textbf{(7)}$$

For the circle in **Figure 3**, the x axis is as shown and the y axis would be perpendicular to it. Angle θ and distance r are shown. A circle centered at x = h, y = o is given by the following equation on page 240 of **Reference 3**:

$$(x - h)^2 + y^2 = R^2 \quad \textbf{(8)}$$

Value R is the distance from P to S, the true radius of the circle. Expanding **Equation 8** you get:

$$x^2 + y^2 - 2hx + h^2 - R^2 = 0 \quad \textbf{(9)}$$

Compared to **Equation 6**, A = −2h, B = 0, and C = $h^2 - R^2$.

So **Equation 7** can be written for the circle of **Figure 3**:

$$r\pm + r(-2h \cos\theta) + h^2 - R^2 = 0 \quad \textbf{(10)}$$

Solve for r using the quadratic equation:

$$r = 1/2\ [2h \cos\theta \pm \sqrt{4h^2\cos^2\theta - 4(h^2 - R^2)}] \quad \textbf{(11)}$$

Using the well-known identity $1 - \cos^2\theta = \sin^2\theta$:

$$r = h\left[\cos\theta \pm \sqrt{\left(\frac{R}{h}^2\right) - \sin^2\theta}\right] \quad \textbf{(12)}$$

Rejecting the negative value gives you **Equation 1**. hr

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2. John R. Pivnichny, N2DCH, "Linear Tuning with a War Surplus Capacitor," *Ham Radio*, June 1989, page 40.
3. C.H. Currier, E.E. Watson, and J.S. Frame, *A Course in General Mathematics*, Macmillan, New York, 1957.

INTRODUCTION TO **WAVEFORM GENERATORS** PART 3

Triangle and sawtooth waveform generators

By Joseph J. Carr, K4IPV, P.O. Box 1099, Falls Church, Virginia 22041-0099

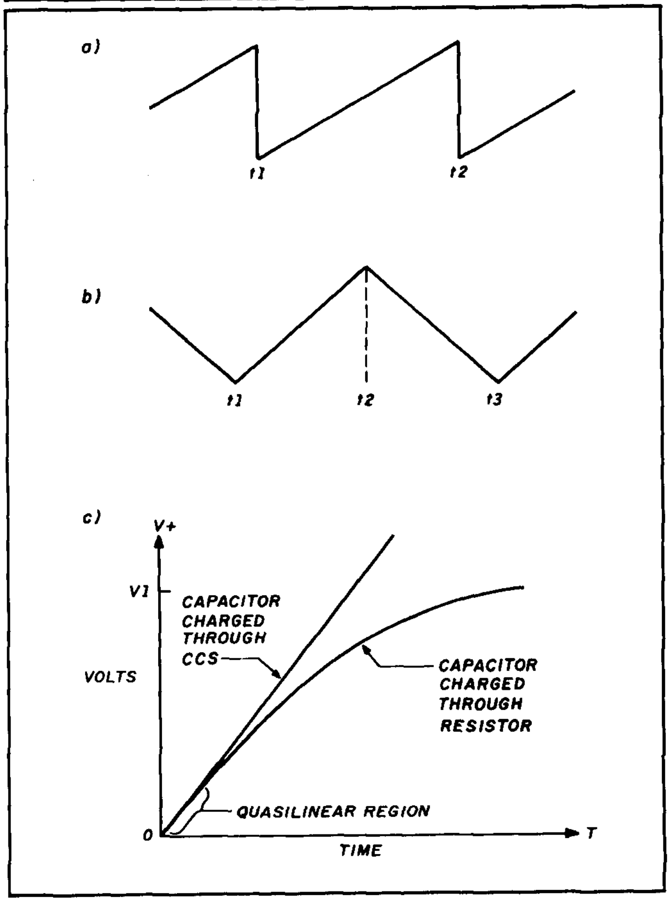
Triangle and *sawtooth* waveforms (**Figure 1**) are examples of *periodic ramp* functions. The sawtooth in **Figure 1A** is a single ramp waveform. The voltage begins to rise linearly at time t1. At time t2 the waveform drops abruptly back to zero, where it starts to ramp up linearly again. The sawtooth is usually periodic, although single sweep variants are sometimes used. The period is defined as T (see **Figure 1A**), so the frequency is 1/T.

The triangle waveform in **Figure 1B** is a double ramp. The waveform begins to ramp up linearly at time t1. It reverses direction at time t2 and then ramps downward linearly until time t3. At time t3 the waveform reverses direction again, and begins ramping upwards. The period of the triangle waveform (T) is T1-T3.

Ramp generators are derived from capacitor charging circuits. I discussed the familiar RC charging curve earlier in this series. It's reproduced in simplified form in **Figure 1C**. The RC charging waveform has an exponential shape, so it's not well suited to generating a linear ramp function. There are two approaches to forcing the capacitor charging waveform to be more linear. The first is to limit the charging time to the short quasi-linear segment shown in **Figure 1C**. The ramp obtained isn't very linear, is limited in amplitude to a small fraction of V1, and has a relatively steep slope that may or may not be useful for any given application. A superior method is to charge the capacitor through a *constant current source* (CCS). Using the CCS to charge the capacitor results in the linear ramp shown in **Figure 1C**.

Triangle and sawtooth waveform oscillators create the constant current form of ramp generator by means of a Miller integrator used to charge the capacitor (see **Figure 2A**). When a Miller integrator is driven by a stable reference volt-

FIGURE 1



(A) Example of a sawtooth waveform. Time t1 to t2 represents one cycle. (B) Example of a triangle waveform. Time t1 to t3 represents one cycle. (C) Graph illustrating why a CCS capacitor produces a more linear and uniform ramp.

age, the output is a linearly rising ramp. The ramp voltage (V_o) is:

$$V_o = \frac{V_{ref}}{T} \quad (1)$$

or, because T = RC:

$$V_o = \frac{V_{ref}}{RC} \quad (2)$$

If V_{ref} = +10 volts DC, and the RC time constant is T = RC = 0.001 seconds, the ramp slope is:

$$V_o = \frac{10 \text{ volts}}{0.001 \text{ sec}} \quad (3)$$

$$V_o = 0.10 \text{ volts/second} \quad (4)$$

Triangle generators

Figure 2A shows a simplified circuit model of a triangle waveform generator. This circuit consists of a Miller integrator as the ramp generator, and an SPDT switch (S1) that can select either positive ($+V_{ref}$) or negative ($-V_{ref}$) reference voltage sources.

For purposes of discussion, switch S1 is an electronic switch that's toggled back and forth between positions A and B by a square wave applied to the control terminal (CT). Assume an initial condition (see **Figure 2B**) at time t2, at which point $V_o = -V1$, and the input of the integrator is connected to $-V_{ref}$. At time t2 the square wave switch driver changes to the opposite state, so S1 toggles to connect $+V_{ref}$ to the integrator input. The ramp output rises linearly at a rate of $+V_{ref}/RC$ until the switch toggles again at time t3. At this point the ramp is under the influence of $-V_{ref}$, so it drops linearly from +V1 to −V1. The switch toggles back and forth between $-V_{ref}$ and $+V_{ref}$ continuously, so the output (V_o) ramps back and forth between −V1 and +V1.

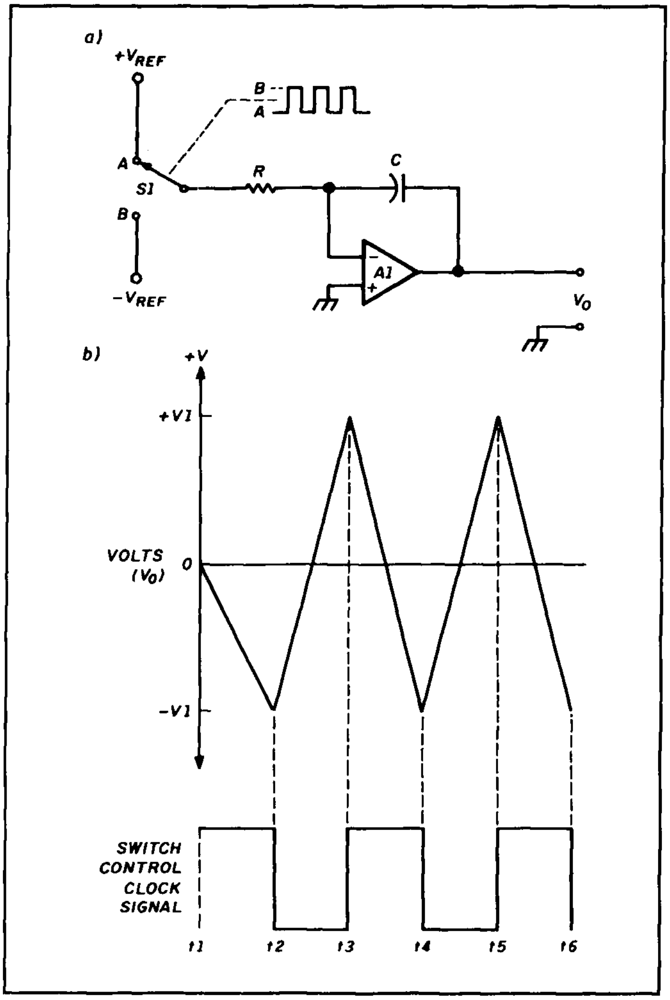
The circuit of **Figure 2A** isn't practical, but it serves as an analogy for the actual circuit. **Figure 3A** shows the circuit for a triangle waveform generator in which a Miller integrator forms the ramp generator and a voltage comparator serves as the switch. The comparator uses the positive feedback configuration, so it operates as a noninverting Schmitt trigger. Such a circuit snaps **HIGH** ($V_B = +V_{sat}$) when the input signal crosses a certain threshold voltage in the positive going direction. It will snap **LOW** again ($V_B = -V_{sat}$) when the input signal crosses a second threshold in a negative going direction. The two thresholds aren't always the same potential.

Because zener diodes CR1 and CR2 are in the circuit, the maximum allowable value of $+V_B$ is $[V_{CR1} + 0.7]$ volts, while the limit for $-V_B$ is $-[V_{CR2} + 0.7]$ volts. If $V_{CR1} = V_{CR2}$, then $|+V_B| = |-V_B|$. These potentials represent $\pm V_{ref}$ discussed in the analogy, so are the potentials that affect the ramp generator input.

Consider an initial state in which V_B is at the negative limit $-V_B$. The output V_o begins to ramp upwards from a minimum voltage of:

$$V1 = \frac{V_A(R2 + R4)}{R4} - \frac{V_BR2}{R4} \quad (5)$$

FIGURE 2



(A) Example of a Miller integrator used to create the constant current ramp generator. (B) The square wave signal going to the circuit of *A* and its resulting triangle wave output.

The output will continue to ramp upwards towards a maximum value of:

$$V3 = \frac{V2_A(R2 + R4)}{R4} + \frac{V_BR2}{R4} \quad (6)$$

causing a peak swing voltage of:

$$V_p = V3 - V1 \quad (7)$$

$$V_p = \left[\frac{V_A(R2 + R4)}{R4} + \frac{V_BR2}{R4}\right] - \left[\frac{V_A(R2 + R4)}{R4} - \frac{V_BR2}{R4}\right] \quad (8)$$

$$V_p = \frac{V_BR2}{R4} + \frac{V_BR2}{R4} = \frac{2V_VR2}{R4} \quad (9)$$

(See **Figure 3B** for details.)

Comparator switching occurs when the differential input voltage V_{id} is zero. The inverting input (−IN) voltage is V_A,

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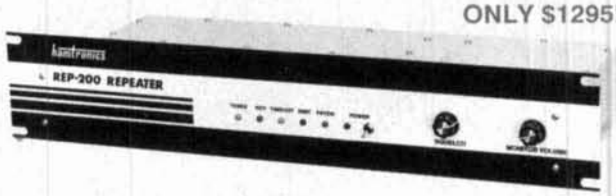

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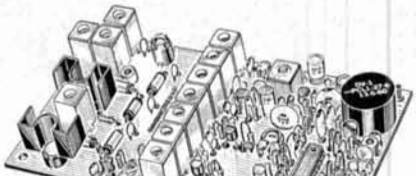

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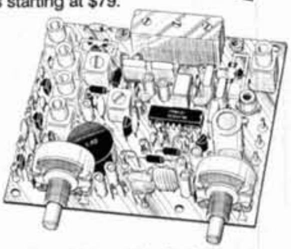

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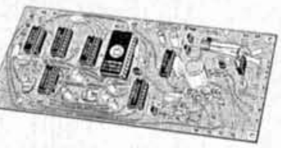

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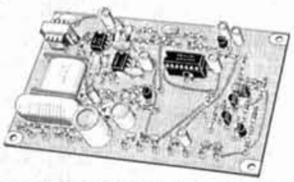

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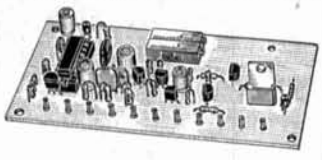

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- **High gain:** 13-20dB, depends on freq
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- **Stable:** low-feedback dual-gate FET

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LNW-(*) MINIATURE GaAs FET PREAMP

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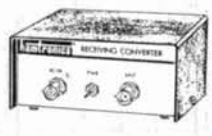

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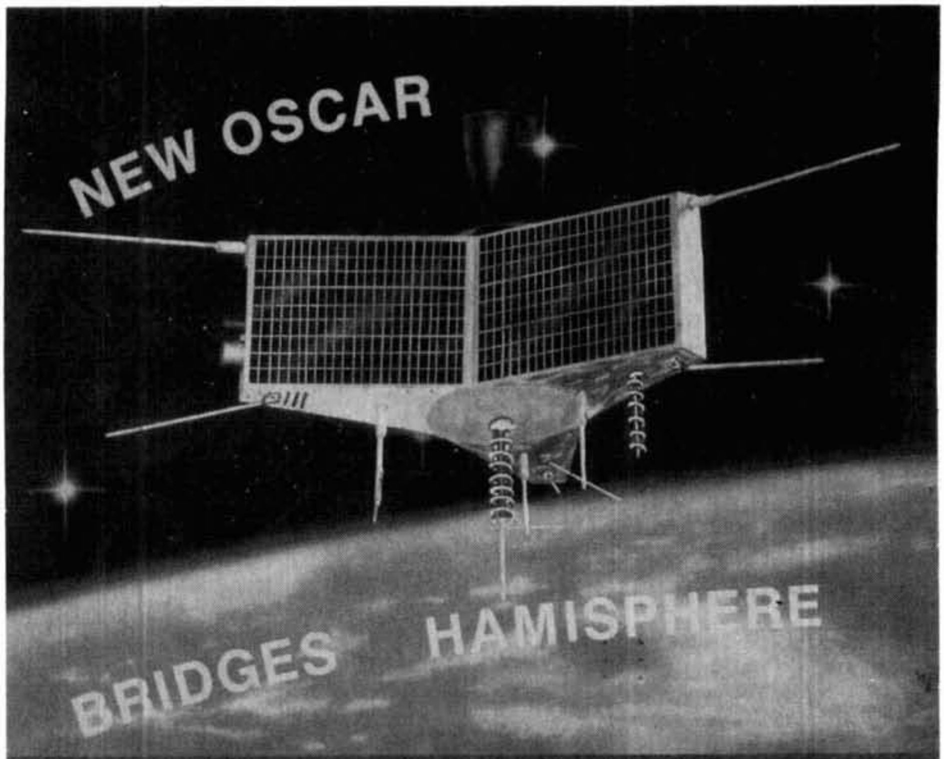

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which is a fixed reference potential. The noninverting input (+IN) is at a voltage (V_F) that is the superimposition of two voltages, V_o and V_B:

$$V_F = \frac{V_oR4}{R2 + R4} + \frac{+/- V_BR2}{R2 + R3} \qquad (10)$$

If $+V_B = -V_B$, then the positive and negative thresholds are equal.

