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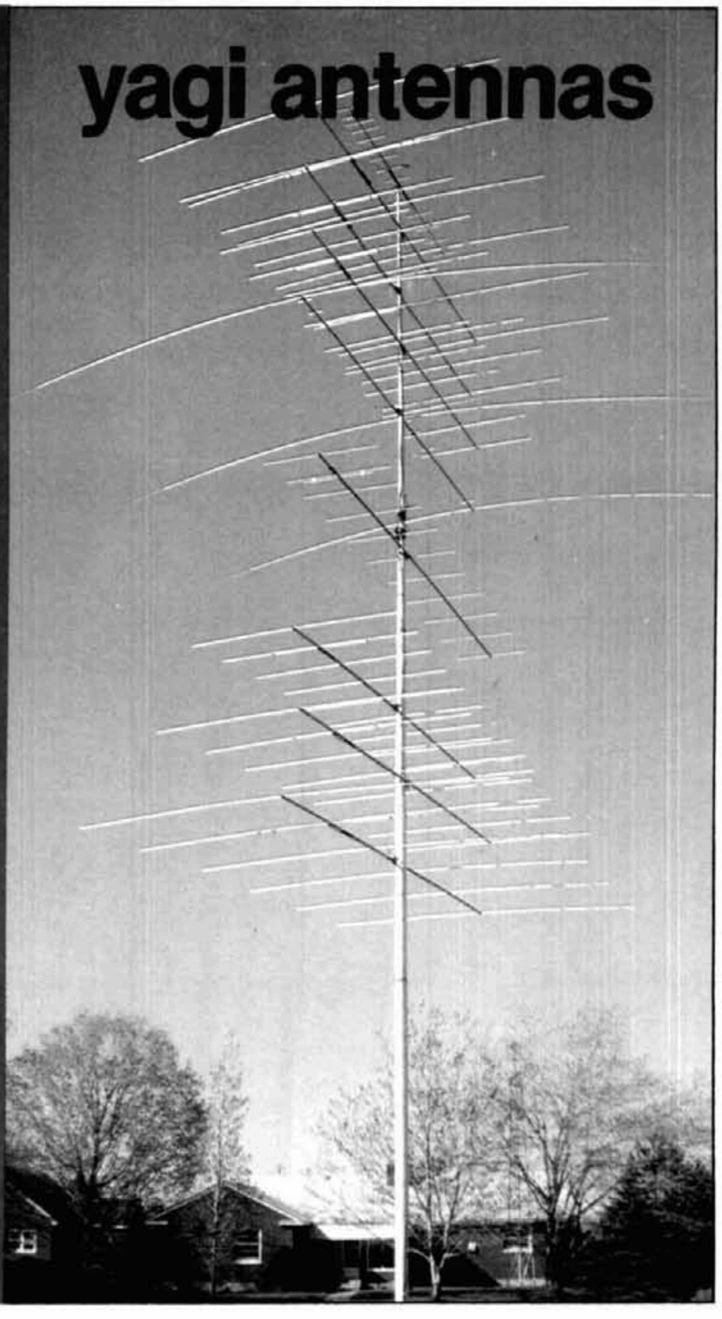
ham radio

magazine



AUGUST 1979

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The 1KD-5 is a 1200 watt PEP input (700 watt PEP nominal output) RF linear amplifier, covering the 80, 40, 20 and 15 meter amateur bands. (10 meters on units shipped outside the U.S.)

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Input Circuits: Cathode Pi input matching circuits for maximum drive and linearity.

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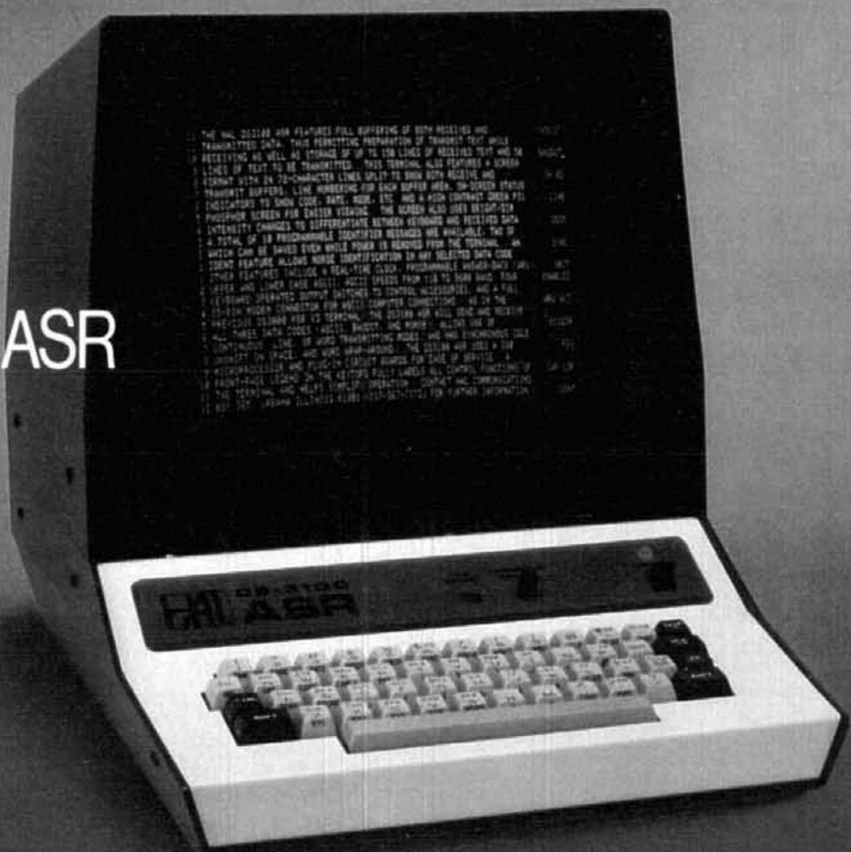

More Details? CHECK — OFF Page 110

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contents

a second look

by Jim Fisk

Many of the problems that Amateur Radio has had to face over the past few years — and will continue to face in the future — can be traced directly to one cause: the demands of an increasing number of Radio Amateurs for finite space in the radio spectrum. More and more stations have been squeezed into the same bands, creating a congested mess for the Amateur operator, particularly during peak occupancy periods on weekends and holidays. In many cases the effects of crowded band conditions are aggravated by poorly designed ham equipment: transmitters which contribute broadband noise and splatter, and receivers which cannot cope with nearby strong signals. The technology to solve these problems is available, but very seldom is it put to work; and until Radio Amateurs demand improved equipment performance it probably won't be.

Herein lies the problem. How do you press for cleaner emissions from transmitters or push for receivers that will handle strong signals without overloading when there are no performance standards? And not only are there no performance standards, in general the published equipment specifications have not kept pace with technology. Gone are the days when receiver sensitivity and selectivity were the only things you looked for in a communications receiver; although today's receivers must contend with an abundance of closely-spaced strong signals, receiver "specmanship" has changed little since the days of vacuum tubes.

A few of the manufacturers have begun to provide data on dynamic range, intercept point, and blocking, but you cannot compare equipment from different manufacturers because they don't use the same standards or test procedures. And since there are no standards, receivers with identical operating specifications often have vastly different on-the-air performance. Intercept point is currently in vogue, and as one of my correspondents recently pointed out, "everyone suddenly has a '+20 dBm' receiver — whether it costs \$250 or \$5000!" This points up the need for standardized test procedures. Specifications for intercept point and dynamic range are meaningless unless the input signal separation is specified, and that crucial information is usually not available to the consumer. If it's not, *caveat emptor*!

The preponderance of "+20 dBm" receivers reminds me of the time a few years ago when every ssb transmitter on the market was advertised with third-order IMD down "more than 30 dB." It didn't matter whether the final was built with rf power tubes, TV sweep tubes, or transistors — the magic number for third-order IMD was always −30 dB. Then W6SAI and a few others pointed out that most of the TV sweep tubes couldn't do better than −22 dB in rf linear service, and some were as bad as −18 dB! That spelled the beginning of the end for TV sweep tubes in amateur transmitters; as new ssb transmitters were introduced, more and more were designed around tubes and transistors which were intended for linear rf service.

Receiver intercept point and transmitter IMD are only two of the problem areas. How about those built-in speech "processors" that often add so much distortion they make large sections of the band virtually useless? (And as an aside, what are we to do about the operators who refuse to turn them off even when they're told how bad they sound?) Established performance standards won't improve operating habits, but they would make it a lot easier to purchase equipment that meets your needs. And in the long run, a realistic set of standards will inevitably result in better Amateur equipment for all of us.

Jim Fisk, W1HR
editor-in-chief

ICOM squeezes optimum performance into even the tightest spaces.

Detachable control head of the **IC-280**, remotely mountable 2 meter mobile transceiver

ICOM Performance comes in full feature, multi-mode fixed station transceivers and also in the diminutive **IC-280**, designed to fit the most cramped modern vehicle. This heavily endowed performer is microprocessor controlled with the most sophisticated program of any of the ICOM radios. Small size means big performance with ICOM.

IC-280 control head mounted in Datsun 280Z

Touchtone capacity for the IC-280 is provided by the optional TT1215 which plugs into the 280's mic socket with no modification to mic or radio (no battery).

A 25 watt output module is available on special order from ICOM East or ICOM West. (Optional at extra cost; installation extra.)

The totally detachable small front section of the **IC-280** houses the microprocessor for frequency control and memory. The **IC-280's** control head can store three frequencies of your choice which are selected by a four position front panel switch; and these frequencies are retained for as long as power is applied to the radio's memory pin . . . even when the front panel switch is turned off or power from the ignition is interrupted. And when power is completely removed from the **IC-280** the ±600 KHz splits are still maintained!

Frequency coverage of the **IC-280** is in excess of the 2 meter band and its performance can easily accommodate the 144-145 (20 KHz/step) band plan. The main section uses the latest innovations in large signal handling FET front ends to provide excellent intermodulation character and good sensitivity at the same time. The IF filters are crystal monolithics in the first IF and ceramic in the second, providing narrow band capacity for today and tomorrow's crowded conditions. The **IC-280** will be providing ICOM Performance for years to come.

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All ICOM radios significantly exceed FCC regulations limiting spurious emissions.

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comments

noise-figure measurements

Dear HR:

Bob Stein's article on noise-figure measurement in the August 1978, issue was very good but I disagree with his statement that, for equal signal and image channel gains, the error will be 3 dB. The correct expression is:

$$F_{double} = \tfrac{1}{2}\,(F_{single} + 1)$$

and can be found in *Radio Astronomy* by John Kraus. In decibels the proper difference is:

F_{double}	F_{single}
10 dB	12.8 dB
6 dB	8.4 dB
2 dB	3.4 dB

Stein's comment about putting a filter at the input of a preamp and not putting one after the preamp is very important. If one were to build a receiver with no filter after the preamp, the noise-figure meter would be correct for the entire receiver and best performance would not be achieved.