The duration of each ramp (t_a and t_b) can be found from:

$$t_{a,b} = \frac{V_p}{\left| \frac{V_B}{R1C1} \right|} \qquad (11)$$

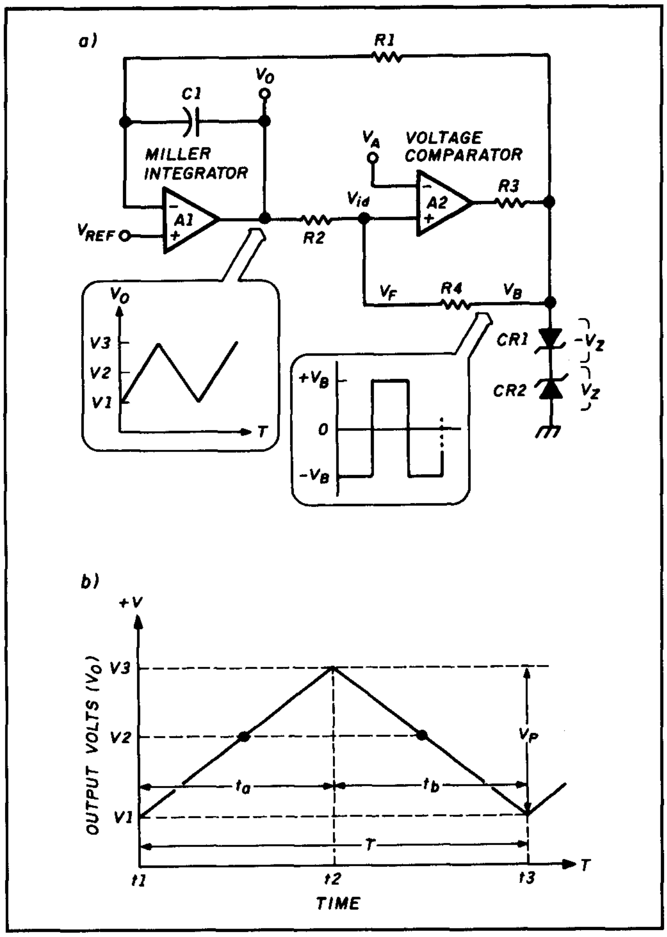
The value of V_B is selected from $-V_B$ or $+V_B$ as needed. In **Equation 10** you find that $V_p = 2V_BR2/R4$, so:

$$t_{a,b} = \frac{\left| \frac{2V_BR2}{R4} \right|}{\left| \frac{V_B}{R1C1} \right|} \qquad (12)$$

$$t_{a,b} = \left| \frac{R1C1}{V_B} \right| \left| \frac{2V_BR2}{R4} \right| \qquad (13)$$

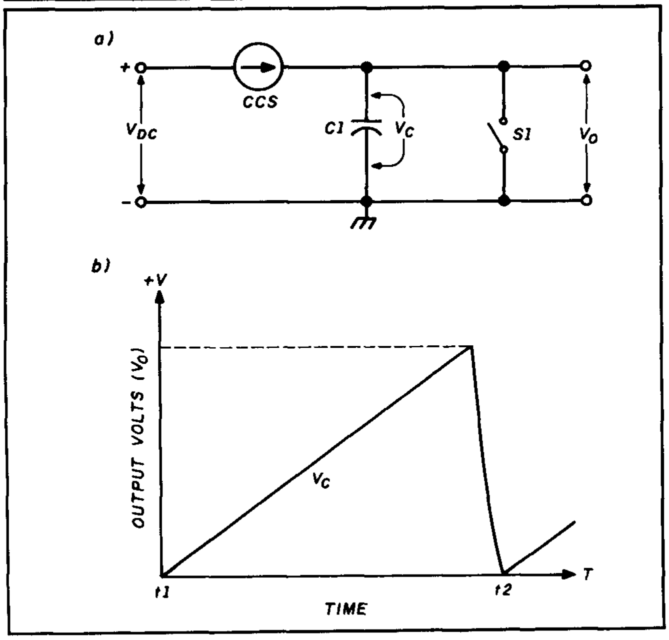
$$t_{a,b} = R1C1 \left| \frac{2V_BR2}{R4} \right| \qquad (14)$$

FIGURE 3



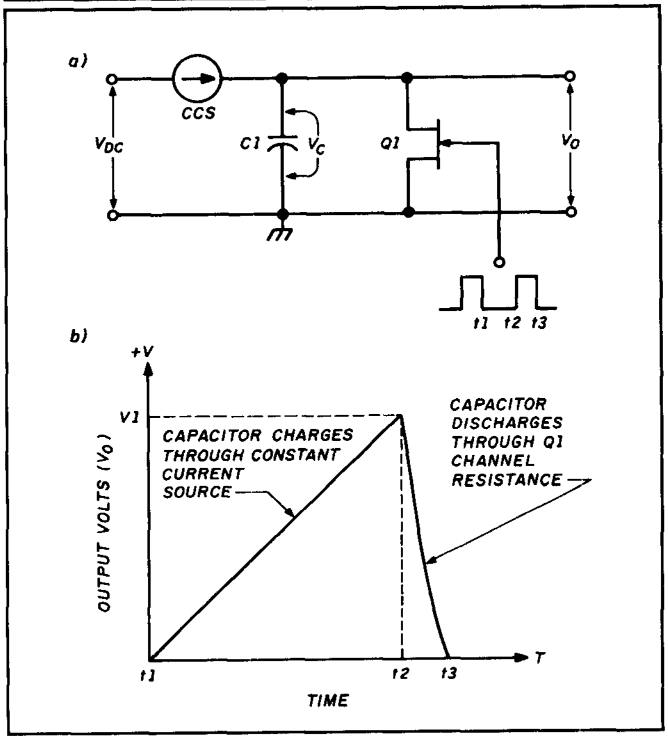
(A) A practical circuit that produces the waveform seen in *Figure 2B*. (B) Detailed breakdown of one cycle of the triangle wave generator.

FIGURE 4



(A) Simple design of a sawtooth wave generator. (B) Output of the sawtooth generator; a CCS is used to charge the capacitor.

FIGURE 5



(A) An example of a periodic sawtooth oscillator. (B) The same basic wave output.

or, in the less general (but more common) case of $t_a = t_b$:

$$T = 2R1C1 \left| \frac{2R2}{R4} \right| \quad (15)$$

The frequency of the triangle wave is the reciprocal of the period (1/T), so:

$$F = \frac{1}{T} \quad (16)$$

$$F = \frac{1}{\frac{4R1C1R2}{R4}} \quad (17)$$

$$F = \frac{R4}{4R1C1R2} \quad (18)$$

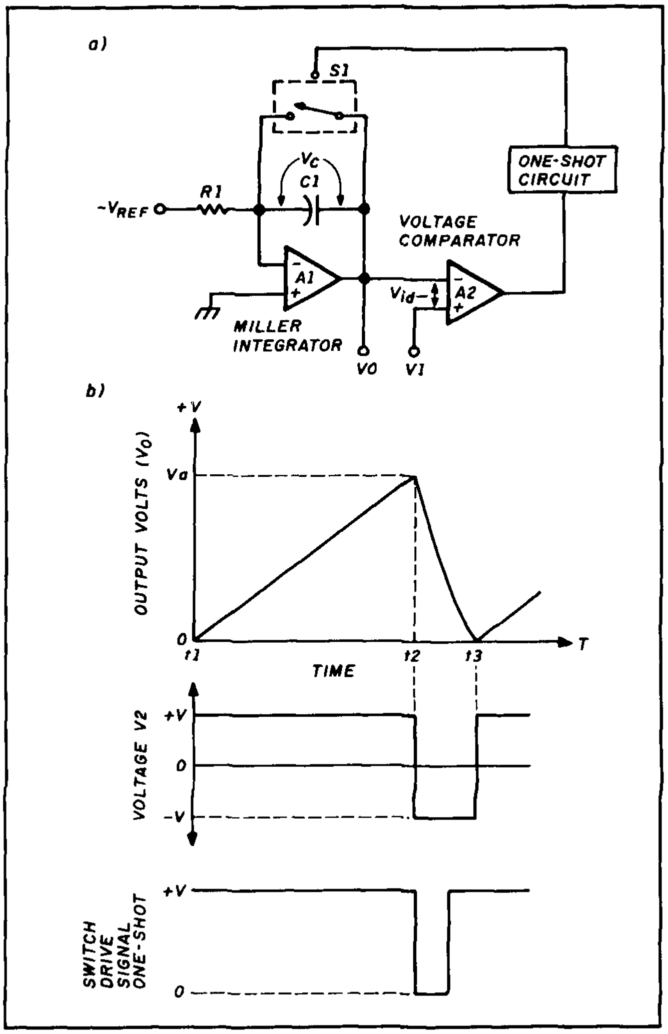
Sawtooth generators

The *sawtooth wave* in **Figure 1A** is a single slope ramp function. The wave ramps linearly upwards (or downwards), and then snaps back abruptly to the initial baseline condition. **Figure 4A** shows a simple model of a sawtooth generator circuit. A constant current source charges a capacitor in a manner that generates the linear ramp function (see **Figure 4B**). *When the ramp voltage* (V_c) *reaches the max*imum point (V_p) switch S1 is closed, forcing V_c back to zero by discharging the capacitor. If switch S1 remains closed, the sawtooth is terminated; if S1 reopens, a second sawtooth is created as the capacitor recharges.

Figure 5A shows the circuit for a periodic sawtooth oscillator. It's similar to **Figure 4A** except that a junction field effect transistor (JFET), Q1, is used as the discharge switch. When Q1 is turned off, the output voltage ramps upwards (see **Figure 5B**). When the gate is pulsed hard on, the drain source channel resistance drops from a very high value to a very low one, forcing C1 to discharge rapidly. In the absence of a gate pulse, however, the channel resistance remains very high. The gate is turned off at time t1, so V_c begins ramping upwards. At t2 the JFET gate is pulsed, so C1 rapidly discharges back to zero. When the pulse *(t2-t3) ends, Q1 turns off again and the ramp starts over.* You can use the same circuit for single sweep operation by replacing the pulse train applied to the gate of Q1 with the output of a monostable multivibrator.

The circuit of **Figure 6A** shows a sawtooth generator that uses a Miller integrator (A1) as a ramp generator and *replaces the discharge switch with an electronic* switch driven by a voltage comparator and one-shot circuit. The timing diagram for this circuit is shown in **Figure 6B**. Under the initial conditions, at time t1, the output voltage (V_o) ramps upwards at a rate of $[-(-V_{ref})/R1C1]$. The voltage *comparator (A2) is biased with the noninverting input (+IN)* set to V1 and the inverting input at V_o. The comparator differential input voltage $V_{id} = (V1 - V_o)$. As long as $V1 > V_o$, the comparator sees a negative input and produces a **HIGH** output of $+V_{sat}$. At the point where $V1 = V_o$, the differential input voltage is zero, so the output of A2 (voltage V2) drops **LOW** (i.e., $-V_{sat}$). The negative going edge of V2 at time t2 triggers the one-shot circuit. The output of

FIGURE 6



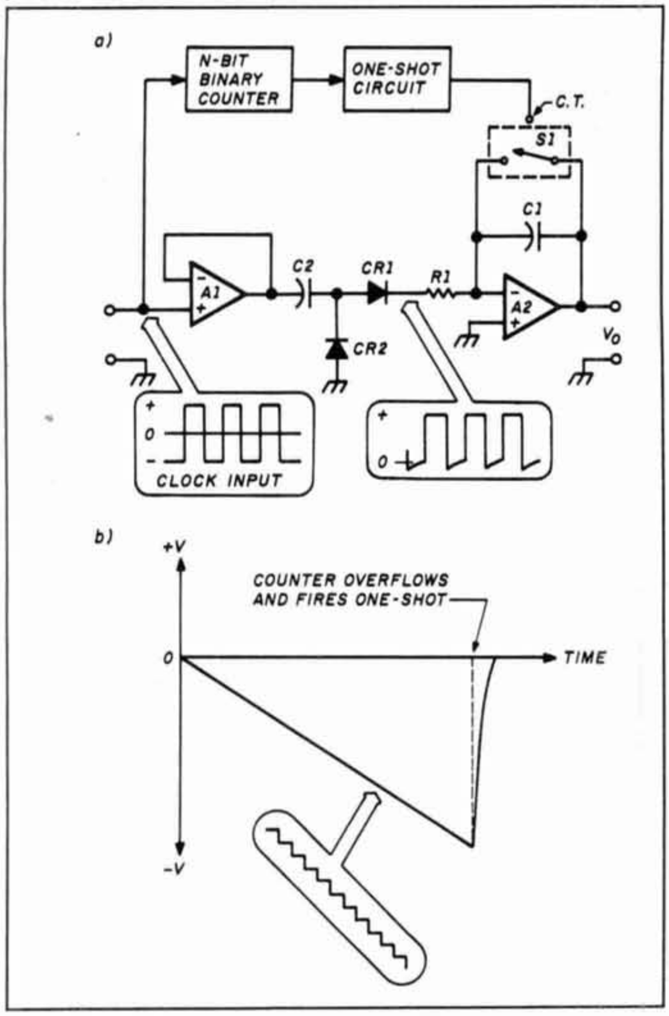
(A) A Miller integrator used as a sawtooth generator. The discharge switch is replaced by an electronic switch driven by a voltage comparator/one-shot circuit. (B) Timing diagram for the circuit in *Figure 6A*. At time t2, the negative going edge of V2 triggers the one shot.

the one-shot closes electronic switch S1 briefly, causing the capacitor to discharge. The one-shot pulse ends at time t3, so S1 reopens and allows V_o to ramp upwards again.

The *staircase generator* in **Figure 7A** is a variant of the sawtooth generator circuit. The input amplifier (A1) provides buffering. A square wave clock signal applied to the input of A1 is passed through capacitor C2 to a diode-clipping network (CR1, CR2). The clipping circuit removes the negative excursions of the square wave (see inset to **Figure 7A**). The remaining positive polarity pulses are applied to the input of the inverting Miller integrator ramp generator circuit. Each pulse adds a slight step increase to the capacitor charge voltage, so (unless there is significant droop between pulses) the output will ramp up to a negative potential in the staircase fashion shown in the inset to **Figure 7B**.

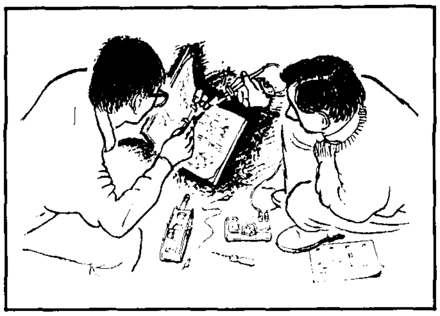
The reset circuitry in this circuit is a little different. Although the comparator method of **Figure 6A** would also work, this circuit takes advantage of the input square wave to provide the period timing of the sawtooth. The square waves are

FIGURE 7



(A) Circuit of a staircase generator. (B) Example of the staircase generator output.

applied to the input of an N-bit binary digital counter circuit. When 2^N pulses have passed, the counter overflows on $[2^N+1]$ and triggers a one-shot circuit. As in the previous case, the one-shot output pulse closes the electronic reset switch shunted across capacitor C1 momentarily.



The 80/40-meter Junkbox Rig Revisited

Some of you may have built the transmitter I described in the December 1989 issue of *Ham Radio*.[1] I hope you've enjoyed this little rig, but perhaps you wish you had just a little more power.

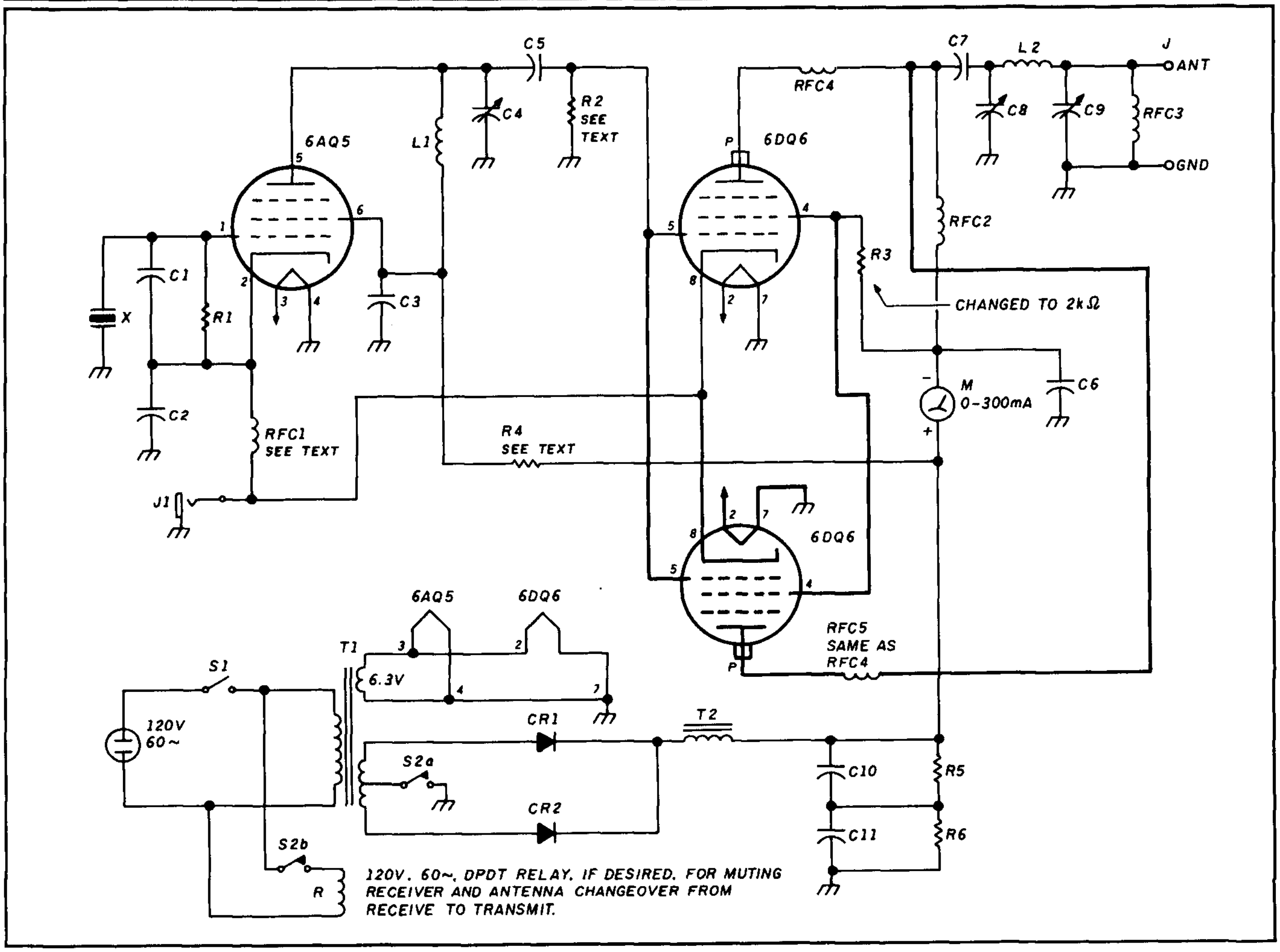
Fret no more. This may be just what the doctor ordered — *parallel* 6DQ6s.

All you need to do is add another final amplifier tube as shown in the schematic diagram in **Figure 1**. If your milliammeter covers only 0 to 150 mA, the range should be doubled to 0 to 300 mA. In other words, if you now load your rig to 125 mA, you should be able to load it to 250 mA. It's possible to almost double your power, or increase it by 3 dB.

Parts to be changed

You must change the following parts. If you refer to the original diagram,

FIGURE 1



Upgraded 80/40-meter Junkbox Rig.

you'll find that R2 is a 27-k resistor, R3 is a 4-k wire-wound resistor, and R4 is a 1.5-k wire-wound resistor. These should be halved. You can reduce R2 to about 12 to 15 k. However, I tried this and the change seemed to make no difference. R3 should now be 2 k; R4 could be either 500 to 1000 ohms, or simply deleted.

I don't use a voltage-dropping resistor for R4 now as I don't exceed 300 volts with this parallel arrangement. You should change RFC1 to 300 mA or move the 6DQ6 cathode wire from pin 8 of the octal socket directly to the ungrounded side of the key jack.

New currents and voltages

The following currents and voltages result from this change:

- 200 mA × 285 volts = 57 watts input. (Formerly 100 mA × 305 volts = 32 watts input.)
- 250 mA × 280 volts = 70 watts input. (Formerly 125 mA × 300 volts = 38 watts input.)
- 300 mA × 275 volts = 83 watts input. (Formerly 150 mA × 295 volts = 44 watts input.)

Loading is the same as before. If you follow the directions in December's article, you shouldn't encounter any difficulties.

Charlie Tiemeyer, W3RMD

REFERENCE

1. Charlie Tiemeyer, W3RMD, "The Five-Band Junkbox Transmitter," *Ham Radio*, December 1989, page 42.

Ezy tune

While tuning around the HF bands one night with my Heath HW-5400, I discovered that I needed an easier way to change frequency than the conventional tuning knob. I came up with a little circuit I call the "Ezy Tune" (see **Figure 1**). It's easy to build and doesn't affect the manual tuning capabilities of the HW-5400.

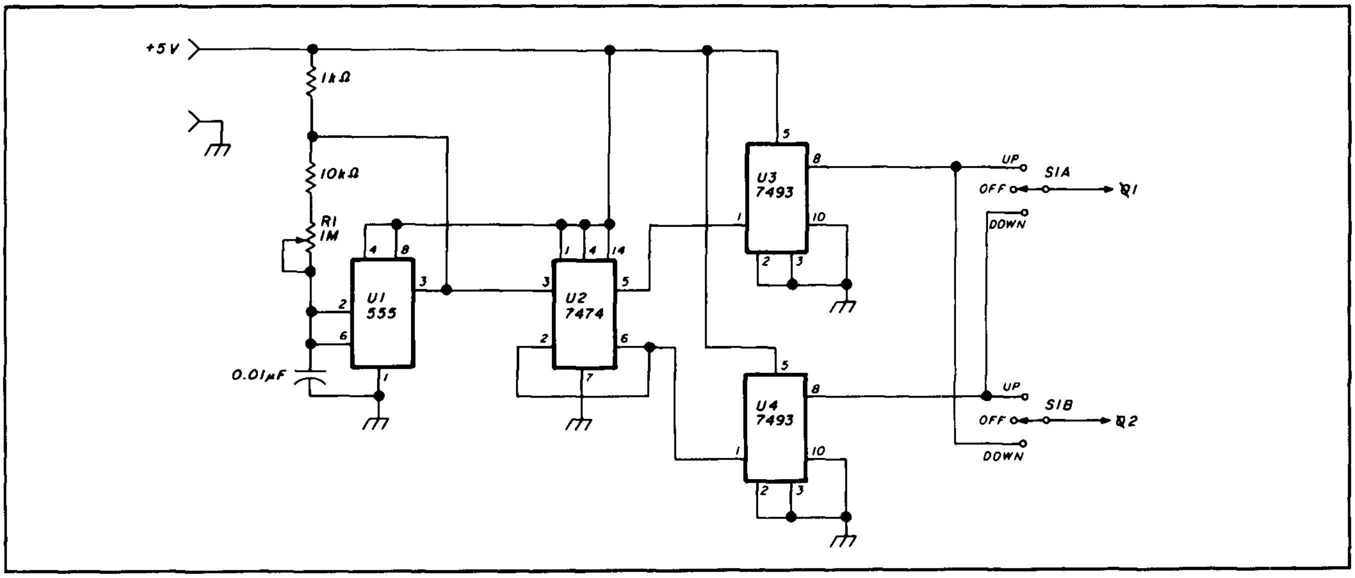
The master oscillator, U1, is a 555 astable multivibrator free running at eight times the tuning rate in steps per second, as desired. The frequency of U1 is adjustable by R1, a 1-meg pot. U2 produces two pulse trains 180 degrees out of phase which, when divided by the two binary counters U3 and U4, deliver two pulse trains 90 degrees out of phase. This is what the optical encoder controlled by the tuning knob on the HW-5400 does. These two signals are switched through S1, a DPDT center-off toggle switch, to the $\theta 1$ and $\theta 2$ inputs on the controller board.

I built the Ezy Tune circuit on a piece of perfboard small enough to mount near the controller board. Power can be supplied by P703 on the controller board; pin 1 is 5 volts and pin 3 is common. S1 can be panel mounted to the lower left or right of the tuning knob.

By the way, this circuit would probably work with other transceivers with optically encoded tuning systems using TTL-level inputs.

Dexter King, AB4DP

FIGURE 1



The schematic of the "Ezy Tune" circuit.

THE QRP TLC-KEYER

By Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825

Preparing for a QRP DXpedition usually means packing to travel light. Unfortunately, adding even a few basic accessories can overload the radio bag in a hurry. Take electronic keyers, for example. Mine is larger than my QRP transceiver, and loaded with features I rarely use. To make life on the road less awkward, I decided to build a miniature keyer — one designed specifically for portable use. Not wanting to spend a lot of money, I settled on a single-paddle type employing inexpensive ICs available from Radio Shack.

The circuit

The design I chose is a popular one using NE555 timers.[1] The circuit performed well on the breadboard, but required over 20 mA at 9 volts to operate. This was too much current for sustained operation with a small 9-volt battery. To solve this problem, I substituted TLC555s — a CMOS direct replacement for the NE555 (hence the name TLC-Keyer). This change reduced continuous current drain to a scant 1.4 mA, making battery operation practical and allowing me to include a reed relay output circuit. I prefer using reed switching because it interfaces with virtually any rig.

The circuit consists of three simple timer stages. U1 generates the space interval between characters, while U2 and U3 generate dot and dash outputs, respectively. A 10-k linear pot varies sending speed by raising or lowering the timing interval of all three chips simultaneously. Spacing and character timing may be altered by substituting new values for the 33 and 82-k series resistors in this portion of the circuit. For example, changing the 82-k resistor to 100 k results in longer dashes.

A 2N2222 DC switch actuates relay K1 whenever the output of U2 or U3 goes high. For self-powered operation from a 9-volt battery, a 470-ohm current limiting resistor is connected in series with the 5-volt relay coil. For 12-volt operation, use 1.2 k or install a jumper and a 12-volt relay.

Construction

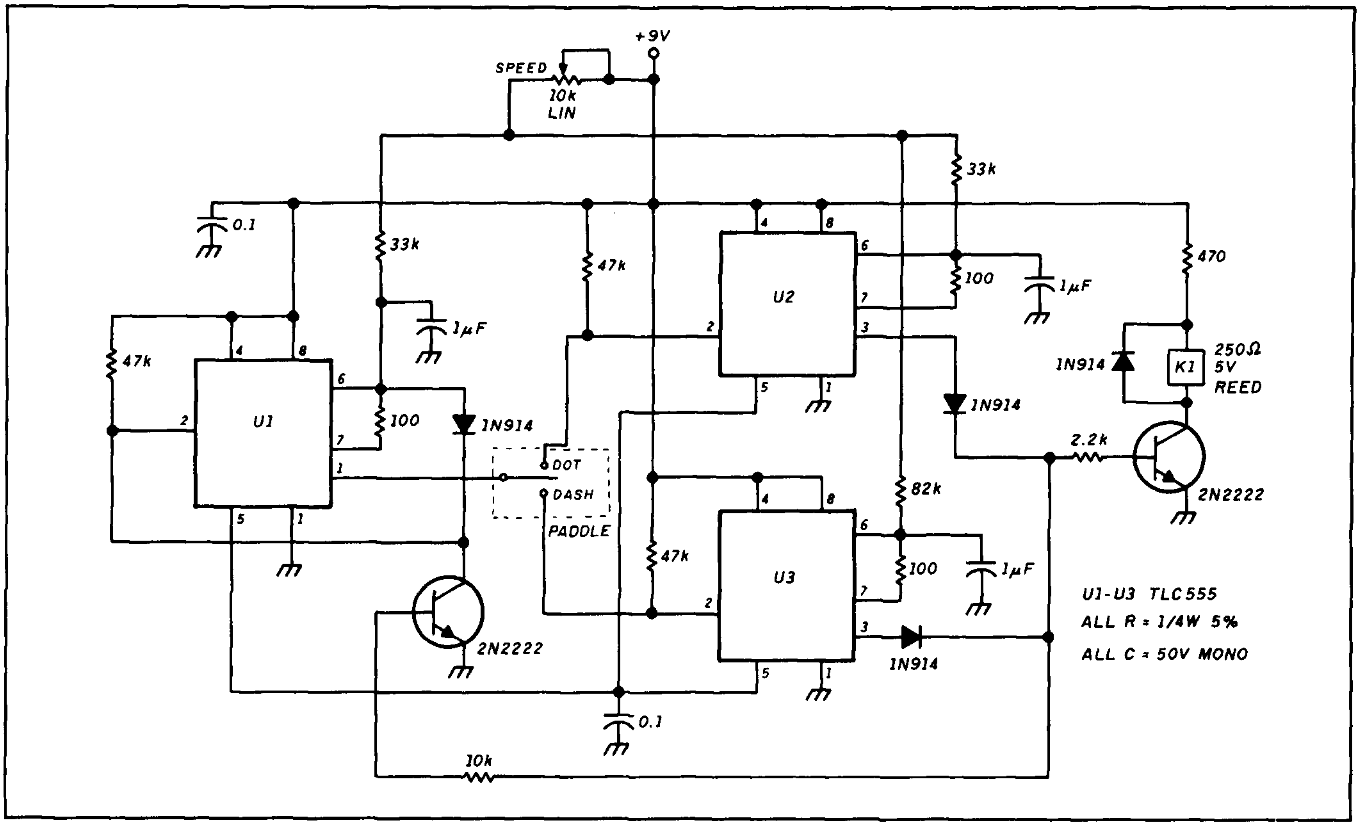
Board construction is straightforward — simply follow the parts placement diagram shown in **Figures 1A** through **1C**. Remember to observe CMOS handling precautions when installing the TLC555s. Also, install jumpers and interconnecting leads.