Charles H. Solie, WB5LHV
Houston, Texas

WB5LHV's letter referenced a book with which I was not familiar, and would have been welcome if for no other reason than bringing it to my attention. As it is, he certainly posed an argument which caused me a considerable amount of thought and research. To start with, the authorities for my discussion of image-response error in my article on automatic noise-figure measurements are as follows:

1. Albert Van der Ziel, *Noise: Sources, Characterization, Measurement*, pages 154-156.

2. George E. Valley, Jr. and Henry Wallman, *Vacuum Tube Amplifiers*, page 720.

3. Merrill I. Skolnik, *Introduction to Radar Systems*, page 365.

4. W.W. Mumford and Elmer H. Scheibe, *Noise Performance Factors in Communications Systems*, pages 45 and 61.

***Eq. 13** in my article appears in slightly different, but equivalent, form in reference 2, above. To clarify the situation brought up by WB5LHV, it is necessary to start with the Friis/IEEE expression of noise factor. By definition, it includes only that noise from the input termination which appears at the output via the principle-frequency transformation of a heterodyne system, and does not include spurious contributions from an image-frequency transformation. The single-sideband (channel) noise factor, F, is defined by the formula*

$$F = \frac{N_{to}}{GkT_oB} \qquad (1)$$

where N_{to} *is the total noise power output from the receiver*
G *is the gain of the receiver*
k *is Boltzmann's constant,* 1.38×10^{-23} *joule/°K*
T_o *is the standard reference temperature, 290°K*
B *is the receiver bandwidth in Hz*

Since the noise output of the receiver is the sum of (a) the internally generated noise plus (b) the termination noise times the receiver gain,

$$F = \frac{kT_rB + GkT_oB}{GkT_oB} \qquad (2)$$

where T_r *is the receiver noise temperature (often shown as* GT_e*, where* T_e *is the effective noise input temperature).*

Consider now a single-channel receiving system in which the receiver has no image rejection (equal gains in the signal and image channels). If a narrow-band noise source were connected to the receiver input, the preceding expressions of noise factors would apply. However, if a broadband noise source is used, there will be noise applied to both channels, so that the double-sideband noise factor, F'*, will be given by the relation*

$$F' = \frac{N_{to}}{GkT_o(2B)} = F2 \qquad (3)$$

or

$$F = 2F' \qquad (4)$$

On the other hand, if a double-channel radio astronomy receiver is under consideration, there is signal information in both channels and the receiver noise contribution is divided equally between channels. Therefore, the noise factor of a double-channel receiver in this application is expressed as

$$F' = \frac{\tfrac{1}{2}(kT_rB) + GkT_oB}{GkT_oB} \qquad (5)$$

$$= \frac{kT_rB + 2GkT_oB}{2GkT_oB} \qquad (6)$$

$$= \frac{kT_rB + GkT_oB}{2GkT_oB} + \frac{GkT_oB}{2GkT_oB} \qquad (7)$$

*Then from **eq. 2**,*

$$F' = \tfrac{1}{2}F + \tfrac{1}{2} = \tfrac{1}{2}(F+1) \qquad (8)$$

Thus, both relationships for F' *are true, but are defined differently, depending on the application. **Eq. 3** is applicable to a single-channel receiver which has no image rejection, because the receiver noise contribution will degrade only the signal channel, there being no signal information in the image channel. In the double-channel radio astronomy receiver, there is signal information in both channels, so that **eq. 8** defines the relationship between the single- and double-sideband noise factors.*

Since in radio communications we are concerned only with single-channel receivers, the discussion in my article is correct.

Robert S. Stein, W6NBI

KENWOOD

TECH TALK 6A79

DFC

(DIGITAL FREQUENCY CONTROL)

in the TS-180S HF Transceiver features four memories with digital up/down paddle-switch tuning.

TS-180S

How will four memories improve operating efficiency on the HF ham bands?

The TS-180S with DFC features four memories, each one digitally tunable up and down in minute 20-Hz steps by means of dual-speed paddle switches. It's like having four remote VFO's in addition to the built-in VFO.

The serious DX chaser, for example, can program various DX pileups into the four memories, and periodically check those frequencies to determine if the DX station is listening for calls from his call area. The memories are usable for transmit, receive, or transceive operation. Therefore, a memory can be used on transmit and the VFO on receive, or vice versa, either of which can be tuned up or down in frequency, for working DX stations who are listening for calls several kilohertz away from their transmitting frequency. With the push of a button, the operator can listen on his transmit frequency, which he can tune, and be ready for a perfectly timed call to the DX station, immediately after another station finishes working the DX station.

The memories are also extremely convenient for contest operating. Pileups can be stored and periodically checked for improved propagation or other conditions for "getting through". A "CQ CONTEST" frequency could also be stored.

The memories are also very useful for storing net and schedule frequencies.

What frequencies are displayed on the digital readout during memory operation?

The digital display shows the memory frequency being used, whether in receive or transmit mode. It also shows the actual VFO frequency when the VFO is activated, or the fixed-channel frequency, or the remote VFO frequency (if the optional VFO-180 is used). Separate RIT (receiver incremental tuning) controls are provided for VFO and memory/fixed-channel operation, and the RIT frequencies, when RIT is utilized, are displayed.

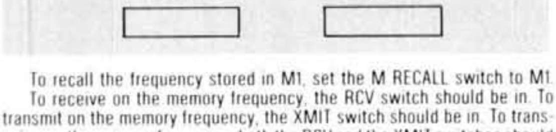
When a frequency is stored in the "M1" memory, the digital display can be switched to indicate the stored frequency and the difference between the stored and VFO frequencies (with signs to show VFO above or below the stored frequency). This function is handy for temporarily moving off of a net frequency with another station by a specified number of kilohertz, and, after completing the conversation, moving back immediately to the net frequency stored in the "M1" memory.

What are the differences between the four memories in the TS-180S with DFC?

The M1 memory is intended for fast or temporary memory operation such as moving off of a net frequency. The $\boxed{M}$, M', and M" memories are used for relatively longer storage applications, such as for net frequencies, schedules, etc. Any of the memories can be used for storing DX or contest "pileup" frequencies or transmit or receive frequencies when working "split frequency" operation with a DX station.

How are frequencies stored in memory, and how are they recalled?

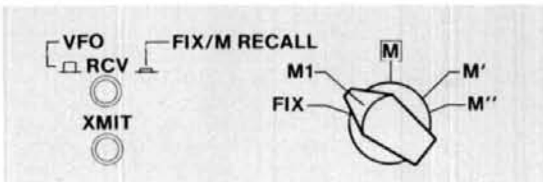
The DFC memories can store frequencies from the TS-180S internal VFO, the fixed channel, and the optional remote VFO. The RIT frequency can also be stored, and frequencies can be shifted from one memory to another. To store an operating frequency in M1, simply set the main tuning to the desired frequency and push the DSP/M1 switch; a "beep" will be heard.



To recall the frequency stored in M1, set the M RECALL switch to M1.

To receive on the memory frequency, the RCV switch should be in. To transmit on the memory frequency, the XMIT switch should be in. To transceive on the memory frequency, both the RCV and the XMIT switches should be in.

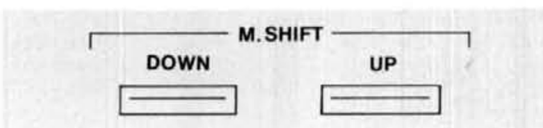
To store frequencies in the other three memories, the main tuning is set to the desired frequency (which we will call frequency A for this explanation) and the $\boxed{M}$ switch is pushed in (a "beep" will be heard). To store frequency B, push the $\boxed{M}$ switch to release it, and then push again ("beep"). Now frequency B will be stored in the $\boxed{M}$ memory and frequency A will shift to the M' memory. To store frequency C, push the $\boxed{M}$ switch to release it, and then push again ("beep"). Frequency C is now stored in $\boxed{M}$, frequency B in M', and frequency A in M".



Storing another frequency in $\boxed{M}$ will shift the memories again, and frequency A will be lost, unless it is recalled and stored in $\boxed{M}$ again before another frequency is stored. Therefore, as stations in memory are worked or, for some other reason, a memory frequency is no longer needed, it can be erased automatically as it shifts out of M" where another frequency is stored in $\boxed{M}$. This method of moving memory frequencies "up the stack" retains the chronological order of entry for easy operation, which is particularly important in a contest. The operator, then, does not need to remember which memory in which he stored a particular frequency. To recall any of the stored frequencies, simply set the M RECALL switch to the appropriate position.

How can the memories be tuned up or down in frequency?

On the front panel of the TS-180S are a pair of paddle switches for digitally tuning any of the memories up or down in frequency.



A memory frequency can be stepped up or down 20 Hz at a time. If the UP or DOWN switch is kept depressed, the frequency changes continuously in 20-Hz steps. The rate of change can be increased by depressing the opposite switch while the appropriate switch remains depressed.

The original frequency can be recalled after it has been digitally tuned by the UP or DOWN switch, by moving the M RECALL switch to any position other than the one on which it is memorized, and then resetting it to the original memory position.

The memory frequency, after it is digitally tuned, can be stored by pushing the DSP/M1 or the $\boxed{M}$ switch.

Will memory frequencies be retained after power is shut off?

All memorized frequencies will be retained for approximately 30 seconds after power is shut off. Memory backup batteries (Panasonic WL-14 or G-13, Eveready 357, Duracell 10L14, or RAY-O-VAC RW-22 or RW-42) may be installed to retain memory frequencies for an indefinite period after power is shut off. These batteries will function for about one year of normal operation. The batteries provide backup voltage for the $\boxed{M}$, M', and M" memories.

The M1/DSP memory is intended for temporary applications, but can be modified for backup battery operation. The batteries are silver-oxide type and are not supplied by Trio-Kenwood. They are commonly available at local stores.

presstop

IARU'S DELEGATES for September's WARC in Geneva have been selected. Included are IARU President VE3CJ as well as G5CO, HK3DEU, JA1NET, K1ZZ, SP5FM, W1RU, W4KFC, WØBWJ, YV5BPG and ZL2AZ. The IARU is expected to be one of a number of international organizations with formal recognition to participate in the WARC as observers, a status not granted to national groups such as the ARRL or RSGB. A large number of Amateurs have also been named to national delegations, of course.

RESTRICTIONS HOBBLING U.S. WARC delegates have been causing quiet concern in and out of Washington for the past few months. As a result of questions arising from another international conference several years ago, delegates drawn from industry are subject to Justice Department "guidelines" that severely limit their contributions in international conferences, in fear that they might act as advocates for their industries or employers instead of for the United States.

It Now Appears that some relief is in sight as a result of Congressional action. Senator Goldwater, whose proposed Communications Act rewrite (S-622) addressed this very problem, is only one of several in Congress who are reported to be working at lifting the Justice Department restrictions so the U.S. WARC delegation will be able to function at full effectiveness.

AMATEUR RADIO PROVIDED EMERGENCY COMMUNICATIONS in wide areas of the country during the early summer months. In Wichita Falls (Texas) a computer teamed up with Amateur (and other) communications networks to provide a fast and efficient means of assessing damage and answering welfare inquiries.

St. Vincent's Volcano was still acting up in June, following its Good Friday eruption, with Amateurs continuing to provide around-the-clock assistance at VP2SRC.

Jacksonville, Florida got help from Amateur Radio mobile and repeater units when communications were needed for firefighters involved with a giant oil-tank fire in nearby Hilliard.

The Tragic Crash of American Airlines flight 191 in Chicago disrupted local communications, and emergency channels were soon completely overloaded. Amateur Repeater W9SRO/R on 147.75/15 was put on emergency status, as was the CD station on 147.3 MHz in the downtown Civic Center. Many Amateurs with mobile and hand-held units provided site-to-hospital, traffic, and crowd-control communications during the first few hours after the tragedy.

A Light Plane Crash In Baja, California gravely injured three Americans, but thanks to Amateur Radio all are recovering. The aircraft went down near the yacht of WA6SAX, at anchor near shore. The three seriously injured survivors were brought on board and WA6SAX/MM immediately called for help on the Manana Net, raising NCS N6AUT/MM and WB6YRC. WA6UWC, a doctor, joined the group and provided much-needed medical emergency advice that kept the three alive until the red tape could be cut for two ambulance planes to fly into Mexico and take the injured back to California.

FCC'S 900-MHZ CB Notice of Inquiry asks many questions, some of them with implications for services other than CB. The basic questions, of course, concern the limitations of present CB services, whether 900 MHz would solve those problems, and how much demand is there for a new CB service. In addition, however, the Commission wants to look at automatic transmitter ID, possibility of repeaters and interconnects, automatic transmitter time out and other built-in rules enforcement, and AM vs SSB vs FM.

Due Date For Comments on the NOI (PR Docket 79-140) is November 30, with Reply Comments due December 31.

HF RADIATION HAZARDS are the subject of a new FCC Notice of Inquiry, General Docket 79-144. Although the Commission noted that promulgation of RF radiation standards is the responsibility of health and safety agencies, it also recognized that it would have to consider radiation exposure standards adopted by other Federal agencies in its licensing activities. With the environment currently a hot public issue, this NOI could easily become a crucial one for Amateur Radio as well as most other radio services.

FCC LICENSE-FEE REFUNDS are now available to licensees who paid more than $20 for their licenses, including Extra-Class Amateurs who paid the $25 fee for a special callsign. Applications for the refund requires a special form, which with its instruction form resembles the infamous IRS Form 1040. Applications are available from any FCC Field Office or Federal Information Center, or can be requested by mail from FCC Fee Refund Program, P.O. Box 1788, Hyattsville, Maryland 20788. Questions about the program (only) will be fielded during business hours on two toll-free numbers, (800) 638-0251 (outside Maryland) and (800) 492-0501 (Maryland only).

CHARLIE CARROLL, K1XX, has joined Sanders Associates as an Engineering Associate and will be working in their Advanced Systems Department; Charlie, a staff editor at Ham Radio for three years, recently received his B.S. degree in economics and management.

New OMNI/SERIES B Filters The Crowd

The new OMNI/SERIES B makes today's bands seem less crowded. By offering a new i-f selection that provides up to 16 poles of filtering for superior selectivity. And a new Notch Filter to remove QRM. No other amateur transceiver we know of out-performs it.

NEW I-F RESPONSE SELECTION. OMNI comes equipped with an excellent 8-pole 2.4 kHz crystal ladder i-f filter which is highly satisfactory in normal conditions. But when the going gets rough, the new OMNI/SERIES B, with optional filters installed, provides two additional special purpose i-f responses.

The 1.8 kHz crystal ladder filter transforms an unreadable SSB signal in heavy QRM into one that gets the message through. The 0.5 kHz 8-pole filter provides extremely steep and deep skirts to the CW passband window which effectively blocks out even the very strong adjacent signals.

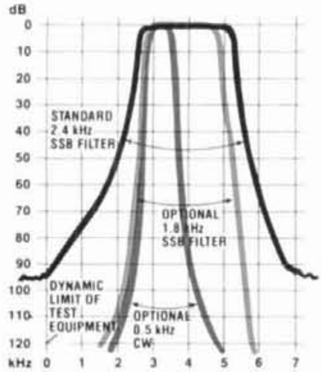
Both of these filters can be front-panel switched in series with the standard filter to provide up to **16 poles** of filtering for near-ultimate selectivity. In addition, the standard CW active audio filters have three bandwidths (450, 300, and 150 Hz) to give even further attenuation to adjacent signals. In effect, OMNI/SERIES B has six selectivity curves—three for SSB and three for CW. That's true state-of-the-art selectivity.

NEW NOTCH FILTER. A variable frequency notch filter in OMNI/SERIES B is placed inside the AGC loop to eliminate interfering carriers and CW signals without affecting received signals. Attenuation is more than 8 "S" units (over 50 db) for any frequency between 0.2 kHz and 3.5 kHz.

OMNI/SERIES B RETAINS ALL THE FEATURES THAT MADE IT FAMOUS.

All solid-state; 160-10 meters plus convertible 10 MHz and AUX band positions; **Broadband design** for band changing without tuneup, without danger; **Choice of readouts** —OMNI-A for analog dial or OMNI-D for digital dial; **Built-in VOX and PTT** facilities; **Selectable Break-in,** instant or delayed receiver muting; **Dual-Range Receiver Offset Tuning,** ±5 kHz or ±0.5 kHz; **Wide Overload Capabilities,** dynamic range typically exceeds 90 dB and a PIN diode switched 18 dB attenuator is also included; **Phone Patch Interface Jacks; Adjustable ALC; Adjustable Sidetone; Exceptional Sensitivity; 200 Watts** input to final with full warranty on final transistors for first year, pro-rata for 5 years; **100% Duty Cycle** for RTTY, SSTV or sustained hard usage; **12 VDC Circuitry** for mobile use, external supplies for 117/220 VAC operation; **Front Panel Microphone and Key Jacks; Built-in 25 kHz Calibrator** in analog dial model; **Zero-Beat Switch; "S"/SWR Meter; Dual Speakers; Plug-In Circuit Boards; Functional Styling,** black textured vinyl over aluminum "clamshell" case, complementary nonreflective warm dark metal front panel; **Complete Shielding; Easier-to-use size:** 5¾"h x 14¼"w x 14"d; **Full Options:** Model 645 Keyer $85; Model 243 Remote VFO $139; Model 252MO matching AC power supply $139; Model 248 Noise Blanker $49; Model 217 500 Hz 8-pole Crystal Ladder CW Filter $55; Model 218 1.8 kHz 8-pole Crystal Ladder SSB Filter $55;

OMNI owners note: Your OMNI can be converted to a SERIES B model at the factory for just $50 (plus $5 for packing and shipping). The notch filter replaces your present squelch control and provision is made for the two additional optional filters; a partial panel with new nomenclature is provided. Contact us for details.



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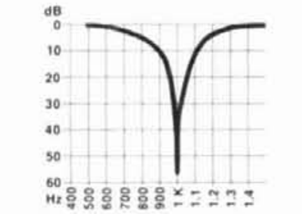

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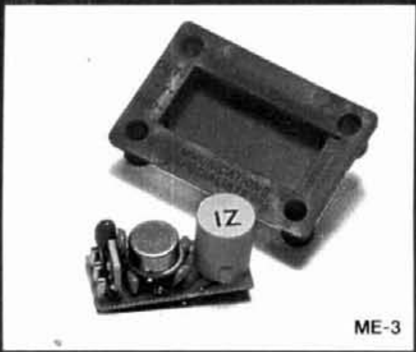

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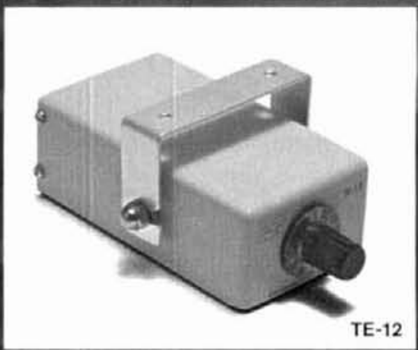

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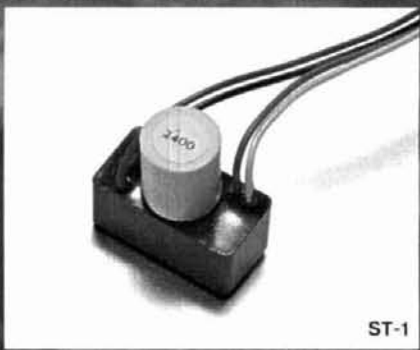

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antenna gain and directivity over ground

A discussion of Yagi gain and directivity, reference antennas, and the effects of planet Earth

The concept of antenna directivity and antenna gain is now several decades old; in fact, the terms are now quite familiar and are used by both technical and nontechnical people alike, apparently without much thought to what they mean — and also what they do not mean!

Directivity is commonly defined as the ratio of the maximum radiated energy flux density (at some "best" azimuth and elevation angle) to the average radiated energy flux density, averaged over the entire solid angle or sphere. Note that this property is determined solely by the complete three-dimensional spatial pattern of radiated energy. Directivity has a nice conceptual ring; it should, and presumably does, measure quantitatively the ability of the antenna to focus, concentrate, or direct its radiated output in a specific direction — compared with a reference antenna which has zero directivity (*i.e.*, equal output in all directions). This reference antenna is often referred to as an "isotropic radiator." However, this reference antenna is totally fictitious — nobody knows even in principle how to make such an antenna.* But it *is* a useful concept.

The gain of an antenna at any azimuth and elevation angle is normally defined as the ratio of actual *maximum radiated* energy flux density to that which would be produced by an isotropic radiator whose total radiated output power is the same as the antenna's input power. The gain of the antenna is then exactly the same as the antenna directivity multiplied by the radiation efficiency of the antenna. The radiation efficiency of an antenna is less than unity due only to conductor losses (and sometimes dielectric losses) and earth (ground) losses. In the remainder of this article I will assume these losses to be negligible and therefore will equate gain to directivity numerically, even though their definitions are different.†

It has been customary to object to the use of an isotropic radiator as the reference antenna because it is fictitious and physically unobtainable. Two suggestions have been made for alternative references:

*It is conceptually possible to approximate an isotropic source by the superposition of a very large number of independent and incoherent dipole sources whose orientations are uniformly distributed over the entire solid angle or sphere. It certainly would not be simple to make such a system, at least in the high-frequency region, nor to prove the accuracy of this approach to the isotropic assumption.

†Nearly all "normal" high frequency antennas have radiation efficiencies which closely approximate unity. This is not true for very short radiators, nor for antenna systems with significant ground losses.

By James L. Lawson, W2PV, 2532 Troy Road, Schenectady, New York 12309

(1) the infinitesimal dipole, whose pattern can be closely approximated by a very short linear radiator; and (2) the half-wave dipole. The infinitesimal dipole has a theoretical directivity or gain (over isotropic) of 1.5 (1.76 dB), and the half-wave dipole an isotropic gain of 1.64 (2.15 dB). Note, however, that these directivities or gains have been stated *only* for free-space conditions. Moreover, these free-space dipole reference alternatives are still fictitious and physically unobtainable in the real world, *where real antennas interact with the real earth.*

Conceptually, one can still use the free-space (fictitious) reference antennas, even though the real antenna is used over earth or ground. This has the difficulty, however, that one cannot experimentally make or use any of the reference antennas. Furthermore, the gain of an antenna referred to a free-space standard, even though quite correct, gives a value which is unnaturally high for most technical users. Nevertheless, it is a value which can in principle be derived, for example, from a complete measurement of the space energy flux density pattern of an antenna. The (isotropic) reference radiation is simply the average flux density over the complete 4π solid angle (complete sphere), which is clearly just one-half of the average flux density over the 2π solid angle of the irradiated hemisphere. The half space below the conducting ground plane is, of course, not irradiated.

table 1. Yagi gain(s) in free space (dB).

reference	lower Yagi	upper Yagi	stacked Yagis
isotropic	10.28	10.28	13.37
infinitesimal dipole	8.52	8.52	11.61
half-wave dipole	8.13	8.13	11.22

Another possibility is to use a reference antenna, preferably one that can be easily constructed, and place it at the same height as the antenna, or perhaps substitute it for the antenna in its actual position. This concept is appealing and is popular* because it suggests a relatively simple measurement technique. Unfortunately, the measurement technique is *not* simple, either in practice or in concept; moreover, gain ratios of different antennas measured in this way are generally *not* the same as if referred to the free-space reference, and also *not* the same as the actual ratios of peak energy flux densities. There is also the nagging question of what the "position" of an antenna system is (where one should substitute a reference dipole). For example, is the "position" of a stacked array over ground its mathematical center? The basic reason for this confusing state of affairs is that a dipole reference antenna itself exhibits a gain (referenced to free space) which depends upon

Antennas — a favorite topic of many, providing unlimited, and often heated discussions. Whether on the air or at any reasonable size gathering of amateurs, antenna facts and fallacies abound — quads vs Yagi, short verticals, EME arrays, the interests are endless.

Undoubtedly, one of the most popular subjects is the Yagi antenna. Everyone, the contester, the DXer, and even the person with just a casual interest, wants the maximum performance from their antenna, and as often is the case, maximum performance for the money spent. In many cases, however, the two do not equate; for its performance, that new five-element, 20-meter monobander on the 30-foot boom might as well be a dipole strung between a couple of trees. Is the manufacturer to blame? Not really, he's just building a marketable product. The fault lies with us, the user. Fact — for the most part, gain of a Yagi antenna is dependent upon boom length, with the number of directors being a significantly less critical factor. However, amateur fallacy would have everyone believe that the greater the number of directors, the better the antenna, regardless of boom length.

In a similar vein, consider the performance of a receiver in the Amateur Radio service. A few years ago performance, or actually lack of, was an often overlooked and misunderstood factor. Today, as a result of numerous articles in the Amateur Radio magazines, most amateurs are acutely aware of performance. This has resulted in a new generation of receivers from the manufacturers; receivers which now exceed previously unheard of performance standards.

Unfortunately, the Yagi antenna is far from being an easy subject. The antenna may appear to be very simple, but its performance depends upon a large number of interrelated variables, each factor affecting the others. As it turns out, the advent of the modern-day, high-speed digital computer has reduced the months of tedious calculations and emperical designs to a few minutes in front of a CRT terminal. This is not as simple as it may seem, for as we all should know, the computer is just a tool. Solving the problem still requires research and most importantly understanding.

As anyone who has heard the antenna talks by W2PV knows, Jim Lawson understands Yagi antennas. A look at Jim's station and its performance should be ample proof. On the personal side, Jim Lawson, W2PV, received his PhD in Physics from Michigan in 1939 and has worked for General Electric since 1945, the last fifteen years with Corporate Research and Development in Schenectady, New York. Jim's amateur career started in 1934 when he was first licensed as W9SSO. His other calls were W8QIU and the more well known WA2SFP from the 1960s.