Details for constructing and mounting the paddle assembly are shown in **Figure 2**. I fabricated the paddle arm from scrap G-10 board (all copper removed). The key contact is a 1/4-inch no. 4-40 screw and no. 4 nut. I filed the screw tip flush with the nut, and polished it to make a better contact surface. Lexan™ or Styrene™ sheet stock makes a good paddle, and is readily tapped to accept no. 2-56 or no. 4-40 mounting screws. Standard 3/8-inch no. 6 spacers and 90-degree L brackets support the paddle assembly above the pc board components. Two 3/4-inch no. 4 spacers serve as dot and dash contacts. Contacts should be roughly aligned and screws tightened before the pc board is installed in a cabinet or on a base.

Final packaging depends on how you intend to power the keyer. One option is to mount the board, paddle, and battery in a small project box. This lets you operate on internal power and use the keyer with any rig. The second option is to borrow power from your transceiver — replacing the key jack with a stereo jack, and using the tip connection to supply 12 volts. Obviously, eliminating the battery will reduce the size and weight of the keyer package.

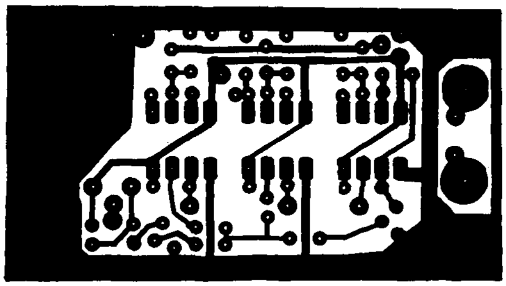
I don't recommend mounting the keyer electronics inside your rig. For one thing, the "common" key line of this circuit is the output of U1, and this must remain isolated from ground. Also, the pc board fits neatly on the keyer base without contributing to its size. No real space saving is gained from putting it inside the radio. Whether you package the keyer in a project box or on a weighted base plate, cement a rubber pad to the bottom. This will reduce skidding on smooth surfaces.

FIGURE 1A



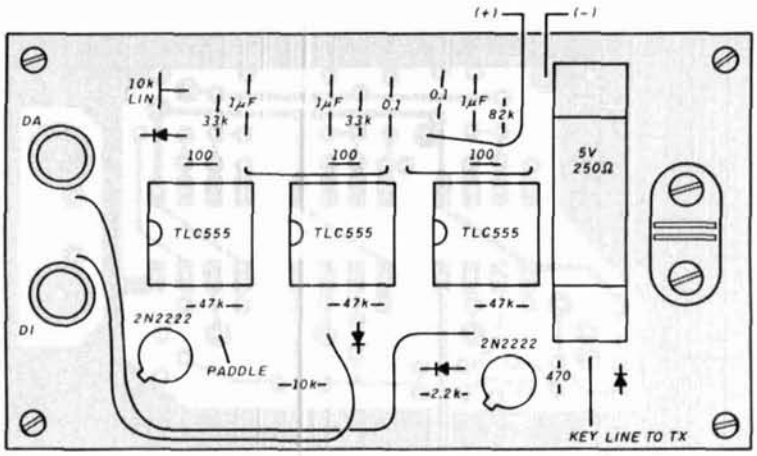
The circuit schematic.

FIGURE 1B



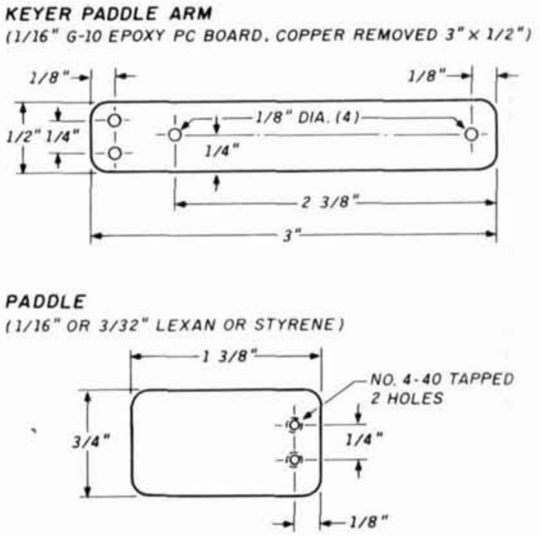
The foil side of the pc board.

FIGURE 1C



The component placement guide.

FIGURE 2



The paddle assembly.

PARTS LIST

Capacitors

2	0.1 µF Mono
3	1 µF Mono or equivalent

Resistors

3	100
1	2.2 k
1	10 k
2	33 k
3	47 k
1	82 k
1	10-k linear pot

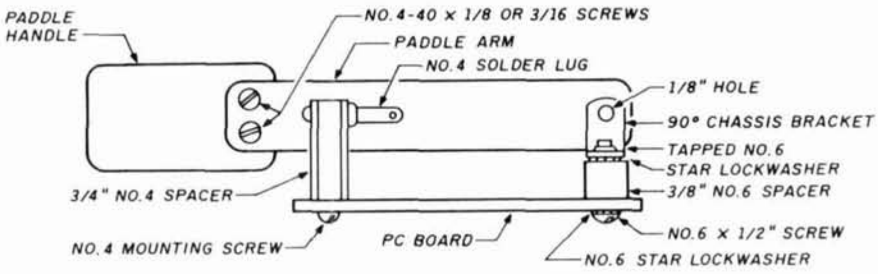
Semiconductors

3	TLC555
2	2N2222
4	1N914

Miscellaneous

1 pc board (Available from Far Circuits, 18N640 Field Court, Dundee, IL 60118, for $4.00. Price includes shipping and handling.)

FIGURE 3



Dimensions of the completed paddle assembly.

Operation

Keyer setup is purely mechanical. To make fine centering adjustments on the arm, place the tip of a flat-blade screwdriver between the two support spacers and torque the arm gently in the desired direction. When you've completed this operation, you may want to readjust the dot/dash posts for the desired contact spacing. Finally, connect the keyer output to an oscillator or rig, set the speed control midway, and start sending. If the keyer fails to operate, confirm that you have power and that diodes, chips, and transistors are positioned correctly.

Conclusion

The finished key, shown in **Figure 3**, measures 2.6 by 1.5 by 1.5 inches, and weighs only a few ounces. This represents a vast improvement in portability over my old one! The keyer works well — with one minor reservation. I had used the Curtis 8044s for years, and the TLC's unbuffered input threw me on my first sending attempts. With no buffer, the keyer can't accept a dot while a dash is completing. Consequently, I rapped out a few "CO DE M1BOTs" before I brought my thumb under control. However, I adapted quickly and can now switch from one keyer to the other without difficulty.

The TLC-keyer is now a permanent part of my QRP station, and I travel several pounds lighter for my effort. If you face a similar dilemma at packing time, give it a try. The price is right, and so is the size! hr

REFERENCES

1. Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, *Solid-State Design For The Radio Amateur*, ARRL, 1985, pages 177-178.

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(continued from page 9)

was also done in the familiar "brunswick green," but it boasted more selectivity and punch. It was the old S-40A. I saved my money for it a long time and finally, when it seemed I could scrape together no more, my parents matched my funds so that I could have it for a birthday gift.

The order was placed with Bob Henry out in Butler, Missouri and the radio was promised for delivery in time for my October birthday. In those days there was no UPS, and a radio the size of the S-40A had to be shipped by Railway Express. Fate intervened in the form of a nationwide railroad strike, and it appeared my gift would arrive long after the birthday had passed.

During those weeks of waiting, my father called Bob Henry several times. When he learned the special occasion for which the radio had been ordered, Bob went the second mile. He put a tracer out with Railway Express and located the radio. It was well over two-thirds of its journey to my South Carolina home, and Bob assured my father that it should reach our town only a day or two after the strike was settled. About that time President Truman intervened, the strike was halted, the trains rolled again, and the radio arrived in Sumter, South Carolina *on the evening train from* Atlanta at 9:05 p.m. on the evening of my 16th birthday!

That radio served me well, even after I acquired my ham ticket several years later. I eventually used it as trade-in towards a better model, the SX-42, but it always held a special place in my heart — even though it was not my first receiver.

The products Bill Halligan's Chicago factory turned out will, I expect, always be held in special esteem by those of us old enough to remember them. I later owned a couple of Hammarlund receivers, which were also very fine radios. But somehow, there was a special mystique about the Hallicrafters that even the National HRO couldn't touch.

Even though Bill's gear no longer graces our shacks, Bob Henry has joined the ranks of the Silent Keys, and the Butler store is gone, there is one ham who will never forget the touch both of them had on his life.

Drayton Cooper, N4LBJ,
Bowling Green, South Carolina

short circuits

Missing Parenthesis

In WA3EKL's October 1989 article "The PV-4 On Your Commodore," there was a small error in the proof program on page 64. Line 170 should be corrected to read:

F1=(1-((10.7575*(LOG(KA)/LOG (10)))-8) Λ -1)/2*A(j))

Program Correction

In N1AYW's article, "Computerizing Smith Chart Network Analysis" (October 1989, page 10), Menu item 6 in the resonant circuit calculations of the Smith Chart program is not functional as it was originally listed; however, the error was corrected in version 2.46. For those readers with versions earlier than 2.46, please insert the following two lines and modify line 3400 as shown below.

```
2915 FR=10 Λ 6/(2*PI*CR*RR*QR)
:RETURN:REM SERIES, C KNOWN
2925 FR=QR*10 Λ 6/(2*PI*RR*CR)
:RETURN:REM PARALLEL,
C KNOWN
3400 GOSUB 2830:GOSUB
2850:GOSUB 2790:ON PC GOSUB
2915,2925:GOSUB 2930:PRINT"F
="FR" and L ="LR:GOSUB
3010:GOTO 2870
```

Short circuit for Tseng Liao

In the Ham Note, "Two in one: Trace doubler for CRO, and square wave and pulse generator," published in the December 1988 issue, there are two misprints:

(a) In **Figure 3A**, C_4 should be C_p and R_{13} should be R_p.

(b) In the "Practical examples" section, R_1 should be R_i.

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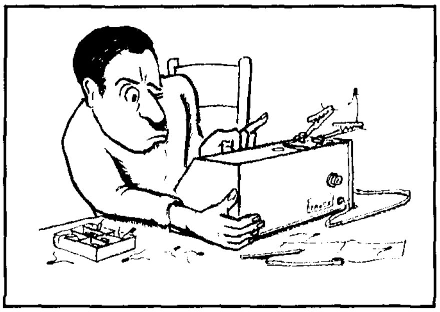
GETTING TO KNOW THE LOGIC FAMILIES — PART 2: CMOS



Complementary metal oxide semiconductor (CMOS) digital ICs are well known and readily available. Designated by "4xxx" series-type numbers, CMOS devices offer extremely low current drain, moderate operating speeds, and low cost. The low current requirements (on the order of a few microamperes) of CMOS technology have made possible a wide range of portable products — from digital watches to calculators to laptop microcomputers. Because of their properties, CMOS devices also make very useful sensing circuits for a variety of applications not always associated with digital electronics. But before getting into the various circuits, let's review the basics of CMOS digital IC devices.

CMOS digital devices

The MOSFET transistor is the basis of the CMOS line of digital ICs. This device offers an extremely high input impedance because the control gate input is isolated from the "channel" by a layer of insulation (see **Figure 1A**).

There are two polarities of MOSFET transistor, determined by the type of semiconductor material used in the channel structure. If N-type material is used, the MOSFET is an N-channel; if P-type semiconductor material is used, it's a P-channel MOSFET. The respective circuit symbols for these two devices are shown in **Figure 1B**.

In digital circuits, the MOSFET will be in one of two conditions. When a bias is applied to the gate, the channel resistance is very high (megohms). On the other hand, the absence of bias causes the channel resistance to be very low (200 to 300 k). Although this explanation doesn't include all possible types and is somewhat simplified, it will do for our purposes.

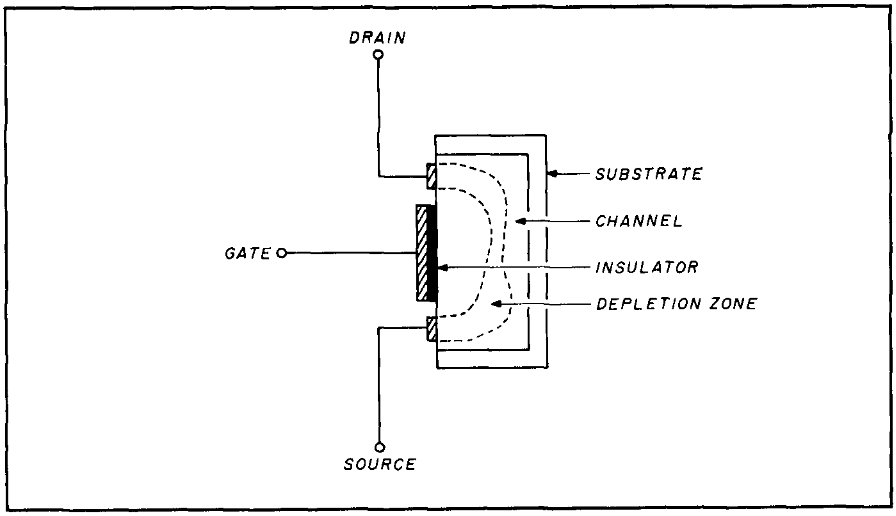
When examining any digital logic element it's useful to consider the case of the inverter as representative of the whole class. **Figure 2** shows the circuit of a CMOS inverter. This circuit consists of an N-type MOSFET and a P-type MOSFET connected with their respective gates in parallel and their channels in series. The input of the inverter is the gate; the output is the junction between the P-channel drain (Q2) and the N-channel source (Q1).