As a preview of what's to come, over the next seven to eight months, *ham radio* will be printing a series of articles written by W2PV dealing with the design of Yagi antennas. Topics will include: computational methodology, simple Yagis, Yagi variations, ground effects, perferred designs, scaling and element tapering, and stacking. However, to start the whole series off in the correct perspective, this article will deal with the antenna in the real world and our perceptions of antenna gain.

Having known Jim for several years and having benefited many times from this material and his knowledge, I can say, for anyone with an interest in Yagi antennas, read the articles; they will be well worth waiting for. K1XX

*See, for example: *The ARRL Antenna Book*, 13th edition, American Radio Relay League, Inc., Newington, Connecticut, 1974, page 43.

height over ground. Most importantly, the gain occurs at an elevation angle different from that of the test antenna, even though the antenna is located in the same position!

An example will illustrate the nature of this confusing conceptual problem. This example will approximate the situation for a large stacked Yagi system now in fairly wide use on the 14-MHz band. The Yagis are each constructed with six evenly-spaced elements on a boom 0.66 wavelength long. The lower Yagi is at a height over ground of 0.6 wavelength and the upper Yagi is at a height over ground of 1.6 wavelengths. I have calculated the pattern(s) and maximum gain(s) of these Yagis (individually and stacked) by methods which I shall not attempt to justify in this article,* but which I believe are essentially correct.

table 2. Reference half-wave dipole gain over earth (dB).

reference (free space)	height 0.6λ	height 1.6λ	height 1.1λ
isotropic	9.18 (25°)	8.52 (9°)	8.69(13°)
infinitesimal dipole	7.42 (25°)	6.76 (9°)	6.93 (13°)
half-wave dipole	7.03 (25°)	6.37 (9°)	6.54 (13°)

These gain figures, together with the elevation angles at which maximum gain occurs, are shown in **tables 1, 2,** and **3. Table 1** shows the (hypothetical) free-space gain of the Yagi system (in decibels) referenced to three different free-space standards. **Table 2** shows the (hypothetical) gain(s) of reference half-wave dipole(s) over ground at the same height(s) as the Yagi system (the "height" of the stacked array is taken as its mathematical center). I've also included the elevation angle at which maximum energy flux density occurs. **Table 3** shows the gain(s) of the Yagi system referred to various standards, including half-wave dipoles at the same "height" over ground.

Constructing **table 3** presents a fundamental conceptual difficulty which needs resolution. In comparing the ratio of energy flux densities of the Yagi with the (substituted) reference dipole, what should be the elevation angle or angles at which this ratio is taken? The energy flux densities of the Yagi system and the reference dipole *both* vary with vertical angle, *but vary differently*. One can now define gain in any of several ways:

A. The maximum ratio of Yagi flux density, F_Y, to *reference dipole flux density,* F_D *(occurring at angle* a_1*);*

B. The ratio of maximum F_Y (occurring at a_2) to F_D at that same angle;

*Computation methodology will be described in a forthcoming article.

C. The ratio of F_Y to the maximum F_D (occurring at a_3);

D. The ratio of maximum F_Y (at a_2) to the maximum F_D (at a_3).

It is interesting that perhaps the most logical definition is the first; unfortunately, a_1 will generally be a vanishingly small angle where the performance of both Yagi and dipole becomes vanishingly low, and where minute ground resistance and height effects make an actual experimental comparison highly inaccurate. Moreover, we are not really interested in using the Yagi at this angle. The most relevant measurement is probably 2, where the Yagi is used at its "best" elevation angle, a_2.

To show how confusing these quantities become, **table 3** shows "gain" at a very low angle — say 1 degree — approximating case A. Also included are the angle for maximum F_Y (case B), the angle for maximum F_D (case C), the "gain" as the ratio of maximum F_Y to maximum F_D (case D), and finally, in case E, the stacked-Yagi system at an angle which obviously produces a remarkable "gain" figure. This pathological behavior is due to the choice of an elevation angle at a fairly deep null in the reference dipole's pattern.

The tables show a perplexing array of gain figures. Which of them is correct? Actually, they are all correct; *all* of the differences are caused by the behavior of the reference antennas. The strange behavior of a reference dipole over ground, as shown in **table 2**, is due to its change in radiation resistance caused by mutual coupling with the ground image. This is a well-known effect.* The elevation angle at which the reference antenna's gain is maximum is generally larger than that for a Yagi (higher-gain) antenna at the same height due to the way in which the "natural" gain of the Yagi falls off at higher angles.

These tables also illustrate that the gain of a real antenna over real earth *can not* be stated unless its height is specified. Moreover, the concept of "stacking gain," *i.e.*, increase in gain due to stacking, is determinable only in free space. Over earth, stacking does produce an increase in gain — but increase over what? It is probably best to avoid the temptation to use any "stacking-gain" figure, but simply to refer directly to the gain of the antenna system, which should now be understood to depend not only on the antenna components (Yagis), but also on their physical locations above ground! The tables also show

*See, for example: John D. Kraus (W8JK), *Antennas*, McGraw-Hill Book Co., Inc., New York, 1950, page 305; *The ARRL Antenna Book*, 13th edition, American Radio Relay League, Inc., Newington, Connecticut, 1974, page 54.

that big Yagis generally perform well over earth, but not quite by the same ratio as free-space gain.

What then should one use as a reference standard? It seems at the outset that the preferred definition should allow natural comparison of two different antennas (say the lower vs the upper Yagi in the previous example). That is, we require that the ratio of the maximum gains of the upper to lower Yagis is simply the ratio of maximum energy flux densities of upper to lower Yagis. This is true in principle, if we use one of the free-space references, but not true for the half-wave, "substituted" reference dipole! In other words, if one used what has become a popular idea — gain "measurements" through a substituted half-wave dipole — the results are guaranteed to be confusing and guaranteed not to represent, even conceptually, a true measure of peak energy flux.

table 3. Yagi gain(s) over earth (dB) and elevation angle of maximum energy flux.

reference	Yagi at 0.6λ	Yagi at 1.6λ	stacked Yagis
isotropic (free space)	15.00 (21°)	16.12 (9°)	17.06 (10°)
infinitesimal dipole (free space)	13.04 (21°)	14.36 (9°)	15.30 (10°)
half-wave dipole (free space)	12.65 (21°)	13.97 (9°)	14.91 (10°)
half-wave dipole at Yagi height			
A angle = 1° (see text)	7.05	7.80	10.60
B see text	5.82 (21°)	7.59 (9°)	8.97 (10°)
C see text	5.27 (25°)	7.59 (9°)	7.75 (13°)
D see text	5.61	7.59	8.36
E angle = 27° (see text)			21.65

If the substituted half-wave dipole is not to be used in gain measurements, how then can one go about experimentally measuring the gain of an antenna that is interacting with earth or ground? It is easy to see that this is a formidable problem. The maximum intensity angle must be determined by a test signal generator or test detector; this must be done at the correct elevation angle and at a range well beyond the near field of the antenna and well beyond the Fresnel zones. The test detector must be calibrated in absolute terms of energy flux per unit area, or, if absolute calibration is not possible, one must accurately measure the entire radiated pattern over the hemisphere, with sufficient accuracy to determine gain with the required precision. That this is a difficult undertaking is obvious; there appears, however, to be no other way of experimentally determining gain.*

In view of these considerations, I would like to suggest that, conceptually, antenna gain be defined simply as the ratio of maximum radiated energy flux intensity at the best azimuth and elevation to the average radiated energy flux intensity over *all* angles, *i.e.*, the full 4π solid angle or full sphere. I suggest that this definition, in fact, is quite common;† it is consistent with using a free-space, isotropic reference standard, and it gives the right ratios of energy fluxes for different antennas and antenna combinations whether in free space or over earth. It can, and I believe should, be used uniformly in all situations (including over the conducting earth). It can, in principle, be measured by integrating the complete spatial energy flux pattern.

Please note that, in contrast, "gain" measurements through dipole substitution, in principle, will give wrong ratios of energy fluxes for different antenna combinations.

This isotropic gain definition (referred to free-space isotropy) will give much higher figures for gain than those to which we have become accustomed. But we can get used to that; after all, we are already used to the outrageous claims for gain made by commercial antenna manufacturers!

To summerize, note the following points:

1. Antenna gain or directivity should be referenced to a free-space standard in order to be useful in making meaningful comparisons.

2. Experimental "gain" measurements over the earth by (dipole or other) reference substitutions will give confusing results and incorrect comparison ratios.

3. Experimental measurement of gain over earth is exceedingly difficult and basically impractical.

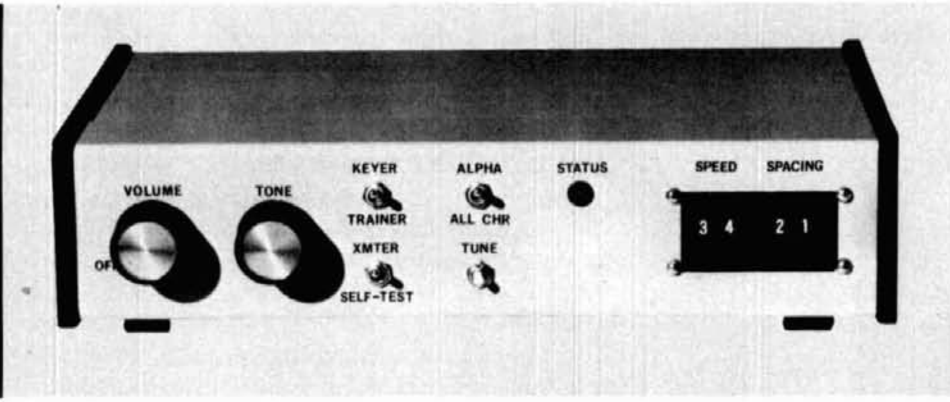
4. Directivity or gain can be calculated! The accuracy depends upon the proper mathematical characterization of the physical antenna (Yagi) and the use of sufficiently accurate computational methods. It is likely that the overall accuracy of gain calculation using modern methods significantly exceeds the practical accuracy of experimental measurement.

5. Large (Yagi) antennas perform well over earth, but not by the same ratio as in free space.

ham radio

*One can probably approximate the gain of an actual antenna by making measurements on a good model. While measurements are usually much easier to make on a (small) model, it is sometimes quite difficult to prove that the model is a faithful representation of the real thing and that all scaling laws are understood and properly applied.

†See, for example: John D. Kraus (W8JK), *Antennas*, McGraw-Hill Book Co., Inc., New York, 1950, page 17; "Reference Data for Radio Engineers," 4th edition, International Telephone and Telegraph Corp., page 703.



CW Trainer/Keyer

using a single-chip microcomputer

Theory and construction details for a keyer that serves as a training device and an iambic keyer with dot and dash memories

Have you ever wanted some code practice to help increase your speed to pass that elusive 13- or 20-wpm barrier, but found W1AW being clobbered by interference and you have all the code tapes memorized? This combination CW trainer/keyer could be just what you need.

As a trainer, the trainer/keyer sends random five-character code groups with selectable speed, spacing, and character set. There's no guessing at what speed the trainer/keyer is sending because the speed and spacing are digitally selected by front-panel thumbwheel switches. Any speed or spacing from 1 to 99 wpm can be selected in 1-wpm steps. With separate speed and spacing switches, the character speed can be, say, 22 wpm while the character spacing is only 9 wpm; any combination is possible as long as the speed is greater than, or equal to, the spacing. Thus, for practice to get past that 13-wpm barrier, set the character speed at 15 wpm and gradually increase the spacing until 15-wpm spacing is reached. This technique, pioneered by Russ Farnsworth (W9SUV) in his "Easy Method" records and tapes, is known from numerous code-learning studies to be the best for rapidly building up code speed. In addition to the selectable speed and spacing, the trainer's character repertory is selectable. The five-character code groups can be constructed from either the alphabet or from the alphabet plus the numbers and punctuation.

In the keyer mode, the trainer/keyer performs as an iambic keyer with both dot and dash memories. As in the trainer mode, sending speed is digitally selectable in the same 1-wpm steps from 1 to 99 wpm. No more guessing at what speed you're sending!

microcomputer control

The trainer/keyer uses a new type of integrated circuit which will revolutionize Amateur Radio: a single-chip *microcomputer*. Notice that it's called a microcomputer rather than a microprocessor, which you've probably read about in equipment reviews or ads. There are several distinct differences.

By John Beaston, N6TY, 4415 Tilbury Drive, San Jose, California 95130

First, a microprocessor requires additional ICs to make a computer: RAM (random-access memory), EPROM/ROM (erasable-programmable or nonerasable read-only memory), and I/O (input/output). Ads for microprocessor systems (computers) usually show circuit boards crammed with these extra components. Microcomputers, on the other hand, have all the electronics from these additional components packed into a single piece of silicon — hence the name "single-chip" microcomputers.

Aside from the obvious difference of size, microcomputers are generally easier to use than microprocessors. A large part of microprocessor system design involves simply getting all the various components playing together. In a microcomputer, this task has already been accomplished by the microcomputer manufacturer. All you must do is tell the microcomputer what's to be done and supply the interface to the high frequency rig, RTTY gear, or whatever.

Now, microcomputers aren't going to make microprocessors obsolete. They are intended for slightly different applications. While microprocessors are perfect for applications such as small-business computers and high-speed communications, microcomputers are designed to bring the power of a computer to control-type applications. Microcomputer applications around the home might include a microwave-oven controller, an energy-management center, a repertory phone dialer, or a burglar/fire alarm system. In Amateur Radio, microcomputers are already appearing in applications such as scanning and remote-controlled high frequency and vhf rigs. Other applications that come to mind are self-tuning transmatches; automated tracking Oscar antennas; digital-station consoles; sophisticated accessories for RTTY, SSTV, and CW; and, of course, the CW trainer/keyer. Only imagination limits the applications.

Before going into the details of the trainer/keyer let's discuss microcomputers in general, since they are so new.

microcomputer basics

All microcomputers are similar internally. **Fig. 1** shows a structure that applies almost universally. For the sake of illustration, let's assume that this microcomputer is being used as a traffic-light controller.

Central processing unit. Looking at the function of the first block in the block diagram, the CPU (central processing unit) can be thought of as the master control sequencer — the brains of the microcomputer. It performs the actual counting of cars and changing of lights at the appropriate times. These actions result from following a list of instructions (the program) stored in the program memory. A typical program might be this: Leave the light green for street A until no cars have passed for 15 seconds, then give street B the green until either five cars are waiting on street A or until 30 seconds have elapsed, whichever occurs first.

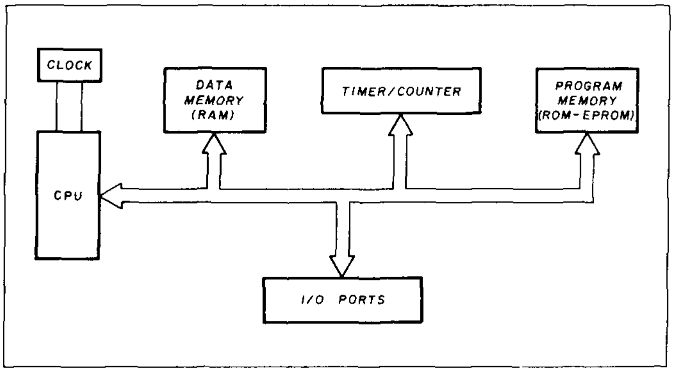


fig. 1. Typical microcomputer structure showing major functional blocks.

I/O section. If our microcomputer is to execute this particular program it needs some way of detecting the presence of cars traveling on street A. Sensors imbedded in the roadway sense the presence of a vehicle. To feed the sensor information into the microcomputer, simply connect the sensor to one of the input ports in the I/O section (assuming voltage compatibility, of course). The CPU then reads information on an input port whenever told to do so by an instruction from the program memory.

Memory sections. Since the CPU must control each light in a traffic situation, it must remember which light is on in addition to other variables. Other such items might be the length of time a light has been lit, how long it needs to remain lit, and how many cars are waiting at street A while street B has the green. Each of these little pieces of information is stored in the microcomputer's data memory.

Let's compare the program memory and data memory, since they sound similar but have distinctly different functions. The program memory is simply a list of instructions in a format the CPU understands (machine language). The CPU reads and executes the instructions in sequence, one by one. For any given traffic intersection the list never changes. The CPU executes the same list of instructions over and over.

The data memory, on the other hand, holds data such as time or the number of cars waiting. Each location in the memory stores a particular piece of information. For example, assume location 3 in the data memory stores the number of cars waiting at street A, while street B is green. As soon as the light at B turns green, the CPU makes the contents of location 3 zero. Periodically the program memory instructs the CPU to check the car sensor, through the input port, to determine if another car has tripped

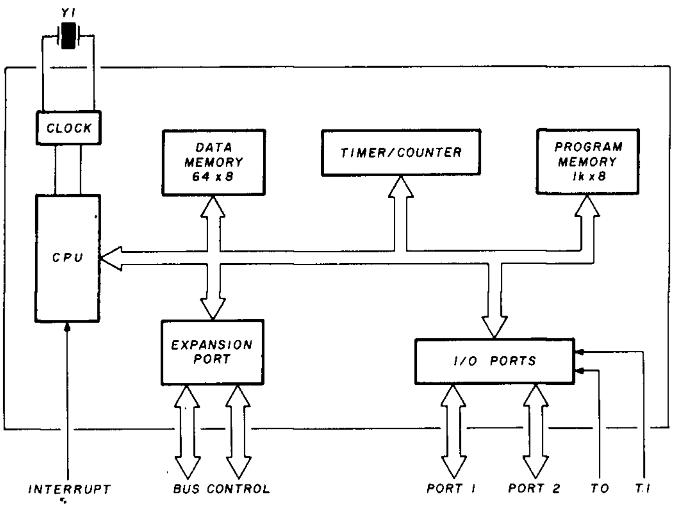


fig. 2. Block diagram of the Intel 8748 showing key elements.

the sensor. If such is the case the program instructs the CPU to increment the number in memory location 3, then to test it to determine if the number is equal to 5. If so, the CPU should change the light at B to red and the light at A to green. If the number is not yet 5, there's no need to change any light, so the program just continues executing without changing anything. The data memory, unlike the program memory, never tells the CPU what operations to perform; the data memory just stores information.

When the CPU determines it's time to change a light, it does so through an output port in the I/O section. Normally, each light is connected to a separate line on the output port. At the appropriate time, the CPU turns a light on or off by switching the port pin associated with a particular light. Since an output port's output level is TTL compatible (either 0 or 5 volts), an external switch between the output port and the light is needed for the actual switching.

Clock. The last block in the diagram is the clock generator. This block determines at what times the CPU reads and executes new instructions from the program memory. All operations within the microcomputer are synchronized to this master clock. The frequency of this master clock is set by an external crystal. Typical frequencies are in the range of 1-12 MHz.

Program memories. There are two different types of program memories, either ROM or EPROM. As the name implies, the ROM-based program memory can-

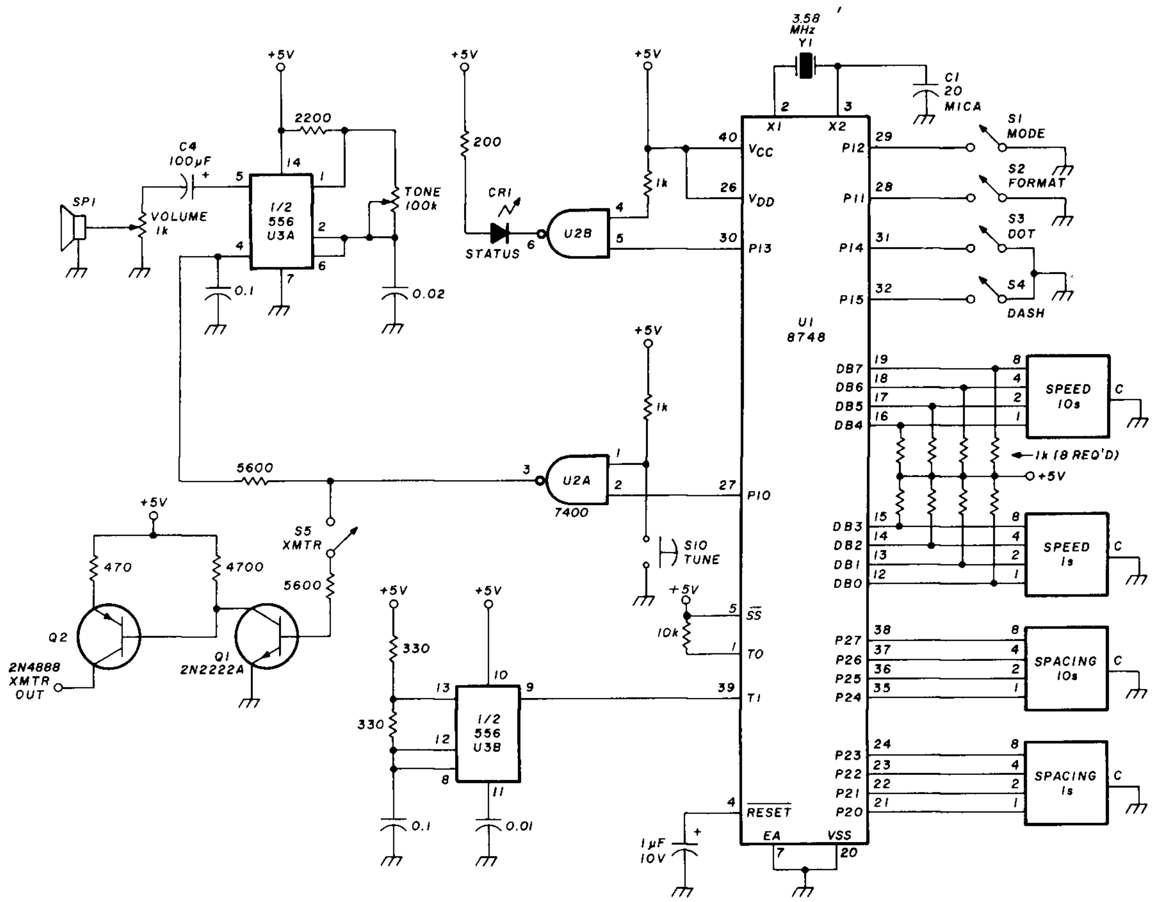


fig. 3. Schematic diagram of the CW trainer/keyer. All resistors are ¼ watt, 10 per cent tolerance. S3 and S4 and the contacts of an iambic paddle.

not be changed. The actual user program is placed into the memory by the microcomputer manufacturer at the time the device is fabricated. Since this involves special tooling, the user is generally required to pay a fee — plus submit an order for a large number of devices. If only one microcomputer is needed for a special project, a ROM-based microcomputer isn't the way to go.

Some microcomputers use EPROM for their program memory. EPROM technology allows the user to erase and reprogram the microcomputer at any time. These devices were originally developed to help the user debug his program before committing it to ROM. However, EPROM-based microcomputers are perfect for one-of-a-kind projects such as we hams usually undertake. They can be changed at any time with no worry about big orders or tooling costs. So if there's a need for a particular gizmo, just use the EPROM version. It's like having your own custom IC!

Intel 8748

The EPROM microcomputer used for the trainer/keyer is the Intel 8748. Its block diagram is shown in **fig. 2**. Notice the similarities to **fig. 1**. The 8748 has 1024 bytes of program memory and 64 bytes of data memory. (Each byte holds one instruction, or piece of data.) This may sound awfully small if you're familiar with microprocessors; however, remember that microcomputers are used mostly for control applications. Very few of these applications require more than 1000 bytes of program. But if your particular application requires more, the 8748 is easily expanded to 4000 bytes of program memory and 320 bytes of data memory using external components.

The 8748 also contains a total of twenty-six I/O lines. There are two 8-bit I/O ports (PORT1 and PORT2) that can be mixed as any combination of input or output lines. Another 8-bit port (BUS) either expands memory or is a simple input or output port. The remaining two lines are the test inputs, T0 and T1. The CPU can test these inputs under program control. They also have special functions depending on the mode of the internal timer/counter.

The programmable timer on the 8748 is an 8-bit up counter. This timer either measures time intervals or counts external events. The specific mode is selected by the program. In addition, the CPU can read, load, start, or stop the timer.

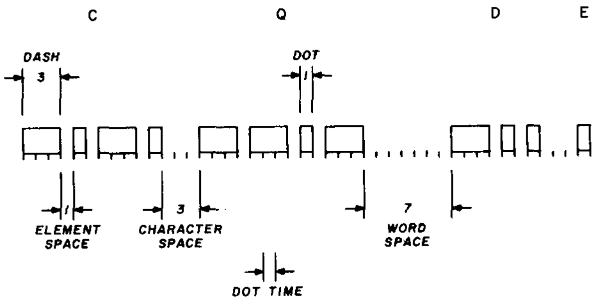


fig. 4. Morse code timing definition example for the Morse characters CQ DE.