Two DC power supplies are shown: V+ and V−. These voltages are typically ±4.5 to ±15 volts DC. In some cases, the V− supply is set to zero, so the V− terminal of the device will be simply grounded.

Because P and N-channel MOSFETs are of opposite polarity, one will have a high channel resistance while the other has a low resistance. The two channels are connected in series, so the overall channel resistance (as measured from (V+) terminal to (V−) terminal) is very high. This resistance is why the CMOS device draws such low current — the power supply sees a resistance in the megohm range. The only time the CMOS devices draw appreciable current is during output transition from high-to-low or low-to-high. At that brief instant, both channel resistances are in a transition region between high and low resistance values.

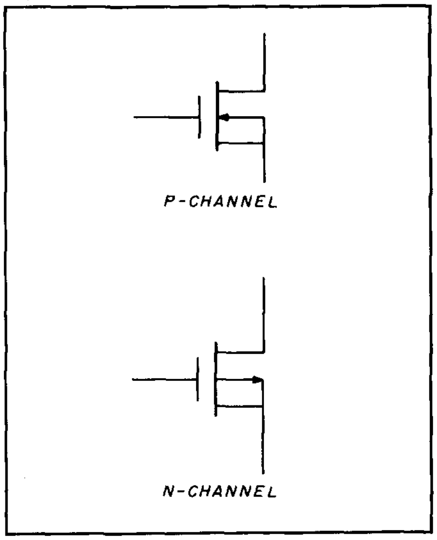
Figure 3 is a graphical representation of the channel resistance relationship.

FIGURE 1A



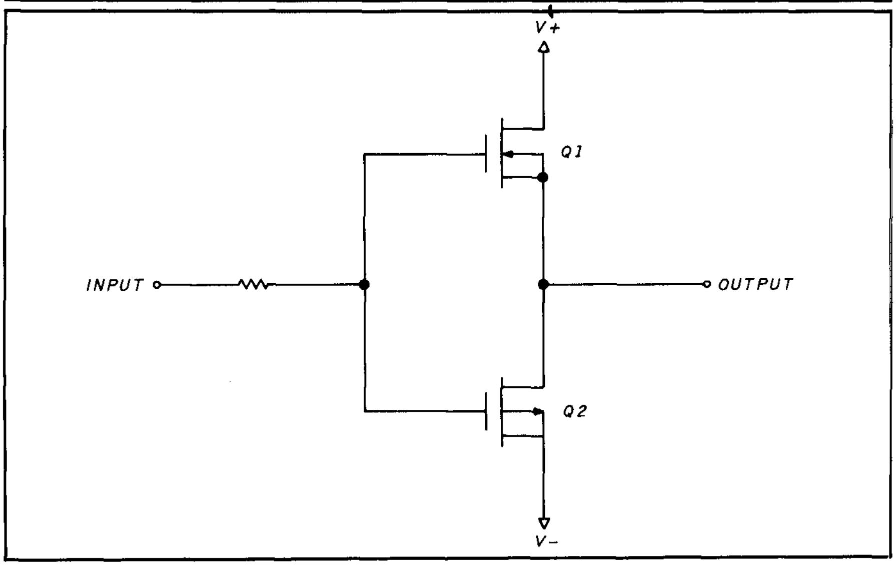
Physical makeup of a MOSFET transistor. These transistors comprise most CMOS devices.

FIGURE 1B



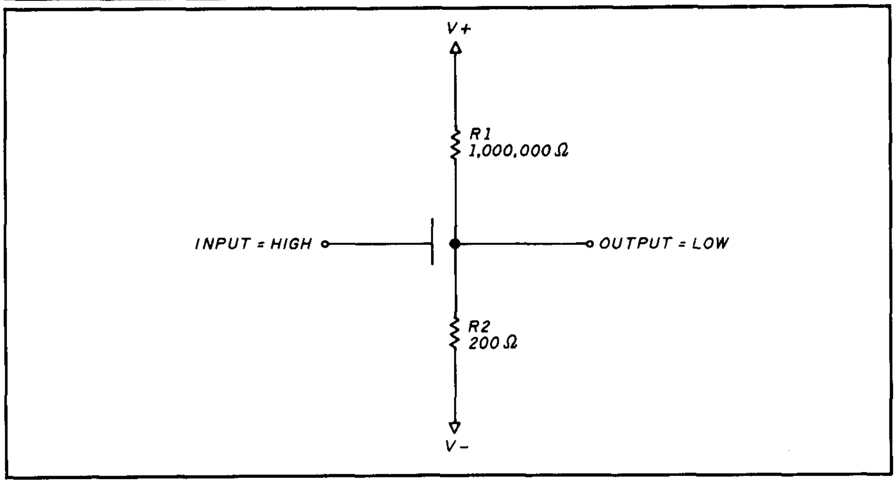
P-channel and N-channel MOSFET transistor designators.

FIGURE 2



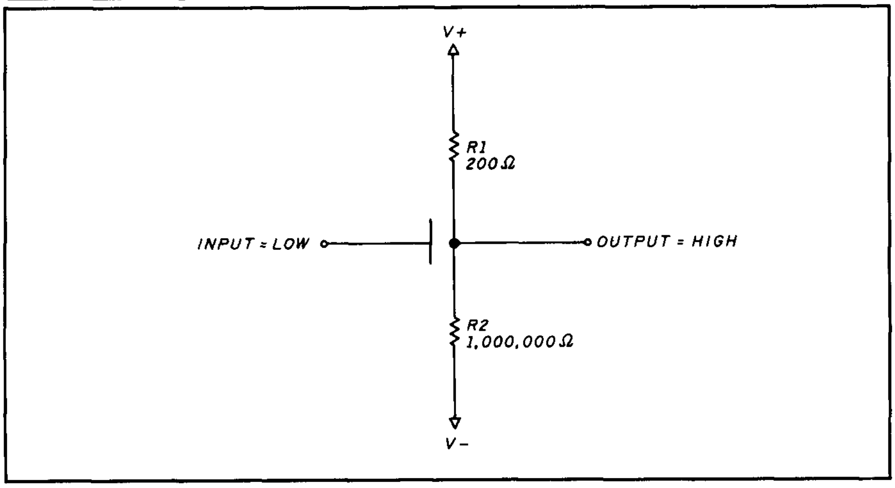
Schematic of a typical CMOS inverter.

FIGURE 3A



Situation where the input of the CMOS inverter is HIGH.

FIGURE 3B



Situation where the input of the CMOS inverter is LOW.

In the cases shown in **Figures 3A** and **3B**, the total resistance (R1 + R2) is the same even though the relationship of R1 and R2 changes. In **Figure 3A** the input of the CMOS inverter (**Figure 2**) is high. The resistance of Q1 (i.e., R1) is high and that of Q2 is low. Thus, the output line is connected through a low resistance to V−. In **Figure 3B** the input is low. Here, the relationship of R1 and R2 is reversed. R2 is high, while R1 is low. This means that the output terminal is connected to the V+ supply through a low resistance.

The definitions of logical high and logical low states are determined by the voltages used. If two potentials are used, V− is low and V+ is high. But if the V− is set to zero, logical low is zero (grounded), while the logical high remains at V+. The transition point between high and low (or vice versa) occurs when the input is at a potential halfway between V+ and V−, or when V− is zero volts (one-half V+).

Electrostatic discharge (ESD) damage

The insulated gate of a MOSFET transistor is very thin. The ability to withstand high voltages is directly proportional to the thickness (for any given material). This thin layer means MOSFETs can handle only 50 to 150 volts (80 volts is common). Greater potentials will pop through the gate insulation, destroying the device. Ordinary handling of tools and other implements can create potentials up to several kilovolts. These potentials can build up in the human body, too. If you don't believe me, walk across a carpet on a dry winter day and then touch a grounded object!

Unfortunately, the damage from ESD doesn't always happen immediately. It can show up as an unexplained "spontaneous" failure sometime later. The usual procedure to minimize ESD damage is to make sure that all pins are at the same potential all of the time. This usually means working on a metal or carbonized foam surface, and storing the devices in a conductive container or on carbonized foam pads. It's also recommended that you discharge the potentials on your body by touching something grounded (but not in the presence of high voltage or AC) just before you touch the MOSFET or CMOS device. Actually, it's a good idea to avoid handling the device at all unless absolutely necessary.

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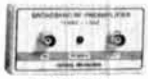

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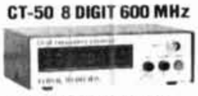

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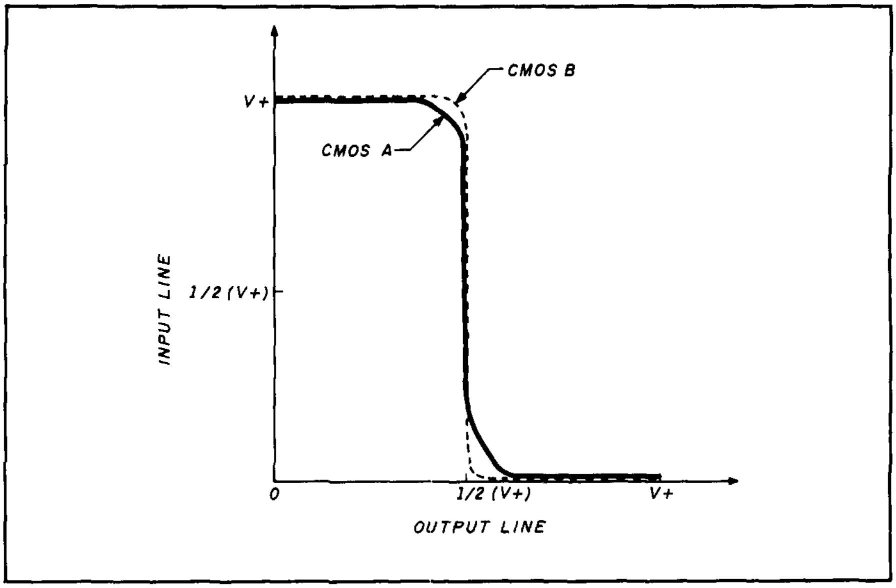
FIGURE 4



Transition time differences between A-series and B-series CMOS devices.

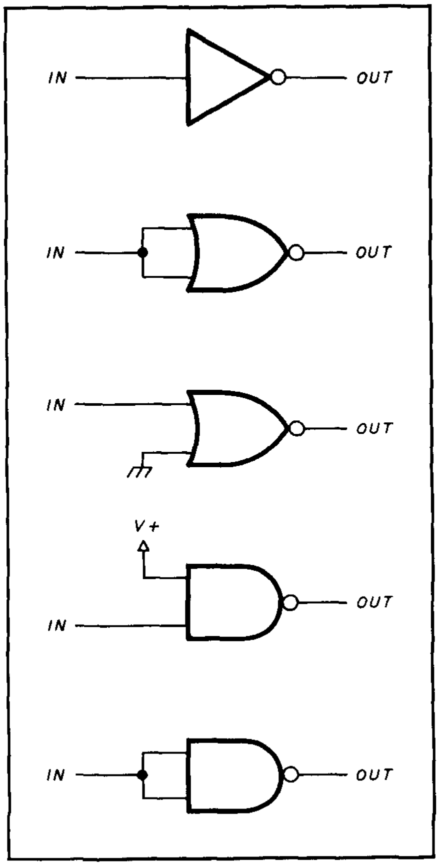
A-series versus B-series CMOS

There are two different types of CMOS devices on the market: A-series and B-series chips. The A-series is the older of the two. These devices are designated either with an "A" suffix on the type number, or no suffix on the type number. For example, both "4013" and "4013A" are designators for an A-series type 4013 device. The B-series is newer; some believe it's an improvement over the A-series. B-series devices are always marked with a "B" suffix on the type number (e.g., 4013B).

There are several notable differences between A-series and B-series devices. Perhaps the most well known is that B-series devices are protected from ESD damage somewhat by internal zener diodes which clamp or bypass the high voltage electrostatic potentials. You can get away with handling B-series devices more often than A-series. Note that the amount of ESD damage on B-series does not drop to zero, but it's very low compared with A-series.

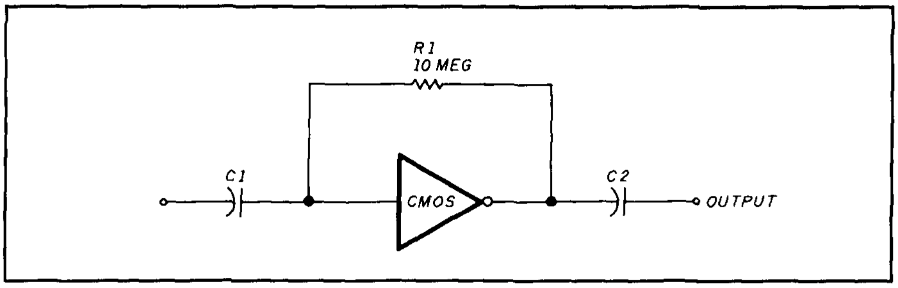
Another difference is the output transition time. **Figure 4** shows the transfer function of the two types of CMOS devices. The B-series makes the transition more quickly, creating a sharper, faster rise time pulse. A final difference

FIGURE 5



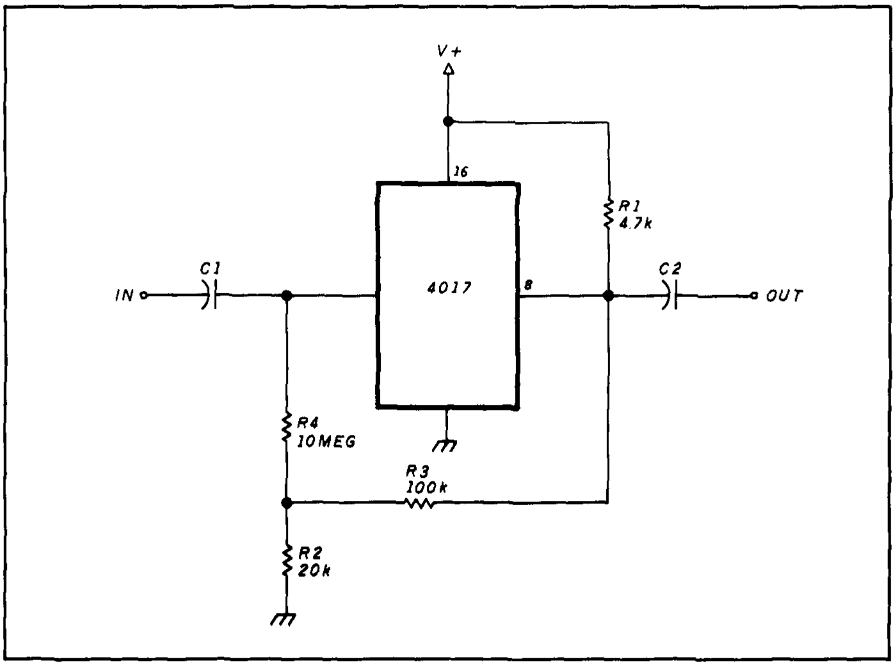
Several methods of "making" an inverter from CMOS NOR and NAND gates.