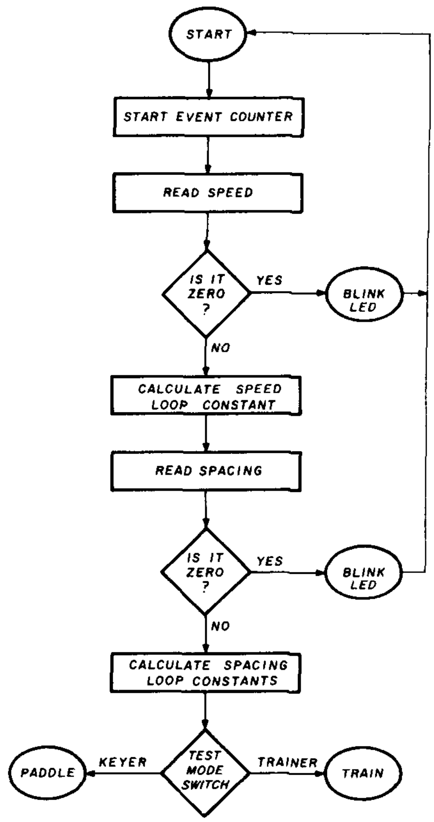


fig. 5. Flow chart for the START routine in the CW trainer/keyer software.

Rather than go into greater detail on the 8748, I'd suggest that any interested reader obtain The *MCS-48 User's Manual* from Intel's literature department. This manual provides all the hardware and software details for the 8748 as well as for several other single-chip microcomputers.

trainer/keyer circuitry

Fig. 3 shows the schematic of the 8748-based trainer/keyer. The circuitry is straightforward. It requires only three ICs, a crystal, an LED, and a handful of switches, resistors, and capacitors. The thumbwheel switches determining the character speed (SPEED) and spacing (SPACING) connect to the BUS (DB7 = DB0) and PORT2 (P27 = P20) lines respectively. The trainer/keyer assumes BCD (binary-coded-decimal) coding for the speed and spacing input. The use of BCD thumbwheel switches is the easiest way to get the inputs into this format. Simple spst toggle or DIP switches could also be used; however, the BCD coding must then be done manually. Notice that no pull-up resistors are required on PORT2, although they are needed on the BUS inputs. PORT2 has the pull ups internally.

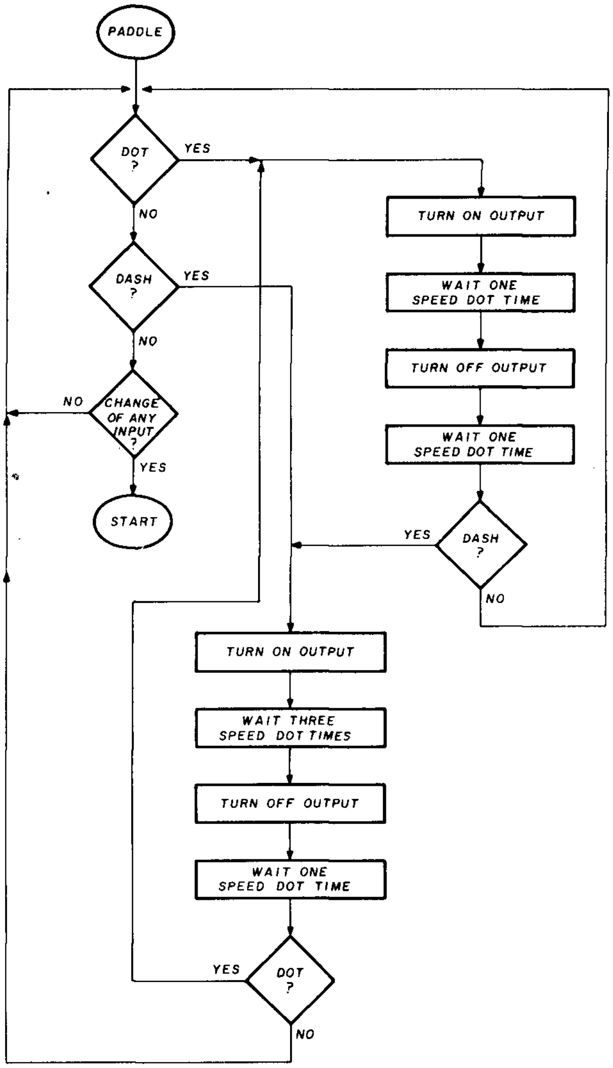


fig. 6. The PADDLE routine implements the iambic keyer section of the trainer/keyer.

PORT1 (P17 = P10) is the remaining 8-bit I/O port. Unlike the BUS and PORT2 ports which are only inputs in this application, both inputs and outputs are mixed on the various lines of PORT1. The inputs on PORT1 are the MODE, FORMAT, and DOT/DASH switches. MODE selects between the trainer and keyer modes. When MODE selects the trainer, the FORMAT switch determines the trainer's character set. With the FORMAT switch open, the trainer sends code groups containing only the alphabet. When FORMAT is closed, the alphabet along with numbers and punctuation form the code groups. If the keyer mode is selected through the MODE switch, a paddle supplies the inputs through the DOT and DASH lines. These inputs are independent, so either iambic or noniambic paddles may be used. The FORMAT and SPACING inputs have no effect when the keyer mode is used.

There are two outputs on PORT1. P10 is the actual CW output and P13 is a status indication output. The two-input NAND gate, U2A, buffers the CW output. The other input is a TUNE switch, which clamps the NAND output high when depressed. This NAND output keys the sidetone generator, U3A, and/or the transmitter. Switch S5 disconnects the transmitter while in the trainer mode if desired. The sidetone generator uses one-half of the 556 as a bistable multivibrator triggered by the CW output. The transmitter keying circuit shown is for grid-block-keyed transmitters. For other keying techniques, a 5-volt relay could replace this circuit.

The status indicator output, P13, notifies the user if an invalid combination of speed or spacing is selected. In normal operation the STATUS LED is lit continuously as a power-on indicator. If 0 wpm is selected, or if the spacing is greater than the speed, the LED flashes on and off until the condition is corrected.

The trainer uses the internal timer/counter in the event-counter mode to generate random numbers. These random numbers are eventually used to select the CW characters within the code groups. U3B supplies the events to be counted. As with U3A, this half of the 556 is wired as a bistable multivibrator. This oscillator output is tied to the 8748 T1 input. T1 is a dedicated input to the event counter when using the event-counter mode. Since U3B is free running, the event counter simply increments through its entire 8-bit range. As we'll see shortly, the program periodically reads the contents of the counter. This number then selects the next CW character to be transmitted. Random character generation is guaranteed because there's no synchronization between the program and the free-running oscillator.

The last piece of hardware is the crystal. The crystal supplies the basic time interval in which the CPU steps through the program in the program memory. Keeping cost in mind, a standard TV color-burst crystal, 3.58 MHz, was chosen.

the code

Before describing the software, let's review just how a Morse code character is developed. Every character is made up of elements: dots and dashes. One basic time unit relates all the elements and the spacing between them. Dots are one dot-time long, while dashes are three dot times in duration. Within a character, elements are separated by an inter-element space equivalent to one dot time. The space between characters within a word is defined as three dot times. Spaces between words are seven dot times. The basic time interval is a dot time. **Fig. 4** illustrates this timing for "CQ DE".

For any given speed, the trainer/keyer uses the time for one dot element as the basic time unit. To convert from words per minute to this basic time unit, we use the equation found in the *ARRL Handbook*:

$$wpm = 2.4\ (dots/second)$$

Since in this formula a dot is made up of both the dot itself and the space between it and the next dot, the equation for the basic time unit becomes:

$$dot\ time\ (second/dot\ element) = 1.2/wpm$$

We'll call this basic time unit a "dot time," with the understanding that it is the time equivalent to a dot element itself, not the dot element and the following space. For example, at 20 wpm, the dot time is 1.2/20, or 60 ms.

The trainer/keyer has a short delay program that takes 0.1 ms to execute. This program does nothing except wait for 0.1 ms. To get the time interval needed, say, for 20 wpm, we simply make this program execute 60 ms/0.1 ms, or 600 times. At one wpm, we need 1.2s/0.1 ms, or 12,000 times; while at 100 wpm the count is only 120. The trainer/keyer uses this software technique to generate the time for each code element.

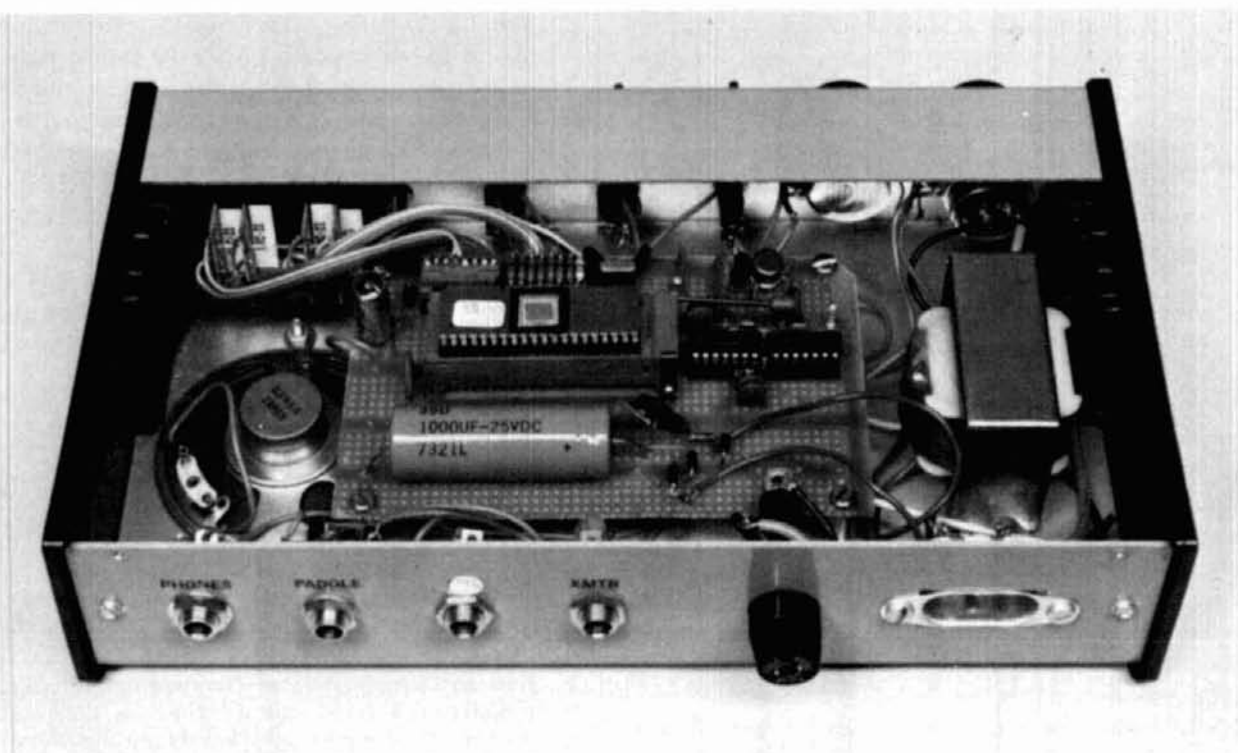
The program is the heart of the trainer/keyer. It has three basic sections: start, keyer, and trainer. The flow charts for each of these sections are shown in **figs. 5** through **7**.

Program start. When power is turned on, the 8748 begins executing the program corresponding to the START flow chart, **fig. 5**. This routine first starts the event counter, then reads the speed selected through the SPEED thumbwheel switches. If the selected speed is 0 wpm, the program branches to a routine that flashes the STATUS LED once and returns to START. If the selected speed is something other than 0 wpm, the routine converts the BCD number into binary and uses this binary number to calculate how many 0.1-ms steps are needed to give the desired speed. This number of steps is called the SPEED loop constant. Once the SPEED loop constant is found, the same procedure is used for reading the SPACING thumbwheel switches and computing the SPACING loop constant.

Once both loop constants are known, the MODE switch is tested. If the trainer is selected, the program branches to the routine called TRAIN, **fig. 7**. If the keyer is selected, the PADDLE routine is executed, **fig. 6**.

Keyer routine. Looking at the latter first, PADDLE simply tests the DOT and DASH inputs. If the dot side of the paddle is pressed (the P14 input is 0), the routine sends a dot element by turning on the CW output, waiting in the delay loop for one SPEED dot time, turning off the CW output, and waiting out the

Internal view of the CW trainer/keyer. As can be seen, this version was constructed on perf board rather than using a printed circuit board. Interconnections between the digit switches and the circuit board are made by using component carriers, which also hold the pull-up resistors (*photo courtesy WB6SFC*).



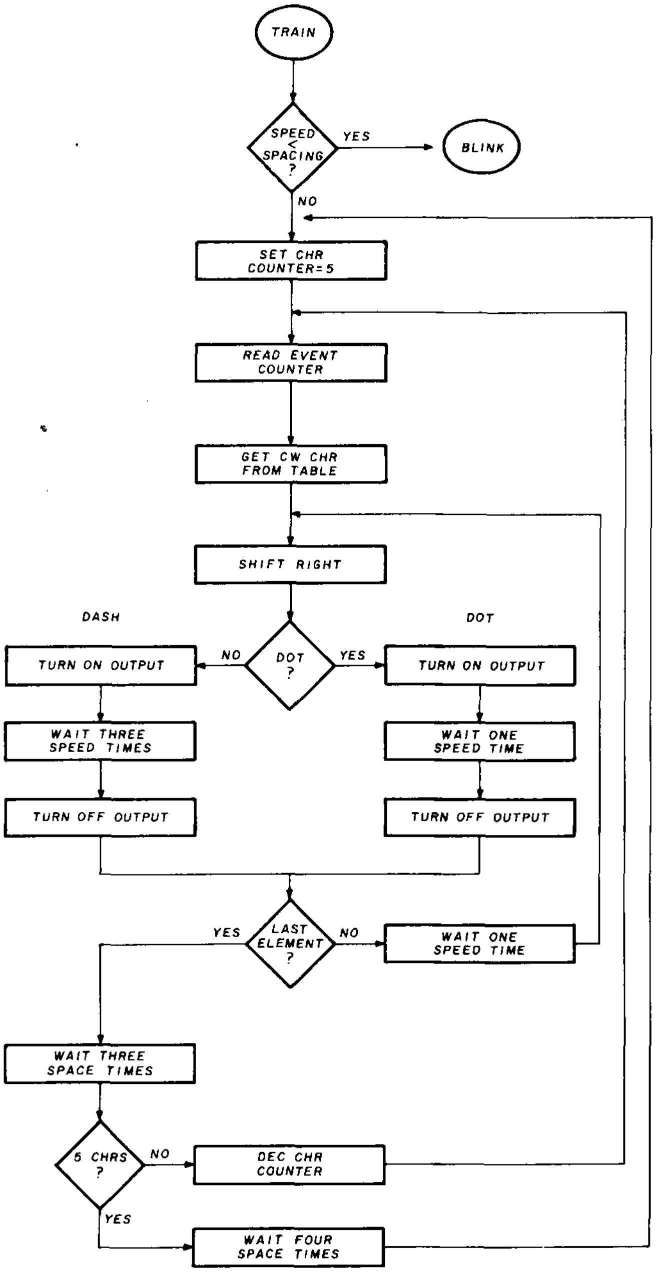


fig. 7. The trainer section of the trainer/keyer uses the TRAIN routine.

inter-element space for one more dot time. Then, to give the iambic nature to the keyer, the DASH input is examined to determine if the dash paddle is pressed. If so, a dash is sent by turning on the CW output for three SPEED dot times and waiting the one-dot-time inter-element space. Then the DOT input is tested again and the process repeats.

If neither side of the paddle happens to be pressed, the routine checks if either the SPEED, SPACING, or MODE inputs have changed. If one or more has changed the routine branches back to START to recalculate the loop constants, change modes, or both. If not, the DOT and DASH are tested again.

The one area not shown in the flow chart is how the dot and dash memories are incorporated. During the delay time of sending an element or an inter-element space, the input for the other side of the paddle is tested occasionally. If it's pressed, a software flag (special bit) is set to indicate that memory is needed. When the current element is complete, this flag is tested. If it's set, the opposite element is sent before continuing. No action is taken if it's not set.

Trainer routine. The trainer routine is similar to that of the keyer except that the inputs come from internally selected characters. These characters are located in a special section of the program memory called the character table. The total number of characters in the table is 128. The frequency of occurrence of each character in the table roughly reflects its occurence in everyday text. In other words, the table contains seven A characters, six Es, six Ns, *etc.*, while containing only two Js, two Zs, and so on. Each number and punctuation character has two entries.

When the trainer needs a new character, it reads the internal event counter, which is driven from the free-running oscillator. This number is used as an offset into the character table to select the next character. If the event counter happened to be 27 when it was read, the twenty-seventh character in the table (in this case it is a G) is the next character transmitted.

Since the character set is variable, some testing is needed of the number read from the event counter. These tests ensure that the offset is within the table limits as well as within the selected character set. If the FORMAT selects all characters the entire table is used. If only alphabet characters are selected the offset range is restricted to only that particular portion of the table.

Characters in the table are stored in a binary form equivalent to Morse code. This form specifies that a dot is represented as a binary 1 while a dash is a 0.

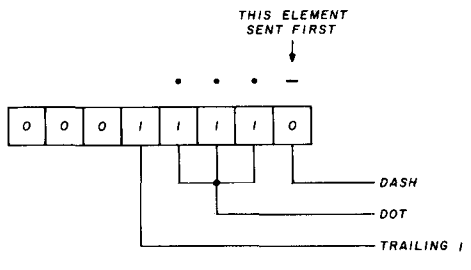


fig. 8. Binary format in the character table for the character B. All characters are read right to left and contain one extra trailing one. All remaining positions out of eight total are filled with zero.

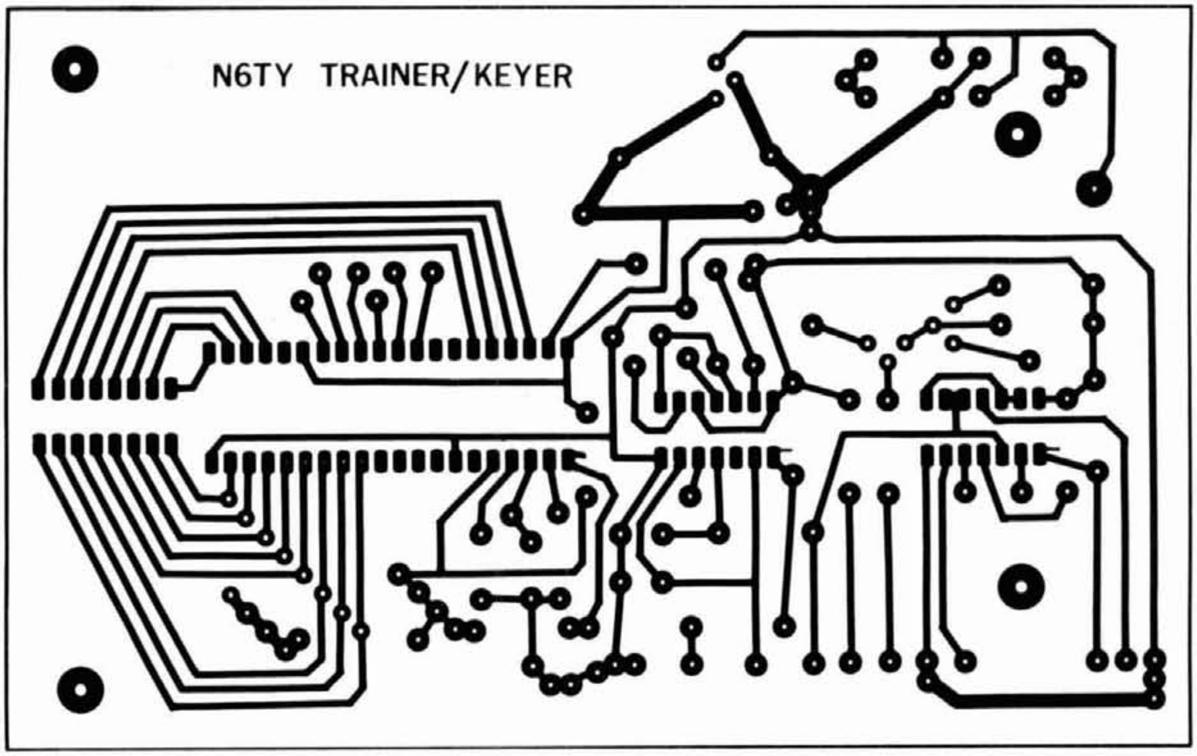
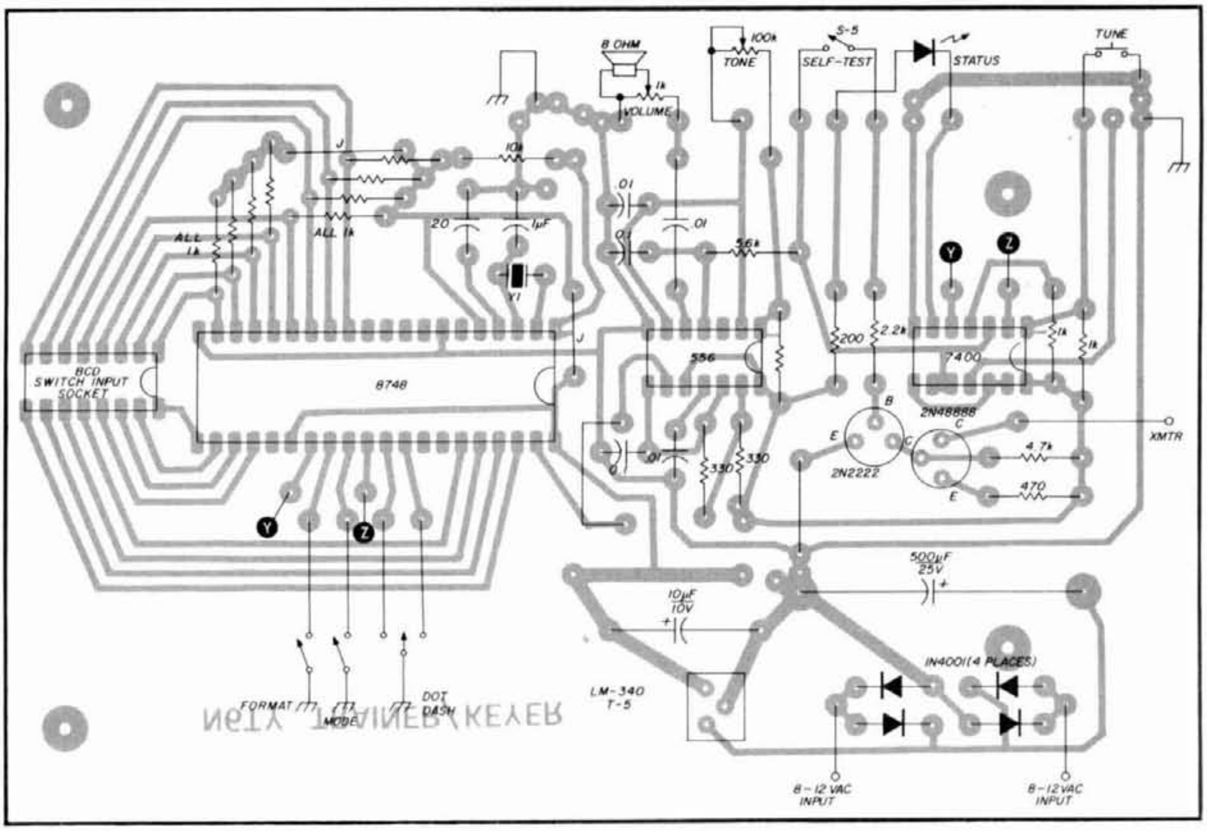


fig. 9. PC-board layout for the CW trainer/keyer above and component layout diagram below.



Each of the 128 entries requires one byte (eight bits). The characters are right-justified and contain a trailing 1. **Fig. 8** illustrates the format for the letter *B*. To reproduce the Morse code equivalent, the trainer simply shifts the whole character one position to the right and tests the bit that falls off the right-hand end. If the bit is a 1, it sends a dot; if it's a 0 a dash is sent. This process repeats, bit-by-bit, until all the positions contain zeroes except the right-most. When this occurs, the character is complete, and a new character is fetched from the table.