FIGURE 6A



An elementary biasing scheme for using a CMOS device in the linear mode.

FIGURE 6B



A 4017 CMOS device used as an audio amplifier.

is that most B-series CMOS devices will drive a larger load than their A-series cousins. In one case, for example, the B-series will drive a load three times heavier than the equivalent A-series device.

CMOS inverters

Most of the circuits in this article are based on the inverter. There are several inverters in the CMOS line. You can also make an inverter from available NOR or NAND gates. **Figure 5** shows how to make an inverter from other logic elements. For both the NOR and NAND gates, connecting the inputs together will cause the element to work. You could also make an inverter by grounding one input of a NOR gate, or connecting one input of a NAND gate high. Another alternative is to use a CMOS transistor array like the CD-3600 or the 4017 device.

Linear operation of CMOS devices

You can make the CMOS digital IC into a linear device using appropriate biasing methods. **Figure 6** shows two examples of linear operation of a CMOS inverter.

The elementary bias method is shown in **Figure 6A**. This circuit is quite simple. It consists of a pair of coupling capacitors (one on the input and one on the output) and a feedback resistor between output and input. It's possible to exert a small degree of control over linearity by varying the 10-meg value.

The circuit of **Figure 6B** is an audio amplifier based on the CMOS transistor array, type 4017. The 4017 array consists of three independent N-channnel/P-channel complementary pairs. In this project, I'm using one of the 4017 transistors. The bias is derived in a similar manner from the output, and also from the V+ power supply.

The values of input and output capacitance for both circuits depend on the lower −3 dB frequency response desired. This capacitance is set according to **Equation 1** if you use 10 megs for the resistance seen by the input signal (as in **Figure 6**):

$$C\mu F = \frac{0.1}{2\pi F} \qquad \textbf{(1)}$$

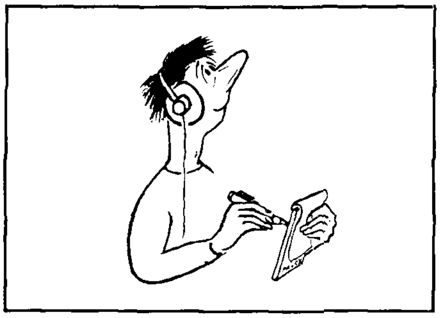
Where:

$C\mu F$ is the capacitance in microfarads

F is the −3 dB point in the desired frequency response curve, in hertz

Conclusion

Although CMOS devices are normally thought of as "digital," their unique properties make them useful in a lot of other applications. Understanding the properties of the CMOS device will help you make them work in other than normal circuits. **hr**



By Garth Stonehocker, KØRYW

THE DX BEACON GAME

Some radio stations can be used as beacons for DX propagation and research studies. There are three criteria for a radio station to be a beacon: its location, its identification (including frequency and modulator), and a useful schedule — in that order of importance. Most frequency ranges (VLF, LF, MF, HF, and VHF) contain radio stations which are used as beacons. In the LF range, the frequency band from 200 to 400 kHz is set aside for beacon stations used by marine and aeronautical radio direction-finding receivers for determining position location. The MF/AM broadcast stations form a secondary group of beacons also for this purpose. Other frequency ranges are generally used for other purposes and meet enough of the criteria to be useful as beacons only by coincidence. Of course, Amateur Radio, research, and government communities have set up specific radio stations as beacons in many locations on many frequencies with usable schedules.

The frequency ranges useful for ionospheric propagation are generally MF, HF, and the lower VHF. The beacons in these frequency ranges are mostly individual radio stations run by Amateurs, broadcasters, researchers, and governments. Of note is an Amateur network, PROPNET, with several locations using one frequency — 14.1 MHz. Each of ten stations transmits an identification in CW on a 1-minute time schedule with three power levels. The stations are located in New York, San Francisco, Hawaii, Japan, Israel, Finland, Madeira Island, South Africa, Buenos Aires, and Columbia. Not all of these stations are on the air consistently, so their minute time slot is not always in use.

The radio stations of world time and frequency standards offer other opportunities which can be used in the same way. The frequencies set aside for this purpose are generally 5, 10, and 15 MHz; 2.5 and 20 MHz are available in one or two locations. Because there are several stations transmitting simultaneously on each frequency, you need to know the criteria for identification (modulation and schedule) in order to ascertain the usable propagation information from each location. Although these frequencies aren't near most Amateur frequencies, they are near enough to be translatable to the ham bands by interpolating between the several widely spaced frequencies available.

Canada and Russia have transmissions useful for the evaluation of propagation on several frequencies which span some of the ham bands, but they aren't the standard frequencies of worldwide coordination. For example, Canada's CHU (Ottawa) frequencies are 3330, 7335, and 14670 kHz and Australia's VNG frequencies are 4500, 7500, and 12000 kHz. These frequencies are sufficiently close to the 80, 40, and 20-meter ham bands. Russia's frequencies for RID (Tashkent) and RWM (Moskva) are 4 kHz higher and 4 kHz lower, respectively, than the standard frequencies. These systems give the DXer some propagation beacon options to enhance his operation. Next month I'll discuss some low cost and high tech monitoring equipment and its use.

Last-minute forecast

The best time for long skip openings on the higher frequency bands (10 to 30 meters) is the first few days of the first week and the fourth and last weeks of the month. Solar flux is expected to be high and, consequently, raise the MUF at this time. If the flux peaks very high (greater than 250 units), signal levels may be below normal on the lower frequencies. Transequatorial openings should be good some evenings, particularly on days of geomagnetic disturbance. Geomagnetically disturbed days are expected around the 1st, 10th, 20th, and 28th. The latter two dates are disturbances most likely associated with the starting of the winter absorption anomaly (STRATWARM). The lower bands are also affected, but should be best the second week. Expect low thunderstorm noise and good signal levels then.

Lunar perigee occurs on the 8th; a full moon appears on the 11th. The Quadrantids — a short, but intense, meteor shower — will occur between January 2 and 4, and last a few hours.

Band-by-band summary

Ten and 12 meters, the highest daytime DX bands, are nearest the MUF for paths to the Southern Hemisphere. They will be open most days during the five hours before and seven hours after local noon for solar flux levels above 220, with shorter hours for lower flux. These bands open on paths toward the east in the morning and close toward the west in the evening. The paths are up to 3500 km (2100 miles) in a single hop and multiple hops are usually available. On occasion, transequatorial openings (multiple hops without ground reflection) produce high strength signals during late evenings.

Fifteen and 17 meters are open most days to the south. They are the transition bands available to the east, or the highest to the west and occasionally to the north when the solar flux is up above 220. When used to the south, these bands have more signal distortion (multipath) than 10 and 12. The exception occurs when the bands are just opening or closing into the night, particularly on 17 meters. They are best used in other directions when the MUF is just above them.

Twenty and 30 meters are now both daytime and nighttime DX bands. Twenty is the lowest band available to

JANUARY

WESTERN USA

GMT	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000
PST	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00
ASIA FAR EAST (N)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	20	17	17	30
EUROPE (NE)	30	30	30	17	15	15	15	15	15	17	30	30	30	30	30	30	30	30	30	30	30	30	30	30
S. AFRICA (E)	12	10	10	10	10	10	10	10	10	10	12	20	20	20	17	17	17	17	17	17	17	15	15	12
S. AMERICA (SE)	10	10	10	10	10	10	10	10	10	10	12	20	20	17	17	17	17	17	17	15	15	15	10	10
ANTARCTICA (S)	10	10	10	10	10	10	10	10	12	17	17	20	17	17	17	15	15	15	12	12	10	10	10	10
NEW ZEALAND (SW)	10	10	10	10	10	12	12	15	17	17	17	15	15	15	12	12	10	10	10	10	10	10	10	10
OCEANIA AUSTRALIA (W)	10	10	10	12	12	15	15	15	20	20	20	17	17	17	17	17	17	15	15	15	10	10	10	10
JAPAN (NW)	12	12	15	17	30	30	30	30	30	30	30	30	30	30	30	30	30	30	20	20	17	15	12	12

MID USA

MST	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00
ASIA FAR EAST (N)	30	30	30	30	30	30	30	30	20	20	30	30	30	30	30	30	30	30	30	20	17	17	30	30
EUROPE (NE)	30	30	30	17	17	15	15	15	15	15	17	20	30	30	30	30	30	30	30	30	30	30	30	30
S. AFRICA (E)	12	10	10	10	10	10	10	10	10	10	10	12	20	20	20	17	17	17	17	17	17	17	15	15
S. AMERICA (SE)	10	10	10	10	10	10	10	10	10	10	12	20	20	17	17	17	17	17	17	15	15	15	15	12
ANTARCTICA (S)	10	10	10	10	10	10	10	10	12	12	17	17	17	17	17	17	15	15	15	12	12	10	10	10
NEW ZEALAND (SW)	10	10	10	10	10	10	12	12	15	15	20	17	17	17	17	15	15	12	12	10	10	10	10	10
OCEANIA AUSTRALIA (W)	10	10	10	10	12	12	15	15	15	15	20	20	20	17	17	17	17	17	15	15	15	10	10	10
JAPAN (NW)	12	12	15	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	20	20	17	15
CST	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00

EASTERN USA

EST	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00
ASIA FAR EAST (N)	30	30	30	30	30	30	30	30	30	20	20	17	30	30	30	30	30	30	30	30	30	30	30	30
EUROPE (NE)	30	30	30	30	17	17	15	15	15	15	15	15	17	20	30	30	30	30	30	30	30	30	30	30
S. AFRICA (E)	15	15	10	10	10	10	10	10	10	10	10	10	10	12	20	20	17	17	17	17	17	17	17	15
CARIBBEAN S. AMERICA (SE)	10	10	10	10	10	10	10	10	10	10	10	10	12	17	17	17	17	17	17	15	15	15	12	12
ANTARCTICA (S)	10	10	10	10	10	10	10	10	10	12	12	17	17	17	17	17	17	17	15	15	15	12	12	10
NEW ZEALAND (SW)	10	10	10	10	10	10	12	15	15	15	15	20	20	20	17	17	17	17	17	17	15	15	15	10
OCEANIA AUSTRALIA (W)	10	10	10	10	12	15	20	15	15	12	12	20	20	20	17	17	17	17	17	17	15	15	15	10
JAPAN (NW)	17	15	17	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	20	20

the south at night and generally to the north in the daytime. Thirty is the main band to the north both day and night, and is the highest band open much of the time at night to the northeast and northwest. These paths may be affected occasionally by 10 to 20 dB of extra absorption from the winter absorption anomaly.

Forty, 80, and 160 meters (the night only DX bands) exhibit short skip propagation during daylight hours, then lengthen skip at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn. These bands can be used to the south, but will exhibit increased signal distortion from multipath. The winter absorption anomaly also affects these bands greatly. hr

NEW PRODUCTS

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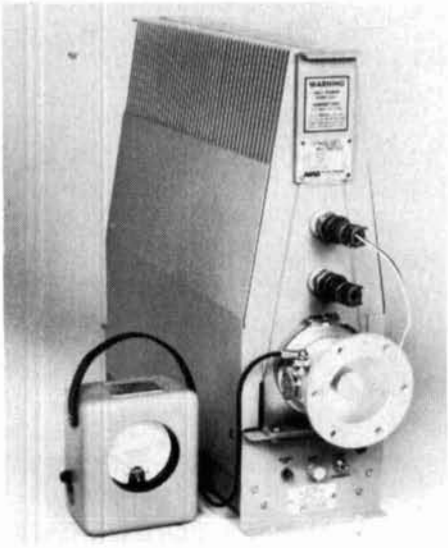
Bird Electronic Corporation has a complete line of high power TERMALINE® absorption wattmeters with power ratings from 1.5 to 10 kW and calibrated frequency ranges of 54 to 890 MHz.



The new Bird high power models feature full capacity loads with built-in wattmeters that use temperature-compensated elements for accuracy. The units are available with 3 1/8" EIA flanged and unflanged connectors requiring no extra wattmeter line sections. All power levels (except the 10-kW models) are available with both convection and blower forced air cooling; the 10-kW versions have forced air cooling only.

All models include a temperature sensitive thermoswitch for air overheating interlock protection. Forced air units include a thermoswitch that turns on the blower automatically when needed. A manual control is provided as well. All models have an accuracy of ±8 percent full scale.

For complete details contact Bird Electronic Corporation, 30303 Aurora Road, Solon, Ohio 44139. Phone: (216)248-1200.

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AEA PakMail Mailbox/Upgrade, New PK-232MBX

Advanced Electronics Applications announces an upgrade for the PK-232 multimode data controller which includes PakMail mailbox with third-party traffic. This upgrade, the PK-232MBX (MailBox), includes firmware and a daughter board. Customers who purchased the PK-232 on or after September 15, 1989 can obtain the update *free* for a $5 shipping and handling fee.

Available to current PK-232 owners, the firmware upgrade with PakMail and daughter board is $65; the firmware only, without PakMail and TDM, is $30.

The price of the PK-232MBX will remain at the current Amateur net of $349.95. To keep the price at this level, AEA will include an RS-232 interface cable with each unit instead of the more expensive "Y" cable. The "Y" cable can be purchased as an option for a suggested retail price of $40.

For details contact Advanced Electronic Applications, Inc., PO Box C-2160, Lynnwood, Washington 98036. To order the upgrade call AEA at (206)775-7373.

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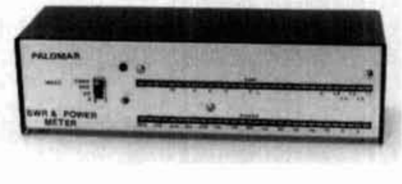
Palomar Engineers has announced a new deluxe SWR and power meter. Model M-835 uses Palomar's patented system that gives readings continuously even when you're operating CW or SSB. It has four power ranges: 2, 20, 200 and 2000 watts. Both power and SWR



(continued on page 90)

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(continued from page 85)

are displayed on 6" light bars with 3 percent resolution. It operates from 1.8 to 30 MHz and requires 12 volts DC power.

The meter sells for $189.95. An AC adapter is $15. A free catalog is available from Palomar Engineers, PO Box 455, Escondido, California 92025. Phone: (619)747-3343.

Circle #309 on Reader Service Card.

ICOM Announces New IC-2SAT, IC-3SAT, and IC-4SAT

ICOM introduces its new IC-2SAT 2-meter mini-handheld transceiver, IC-3SAT 220-MHz FM transceiver, and IC-4SAT 440-MHz mini-handheld transceiver.

The IC-2SAT has an easy access keyboard and built-in rechargeable batteries. Features include:

- 5 watt power output at 13.8 volts DC
- Built-in NiCd batteries
- 48 memory channels
- Quick tuning control
- DTMF code memory
- Built-in clock
- External DC power jack

The IC-2SAT also has auto power off timer function, power saver function, and set modes for numerous settings. Other features include: ICOM scan functions, priority watch, memory masking, memory transfer, and tone squelch. Battery packs and a battery case, chargers, headsets, and other options are also available. The suggested retail price is $439.

The IC-3SAT 220-MHz FM transceiver features:

- Built-in NiCd batteries
- Tuning control and keyboard
- 48 memory channels and one call channel
- DTMF code memory for auto dialing
- Scan functions
- Built-in clock
- External DC power jack with charging capability
- 5 watt output power at 13.7 volts DC.

IC-3SAT options include: the UT-49 DTMF decoder unit, UT-50 tone squelch unit, and the UT-51 programmable tone encoder unit. Suggested retail price is $449.

The IC-4SAT is a multifunctional handheld featuring:

- 5 watt power output at 13.8 volts DC
- Built-in clock
- Built-in batteries
- Keyboard and tuning control
- 48 memory channels
- DTMF code memory

Other features include: an external DC power jack, handy repeater functions, priority watch, and a variety of scan functions. Additional options include the UT-50 tone squelch unit, UT-49 DTMF decoder unit, and the UT-51 programmable tone encoder unit. Suggested retail price is $449.

For more information contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #306 on Reader Service Card.

Picture Perfect Video Digitizer

MFJ Enterprises, Inc. announces the new MFJ-1292 "Picture Perfect" Video Digitizer for IBM compatible computers.

The MFJ-1292 is an expansion card for IBM or compatible computers that lets you plug a camcorder or video camera into your computer and use it to capture digitized video snapshots on floppy or hard disks. Display these digitized video snapshots on your computer screen and use your drawing or paint program to add lettering, color, graphics, or other enhancements.

MFJ-1292 "Picture Perfect" comes with a complete software package plus utilities. One program lets you capture digitized snapshots in VGA, EGA, CGA, Hercules or Raw Data formats. You also get programs that let you view your pictures, capture graphics from your screen into the MFJ-1292 format, convert graphics files to MFJ-1292 format, and transmit your digitized snapshot files using your MFJ-1278, MFJ-1270B, MFJ-1274, or other packet radio controller. A contrast and brightness control unit is included for fine tuning.

The MFJ-1292 sells for $199.99. For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone: (601)323-5869, FAX: (601)323-6551, or order toll free by calling (800)647-1800.

Circle #305 on Reader Service Card.

Cushcraft R5 No-ground Radial Vertical

Cushcraft introduces its new R5 No-ground Radial Vertical for 10, 12, 15, 17, and 20 meters. The new R5 is the third generation of Cushcraft's half-wavelength no-ground radial vertical antenna.

The R5 has optimum current distribution for low angle radiation and DXing. The antenna is only 17 feet high. It can be used for portable or fixed operation and weighs just 9 pounds.

Automatic frequency selection of all five bands is accomplished with high Q traps and a broadband solid-state impedance matching network that accepts 50-ohm input through a PL259 connector.

The R5 is available through Amateur dealers worldwide. For details contact Cushcraft Corporation, PO Box 4680, 48 Perimeter Road, Manchester, New Hampshire 03108. Phone: (603)627-7877.

Circle #304 on Reader Service Card.

Update to Russian Phrases for Amateur Radio

W6HJK has compiled a new 20-page syllabus for *Russian Phrases for Amateur Radio*. A 90-minute audio cassette has also been added to help with pronunciation.

The booklet provides English words and phrases for QSOs, accompanied by the Russian translation and the English transliteration. Sections on the Russian alphabet, phonetics, CW characters, numerals, and given names are included, along with suggestions for addressing mail to the Soviet Union.

For more information write to: Russian Phrases For Amateur Radio, Len Traubman, W6HJK, 1448 Cedarwood Drive, San Mateo, California 94403.

Circle #303 on Reader Service Card.

ICOM Announces New IC-726 HF/50-MHz All Mode Transceiver

ICOM introduces the new IC-726. This small, lightweight HF transceiver allows band operation from 500 kHz to 30 MHz and 50 to 54 MHz. Features include:

- 100 watts power output
- Wide dynamic range
- 26 memory channels
- All mode operation
- Band stacking registers

The IC-726 also includes 10-Hz digit readout, a variety of scan functions, and CI-V system for computer control. Options include an HF automatic antenna tuner and CW narrow filter. The suggested retail price is $1299.

For more information contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #307 on Reader Service Card.

By Tom McMullen, W1SL

ELEMENTARY ELECTRONICS — EXPLORING RESISTANCE

Resistance in an electrical circuit decreases the flow of electrons. To be more specific, resistance regulates electron flow. Resistance is one of the most useful tools available for controlling how many electrons flow and where they go. Also, voltage can be developed across a resistance, and a series of resistances can serve as a voltage divider. The list of resistance applications is long; I'll examine a few of them.

Electron movement

In order to appreciate what's happening in a resistor, you need to take a look at some basic electron theory. You've been told that: (a) electrons orbit around a nucleus in an atom, (b) electrons are very difficult to dislodge from an orbit, and (c) when dislodged, electrons move at nearly the speed of light. Experience with a multitude of electronic devices tends to confirm this theory.

Some materials — like lead, copper, silver, and gold — conduct electricity very well. This indicates that their electrons are easily dislodged from orbit. Other substances — like carbon, steel, nickel, and chromium — conduct poorly. Still other materials — like glass, porcelain, and most plastics — don't allow any current flow to speak of. This means it's a pretty good general assumption that the softer metals (copper, silver) have cooperative electrons, the harder metals (steel, chromium, carbon) have electrons that tend to stay in orbit, and the really hard materials (glass, porcelain) have electrons that are almost impossible to dislodge. Plastics, although not physically hard, have a specialized molecular structure that makes them good insulators.

Moving the electrons

When you connect a source of power (like a battery) to a conductive circuit (a wire), the excess electrons available at the negative (−) terminal try to get to the other, or positive (+), terminal — which has a scarcity of electrons. Imagine that you can see the first atom in a piece of wire, with all its electrons spinning about the nucleus. Along comes an electron from the battery, pushing its way into the crowd. There's only room for a specific number of electrons in each atom (described in the atomic tables found in physics reference books), so in order to let this new electron in, one must be bumped out of place. Because the electrons in the outer orbit have less physical attraction to the nucleus than those in the inner orbits, one of the electrons in the outer orbit is dislodged. It's interesting to note that the good conductors (copper, silver, gold) all have just one electron in their outermost orbit (or shell). This electron is called a "free" electron because it's more easily dislodged from orbit than the electrons in the inner shells. The electrons of the inner shells are called "bound" electrons and are extremely difficult to dislodge.

Because an electron without a home won't survive very long, the bumped electron immediately dashes over to the atom next door and joins it. This dislodges an electron from that atom, which moves to another atom, and so on, down the length of the wire (see **Figure 1**). Eventually the last atom in the wire gets bumped, and the most recently dislodged electron finds a home in the (+) terminal of the battery.

This process continues until the imbalance of electrons in the battery is neutralized and no more current (electrons) will flow. At this point, the battery is "dead." (Other power sources, like rectifiers, also provide excess electrons and accept electrons from the circuit, but it's easier to work with a simple cell or battery when exploring basic theory.)

Even though this representation deals with one atom at a time, remember that there are millions of atoms in a piece of wire, and that this action is taking place in all of them at the same time — causing a great number of electrons to move at once. In fact, the description of a Coulomb (C) involves the number of electrons that pass a given point in one second:

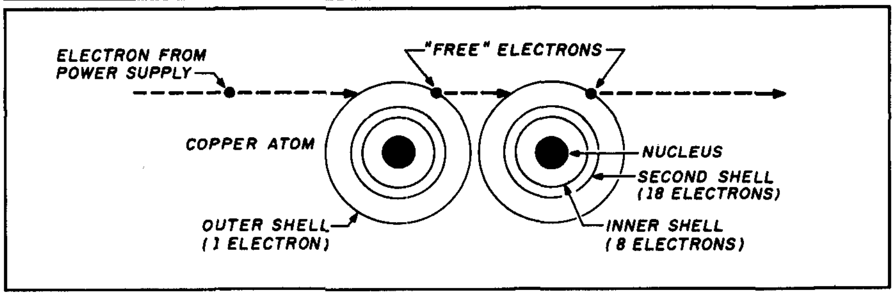
$1C = 6.28 \times 10^{18}$ electrons per second

This also is a current of one ampere.

Controlling the flow

To put the electron flow to use, you must be able to control the amount of current flowing in a circuit. If all the electrons available at the negative terminal of the supply were to rush

FIGURE 1



In this simplified representation of copper atoms, an electron from an external power source joins the outer orbit (shell) of an atom, dislodging its "free" electron. That electron migrates to the next atom, and so on. This action is repeated for the length of the wire as long as the power source povides extra electrons.

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SWAN 500 CX/117XC TRANSCEIVER/PS $250. Kenwood TS-820S Transceiver $450. David Gater, WD4MWR, 1000 Tarpon Ct, Nokomis, FL 34275. (813) 485-8937.

10 Mtr FM Hy-Gain CB Board with instructions $9.95. FM DET Kit $7.00. 40 channel switch $5.00. Crystal $5.00. SQ/VOL pots $2.00/pair. All for $24.95 plus $2.00 s/h. MORNING DISTRIBUTORS, PO Box 717, Hialeah, FL 33011. (305) 884-8686.

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WANTED: Pre-1942 TRANSMITTER. Any condition or part considered. Also Hammarlund SuperPro SP-10 thru SP-220. Bob Mattson, KC2LK, 10 Janewood, Highland, NY 12528. (914) 691-6247.

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HAM SOFTWARE IBM/Compatibles 10 disks $26.95. MC/VISA/Discover. N5ABV EAPCO/H, Keller, TX 76248-0014. (817) 498-4242. 1-800-869-7208.

CHASSIS AND CABINET KITS. SASE. K3IWK, 5220 Harmony Grove Rd, Dover, PA 17315.

PK232 QUICK REFERENCE. All commands through the October 1989 firmware revision functionally grouped. Send $4.95 to Bryan R. Leipper, K1CD, 714 Terra Court, Reno, NV 89506.

POLICE/FIREFIGHTER HAMS. Please send your call, name, address, rank, department name for inclusion in special roster, available early 1990. Capt. Bob Blakeslee, N2IHQ, 1-1/2 Macomber Avenue, Binghamton, NY 13901.

WANTED: Technical information on Rubidium Frequency Standards made by Collins/GenRad (O-1622/AFS-81). Also interested in spares and parts for two units. Kirk Bailey, N7CCB, PO Box 1702, Corvallis, OR 97339. (503) 753-9051.

RTTY JOURNAL published 10 times per year for those interested in digital communications. Read about RTTY, AMTOR, MSO'S, PACKET, RTTY DX and Contesting. Plus technical articles concerning the digital modes. $12.50 per year (foreign higher). RTTY JOURNAL, 9085 La Casita Ave, Fountain Valley, CA 92708.

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IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instand mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 144 N. Putt Corners Rd, New Paltz, NY 12561.

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BEAT THE COLD! Melbourne, FL QTH: 4:2:2 (3100 sq/ft) house, 1.6+ acres, 220V wired shack with coax races built in, RHON/25 pad, workshop, pool, sprinkler system, in the country no restrictions, many tall pines and oaks, easy commute to Cape Canaveral, close to fishing/beaches/shopping, SAE for details and photos, $209,000. N0DH/4.

DIGITAL AUTOMATIC DISPLAYS. Any Radio. Be specific. Large 45 cent SASE. GRAND SYSTEMS, POB 2171, Blaine, WA 98230.

AVANTEK ATF10135, $12.00, MMIC's, P.C. board, SASE: WA3IAC, 7148 Montague St, Philadelphia, PA 19135.

"HAMLOG" COMPUTER PROGRAM. Full features, 17 modules. Auto-logs, 7-band WAS/DXCC. Apple $19.95. IBM, CP/M, KAYPRO, Tandy, C128 $24.95. HR-KA1AWH, POB 2015, Peabody, MA 01960.

TEST EQUIPMENT—reconditioned (guaranteed), terrific prices, NBS Calibration available. VISA, M/C, Amex, COD. ELECTRONIC SURPLUS, INC, 4350 Town Plaza, Suite 203, Houston, TX 77045. (713) 728-9718.

WANTED: Dentron CM-U. N0BUC, 118 Elizabeth Drive, Aberdeen, SD 57401.

YAGI BUILDERS. 6061-T6 tube traps. Good for 1500 PEP. SASE for details. No collect calls. BROWN ENGINEERING INC, 5501 SW 25th Court, Hollywood, FL 33023. (305) 989-4658.

FREE Ham Gospel Tracts, SASE, Steve Forst, N3FTT, 5133 Gramercy, Clifton Heights, PA 19018.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people nationwide. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. If you call or write today it's not too late to get a 1989 tax deduction. It's easier, faster, and usually more profitable to donate than to sell. Most important, you're helping. Write us at: PO Box 1052, New York, NY 10002. Round the clock hotline: (516) 674-4072.

450 MHz SPECTRUM ANALYZER. Adapted from Nov 85 QST article by Al Helfrick, K2BLA. Features: Three digit LED center frequency digital readout. 12 position calibrated Scan Width, 1 kHz to 50 MHz, switchable bandwidth; Wide ⁵ 300 kHz, Narrow ⁵ 10 kHz. Use your low frequency scope for the display portion. Switchable 10 kHz video filter. Variable IF attenuator, LOG output calibrated in 10 db steps. For complete kit, order #450-KIT $459.95 plus $4.50 s/h. For assembled and tested unit, order 450-AST, $799.95 plus $6.50 s/h. Calif residents add 6% sales tax. Foreign orders add 15% for shipping. A & A Engineering, 2521 W. LaPalma, #K, Anaheim, CA 92801. (714) 952-2114.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

FOR SALE: Kenwood R-2000 SW receiver, $400. Ranger AR-3500 10 meter, 100W mobile XCVR, $300. Both excellent condition and appearance. Matt, WA1HRE, (203) 693-0468/693-6596. Leave message.

1989 CALLBOOK - US $14, foreign $17. Only have one copy each, include SASE in case already sold. Nate Williams, W9GXR, 6915 Prairie Drive, Middleton, WI 53562.

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COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

INDIANA: December 31. South Bend. Hamfest Swap & Shop, December 31, last day of 1989 BEFORE New Year's Day at CENTURY CENTER downtown on U.S. 33 ONEWAY North between Trustcorp Bank Building and river. Four lane highways to door from all directions. Tables: $5/5 ft. Round; $15/8x2.5 rectangular; $20/8 ft. Wall locations. Over half acre on carpeted floor. Electric NO charge— Bring long cord. Talk in 52, 39, 09, 94, 145.29. Call 219-233-5307, write Wayne Werts, K9IXU, 1889 Riverside Drive, South Bend, IN 46616.

FLORIDA: January 20. The 10th annual Citrus County Hamfest sponsored by the Sky High ARC, National Guard Armory, Crystal River. Open to public 9 AM. Exhibitors 7 AM. Tickets $4/advance by Dec. 20 and $5 at door. XYL's free with OM. Contact Del Slocum (904) 726-0725 or write SHARC Hamfest, 3101 E. Oakton, Hernando, FL 32642 for tickets, tables, flea market space or info.

NEW YORK: January 21. Electronics Fair and Giant Flea Market sponsored by the Metro 70cm Network, Lincoln High School, Kneeland Avenue off Yonkers Avenue, Yonkers. Setup 8 AM. Public 9 AM. Rain or shine. Admission $3. Tables $12. Contact Otto Supliski, WB2SLQ, 53 Hayward St, Yonkers, NY 10704. (914) 969-1053.

MISSOURI: January 27. The St. Louis Repeater Club's "Winterfest", Stratford House, I-44 just west of I-270. 9 AM to 3 PM. Sellers admitted 7 AM. Features VE exams, indoor flea market and refreshments. Admission $1.00 per person. $5/selling space. For reservations and information call WA0FQK. (314) 351-7732.

YOUTH LINK NET. Open to all Hams under age 18. Saturdays at 2000 UTC, 28.425 MHz. For more information contact Net Control, George Manning, WB5NMH, 602 Glendale St, Burkburnett, TX 76354.

FREE 1989-90 Florida two meter repeater directories are currently being distributed by the Hernando County Amateur Radio Assn. of Brooksville, FL. Ask for one at any official Florida Welcome Center or SASE to Repeater Directory, Hernando County ARA, POB 1721, Brooksville, FL 34605-1721.

LAUREL ARC monthly (except December) Amateur exam sessions for all license classes. No fee is charged. Pre-registration is required. Call (301) 725-1212, Maryland Radio Center, 8576 Laureldale Drive, Laurel, MD 20707.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

through the circuit immediately, you would quickly have a dead battery, and the wire would probably vaporize in a bright flash (more on this later).

Reducing the size of the wire is one method of controlling current flow, but this really isn't practical. A piece of wire the size of a hair still contains several million atoms in a cross section. By selecting your materials carefully, you can build a current-restricting device. Interestingly enough, it's called a resistor because it resists the flow of electrons.

One of the most common resistor materials is carbon — a very hard substance. By carefully controlling the mixture of carbon with other materials, and the size and shape of these materials as they are combined in the resistor, you can tailor resistance to suit a particular need. Smaller numbers of electrons moving through a circuit will be admitted into a carbon-composition structure, allowing fewer electrons to flow at any given time.

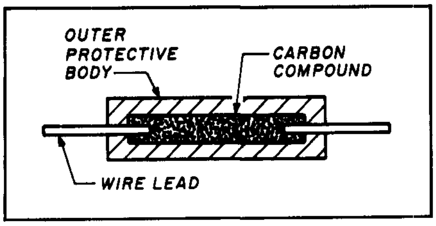
Early resistors were simple rods made of carbon and some type of cementing material. Some were 1/4 inch in diameter and 1 or 2 inches long; some were the size of the lead in a pencil and 1/2 inch or less in length. These carbon rods had wires wrapped around their ends and were glued in place with conductive paste. Later models had a similar rod structure, but used a crimped brass or copper cap on the end; wires were either welded or soldered to the caps. Modern day resistors come in a variety of sizes — some are still 1/4 inch or more in diameter, while others are tiny chips less than 0.1 inch square. There are also variations in the materials used. Carbon-composition resistors are still the most widely used type (see **Figure 2**). There are also metal film resistors made of a very thin metallic film deposited on a ceramic or glass base with attached leads. Some resistors are made out of ceramic tube covered completely with resistive material, with portions of the material etched away in a spiral path to obtain the desired resistance.

Using resistance

Resistance has so many uses that I can't begin to discuss them all here. Let's look at some of the most common ones.

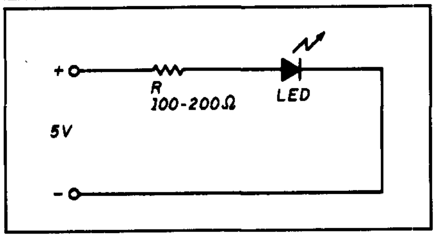
Current limiting. A resistor placed in an electrical path limits the number of

FIGURE 2



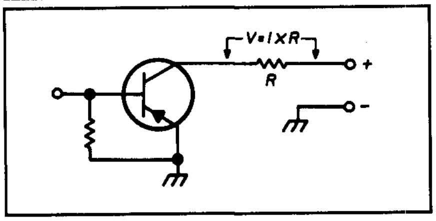
A cut-away view of a carbon-composition resistor. The composition determines the resistance and the physical size determines the heat (power) dissipation capability of the resistor.

FIGURE 3



A resistor in series with an LED serves to limit the current flow through the LED, thus preventing the diode from burning out.

FIGURE 4



A resistor in series with the collector of a transistor limits current flow. At the same time, it provides a voltage change that varies with the drive signal applied to the transistor base.

electrons (current) that can flow, thus protecting the device in the circuit from being overheated by excess current.

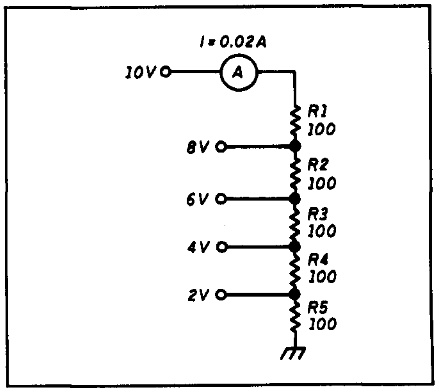
A good example of this situation is the resistor that's almost always used in series with an LED indicator (**Figure 3**). The LED, being a diode, will conduct at approximately 0.45 volts. But most of the circuits using LEDS have a 5-volt supply. The series resistor limits the current that can flow in the diode, and also drops the supply voltage to the level the diode needs to conduct and illuminate. Transistors and vacuum tubes require a similar protection scheme to prevent the burnout that results from too much current flow.

Current-restricting resistors can be used in another way. As shown in **Figure 4**, the resistor between the supply voltage and the transistor collector will limit the current flow and, in doing so, will cause a voltage difference between one end and the other. Because voltage is related to current flow and resistance (Voltage = Current × Resistance), you can change the voltage across the resistor by changing the current flow. This is how a "signal" is developed. Changing the driving signal to the base causes the transistor to conduct more or less, changing the current flow and, in turn, creating more or less voltage across the resistor. This voltage change is thus a larger (amplified) replica of the input signal to the transistor.

Voltage divider. Sometimes you need a voltage less than that available from the supply. Conveniently, several resistors can be placed in series to provide a selection of voltages at each junction (see **Figure 5**). Note that the total current flow is determined by the total resistance in the circuit (R1 + R2 + R3 + R4, and so on), while the voltage across each resistor is determined by the current flow and the resistance of that individual resistor (I × R). Also note that the sum of all the voltages must equal the supply voltage — nothing is lost or unaccounted for.

Current divider. What can you do when the available resistors can't handle the current flow? Place two or more resistors in parallel so the current flow is divided among them (**Figure 6**). For instance, say you have a circuit that must dissipate 2 watts of power (Watts = Current × Voltage), but you have

FIGURE 5



Several resistors in series provide a voltage divider. Note that the voltages shown are for the resistor only. Any load connected to a voltage point will use extra current, which will decrease the voltage at that point.

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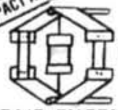

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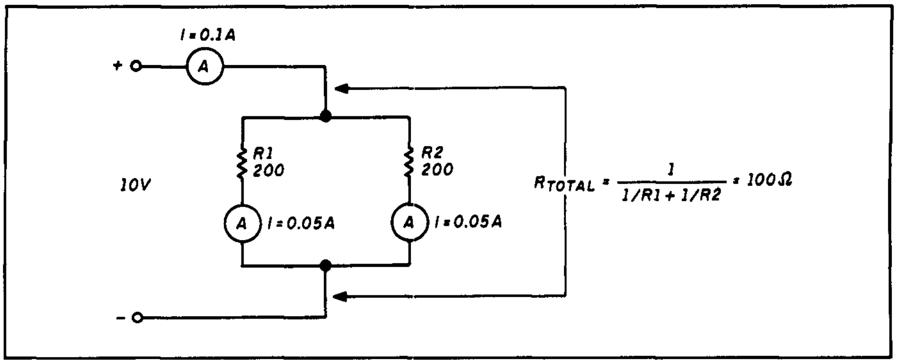
only 1-watt resistors. Use two resistors of equal value in parallel. Because half the current is flowing in each resistor, each is now dissipating (passing current without overheating) 1 watt. However, in order to have the same voltage across the pair, you must use resistance values that are twice that of one resistor. This is because resistors in parallel decrease the effective resistance according to the formula:

R(total) = 1/((1/R1)+(1/R2)+(1/R...)).

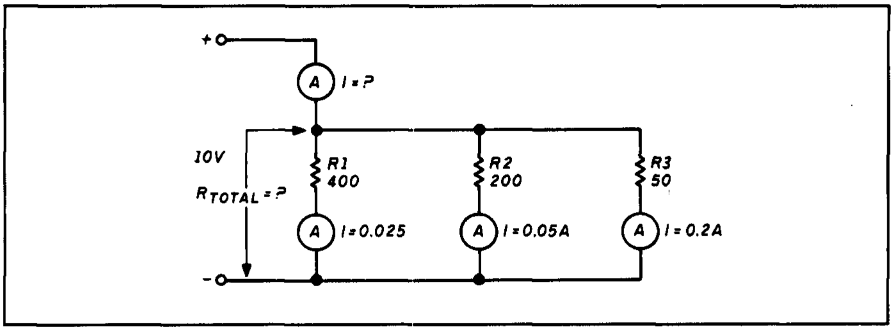
There are a couple of interesting rules involved here. First, the voltage is the same across all resistors. Second, if the resistors aren't the same value, the resistor with the lowest value will carry the most current (see **Figure 7**). It's also interesting to note that the total current in the circuit is the sum of all the currents in the branches: I(total) = I(R1) + I(R2) + I(R...).

FIGURE 6



Resistors in parallel allow the current flow to be divided between them.

FIGURE 7

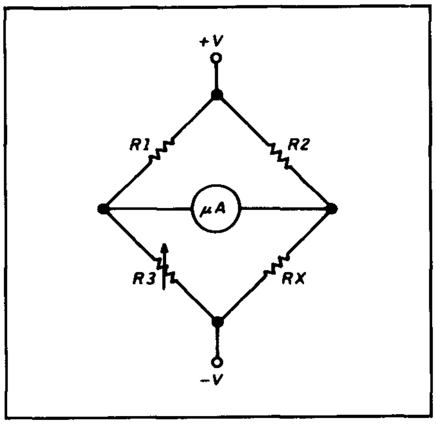


Unequal resistors in parallel carry unequal currents, but the total current is the sum of all the currents. Add the totals of R1, R2, and R3 to find the I(total).

The current-divider principle can provide a very accurate means of finding an unknown resistance. This is called a "bridge" circuit or sometimes a "Wheatstone" bridge (see **Figure 8**).

The circuit is made up of four resistors: R1 and R2, which are of the same value; R3, which is variable with a calibrated dial; and Rx, which is an unknown value. If the resistance values are the same on both sides of the circuit (R1 + R3 = R2 + Rx), then the current flow is equal for both sides. A very sensitive meter (usually a microammeter) is connected across the bridge; it won't show any reading when the two sides are balanced. If Rx is not equal to R3, then the current flow is not equal in both sides of the bridge, and the meter will deflect toward either R3 or Rx — whichever has the lowest resistance. Determine the value of Rx by changing the value of R3 until the meter shows a zero (center) reading, then reading the value of R3 from the meter's dial. This principle is used in electronic circuits from detectors to mixers to SSB generators, along with S-meter circuits, and many more. Variations of this circuit work with measuring inductance, capacitance, and impedance, and with AC or DC currents.

FIGURE 8



A "bridge" circuit is useful for many things, including finding the precise value of an unknown resistor (Rx). See text for a description of how the circuit works.

Hidden resistance

Sometimes resistance isn't obvious. This hidden resistance may be either a help or a hindrance. Another name for hidden resistance is internal resistance. An example of "good" internal resistance is illustrated in the battery and wire experiment in last month's column. Fortunately, the battery has an internal resistance that's large enough to keep infinite current from flowing. Otherwise, the wire would have vaporized — along with the compass, your fingers, and perhaps a good chunk of the workbench. This battery internal resistance results because the chemical (electrolyte) in the battery is able to "liberate" only a limited number of free electrons and make them available to external circuitry. The down side is that this same resistance limits the available current. This means that when your circuit needs more current, you have to use a physically larger battery.

Internal resistance makes things complex in ordinary meters — like voltmeters, ammeters, and ohmmeters. These are all basically current-measuring devices, with resistance networks and calibrated scales that allow you to interpret their reading in volts, amperes, or ohms. The most common type of meter uses a very small coil of fine wire placed between the poles of a magnet. When current flows, a magnetic field is generated which reacts with the magnet. The resulting "push" between the two magnetic fields causes the coil and its attached pointer to move to the location where the force of the field is balanced with that of a small spring attached to the pointer. This small wire has resistance which limits the current flow. This is good because it helps prevent the meter's coil from burning out. However, this resistance must be taken into account when the meter is manufactured and calibrated, and adjustments must be made in the resistor network to obtain accuracy. You, too, will have to account for this internal resistance if you ever try to recalibrate the scale of a meter by placing it in series with another well-calibrated meter. All electronic devices have internal resistance, which often provides protection against excess current flow. In most cases, this resistance is also necessary to make the device work. Just remember that it exists and allow for it in your circuitry whenever precision is vital.

In summary, resistors play an essential part in the world of electronics and can provide material for some fascinating experiments in how electrons behave. Pick up a grab bag of resistors at your next hamfest and try some circuits — series, parallel, series and parallel, and bridge — to see what happens when you use various values and combinations. hr

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