Now that we understand the basic operation of the trainer, let's look at its flow chart again (**fig. 7**). Since the trainer uses both speed and spacing, the first operation checks for the validity of the selected combination. Speed greater than the spacing is invalid, and the STATUS LED blinks accordingly. If the combination is okay, the character counter is set to 5. This software counter keeps track of the number of characters remaining to be sent in a five-character code group. Next, the event counter is read, and a character is selected from the character table.

Character shifting is begun at this point. Let's assume the first element is a dash. The CW output is turned on and the delay routine waits three dot times as specified by the SPEED loop constant. The CW output is then turned off. Since the length of time until the next element depends on whether this element is the last in a character or is simply an intermediate, intercharacter element, the routine checks for the character-done condition of all bits zero except the rightmost. If not the last element, an inter-element space is needed, and the delay routine waits one SPEED dot time before the character is shifted for the next element. If the dash happened to be the last element, the delay routine then waits the intercharacter space of three dot units, using the dot time specified by the SPACING loop constant. Since a character has just been completed, the character counter is tested to see if the character was the fifth character in a character group. If not, the character counter is decremented by one, and the routine reads the event counter and gets the next character.

If the just-completed character was the last of a group, an additional four SPACING dot times are awaited, to give a total of seven SPACING dot times between groups, which corresponds to a word space. The routine then returns to reset the character counter to 5 and begin the next group.

construction

Construction of the trainer/keyer is straightforward. PC and perforated board techniques work equally well. The printed circuit layout is shown in **fig. 9** for those who would rather "roll their own." The only constraint in the construction is that the crystal and its companion 20-pF capacitors be located as close as possible to the 8748 IC. Be sure to bypass all inputs and outputs from the enclosure to minimize rf entering the enclosure. As for the power supply, the trainer/keyer requires only a 5-volt supply. Any 5-volt supply capable of supplying 150-200 mA is sufficient. The PC board layout contains provisions for a diode bridge rectifier and three-terminal voltage regulator.

parts

Many of the larger mail-order IC houses stock 8748s. Otherwise, they can be purchased at any Intel distributor listed in the *MCS-48 User's Manual*. Demand for the 8748 is quite high, so availability may be limited; be sure to call around. Several versions of the 8748 are available. These different versions are denoted by another digit after the 8748; *e.g.*, 8748-4. Any version will work in the trainer/keyer. The 8748-8 is the lowest-cost version, so ask for it if there's a choice. The only difference between different dash-numbered parts is the maximum crystal frequency. The maximum for the -8 is 3.6 MHz, while a "no dash" device works up to 6 MHz.

One caution. These devices are unprogrammed and must be programmed with the trainer/keyer software for use in this application. Intel distributors usually have a programming service available for a small charge, or an 8748 programmer can be constructed based on the timing shown in the user's manual. Programming requires a knowledge of the machine language program. Listings of this program are available from the author.

afterthoughts

The 8748 is an extremely flexible device. The number of applications for it within Amateur Radio are almost limitless. Other applications that have been built are a single-chip Morse code encoder/decoder and a WWVB digital clock that never needs to be set. As an example, the encoder/decoder allows you to receive and transmit CW directly on any Baudot or ASCII teleprinter, plus any terminal unit having RS-232 switching levels (ST-5 or ST-6). For transmit, the encoder accepts either Baudot or ASCII serial characters from the keyboard. Up to thirty-two characters are buffered and transmitted in CW at any speed from 1 to 99 wpm. On receive, the decoder adapts to any CW input speed all the way from 1 to over 100 wpm. Received characters are formatted in either Baudot or ASCII and sent serially to the printer. Why not pick up an *MCS-48 User's Manual* and get into computer-controlled ham radio the easy way?

ham radio


Stalking the Ultimate DX.
E.M.E. HISTORY: K4PKV and Boomer put Tennessee on the map during recent ARRL moonbounce contest.
Now you can really enjoy the challenge of working that tough to work 2-meter DX. The all new Boomer 3.2-λ yagi gives 16.2 dBd forward gain. A high efficiency balanced feed system, with integral balun, gives a clear, precise pattern. The trigon reflector reinforces Boomers' 24 dB front to back ratio. Boomer has that right combination of features which will give you long path DX capability or allow you to participate in tropo, sporadic E, meteor scatter and EME activities.
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dip meter converter

for very low frequencies

Using an ordinary dip meter at frequencies below 100 kHz can be a problem — this converter allows your meter to work accurately to 1 kHz

You're just starting to build some equipment for vlf. There's a tuned circuit that you *think* you've cut to about 100 kHz, but something seems to be wrong. You reach for your trusty dip meter and you find . . . .

If your dip meter resembles my ancient Millen, you find that it cuts off at 1.7 MHz. It doesn't come anywhere near vlf.

When faced with this disagreeable situation, I first devoted some thought to winding a few appropriate coils for the Millen. Then I toyed with the idea of starting from scratch with a VCO chip. Finally I tried a simple and rather obvious approach that worked beautifully.

By using a ripple counter (**fig. 1**) you can divide what you need by what you don't have. Starting with a dip oscillator that's well calibrated, you can go to a frequency as low as you like. No improvising of coil forms, no hunting around for calibration points, and no worries about the mechanical stability of a new tuning mechanism.

The 4040 counter chip divides by 2^1 through 2^{12}. This fits the approximately 2:1 tuning range of the typical dip oscillator and leaves no gaps in the spectrum. Some conditioning of the input is required, but the 4001 is inexpensive and readily available, and it can be used for this purpose.

All that's necessary to measure a resonant frequency is to feed an rf probe from the divider output. Connect the probe directly to the tuned circuit. The rf voltmeter measures the voltage drop across the circuit. When off resonance, the probe is essentially short circuited. At resonance, the test circuit looks like a large resistance, and the voltage rises accordingly. Since the probe is directly connected to the test circuit, it's possible to measure not only the resonant frequency but the resonant impedance and *Q* as well. Seems like a nice bonus to get all this with such a simple apparatus.

the circuit

The first section of the 4001 is biased into its active region for use as an amplifier. This unloads the dip oscillator and helps keep its original calibration intact. There are different ways of handling the bias problem, but the one shown in **fig. 1** proved to be thoroughly stable, and both the A- and B-series chips worked well. R1 provides a certain measure of input protection.

A characteristic of CMOS is that steady-state offsets propagate poorly through a series of gates. Tying together both inputs to the second gate assists the process under certain circumstances. In this case, I found that the third gate could be switched by manipulating the bias on the first gate. The steady-state output, however, could not be set anywhere except at a supply rail. The fourth gate wasn't needed, so it was tied off. Supply voltages can vary from about 7 to 15 volts. For a variety of reasons, 12 volts seemed to be a good compromise.

From the divider chip, a 12-position rotary switch selects the desired subharmonic and routes it to the four output terminals. Terminal A is for using the gadget as a utility squarewave generator. Terminal B is normally connected to terminal C either directly or through R4. This resistor is located outside the case, because it must be changed under certain circum-

By E. G. Von Wald, W4YOT, 932 North Federal Highway, Lake Worth, Florida 33460

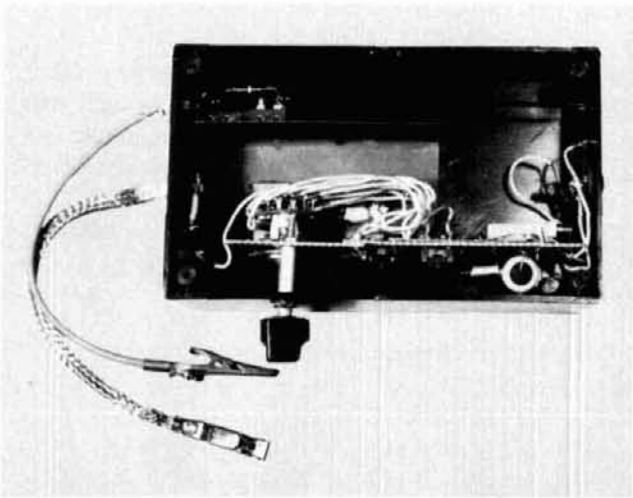
stances, as discussed later. Terminals C and D form the probe. C2 and CR1, with filter R5C3, form the business end of the rf voltmeter. A sensitive, high-resistance indicator — such as an electronic voltmeter — should be used to read the voltage.

As mentioned, the 4040 divides by a factor as high as 2^{12}. When you apply this divisor to the lowest frequency on the Millen, you get an output of a little under one-half kHz. This seemed pretty far below that required for my purposes, so the 12th output on the chip was left unconnected. The open position on the switch allows the instrument to be used as an rf probe with external excitation. It has a resistance (at these frequencies) in excess of a megohm, shunted by several picofarads.

construction

Construction is simple and, allowing for the difficulties of working with quasi microcircuitry, reasonably fast. Since CMOS lends itself to point-to-point wiring, the additional problems of working up an etched circuit board are avoided. Fiberglass perfboard with 2.6-mm (0.1-inch) hole spacing was used with no. 24 AWG (0.5-mm) solid wire. Stripped of its insulation, this wire laces nicely through two or three adjacent holes. When pulled up tight, it holds its position well, forming a stable anchor to the perfboard. Trim the wire about 5-mm (0.2 inch) above the adjacent socket terminal. Then use a soldering tool to bend the trimmed stub over against the terminal. Twist the wire so that it stays against the terminal by itself. Soldering becomes very easy this way.

The photograph of the instrument interior shows the mechanical layout. Metal shielding should be used to keep stray fields from the 4040 out of the rectifier circuit. Shielding was made from scrap flashing copper. The shield also serves as a mounting bracket. A spacer and bolt were inserted close to the switch to provide extra rigidity when switching.



Inside the vlf dip meter converter. The case is plastic with an aluminum top panel (not shown). Plastic is inexpensive and easy to work but mars easily. Static electricity is no problem.

A word about using resistors at radio frequencies. The resistance values tend to fall off as frequency is raised. Henney[1] gives some data for ½-watt film- and slug-type resistors. **Fig. 2** summarizes this information for the frequency-resistance range likely to be encountered here.

adjustment

When the circuit has been wired and checked for accuracy, insert the chips and power up. Use a VOM set to about 10 mA in series with one of the supply leads. Set the selector switch about mid range.

Screw R2 all the way to one limit, then slowly bring it back past its midpoint. Supply current should

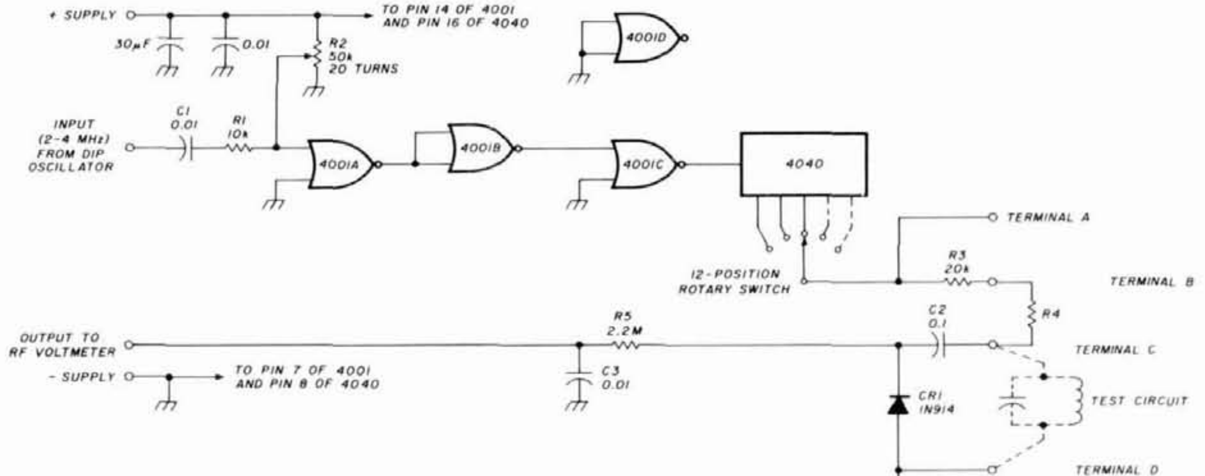


fig. 1. Vlf converter schematic. R4 will vary, as described in text.

be negligible until you get near the active region, when it will jump rather suddenly to several milliamperes. Even with a 20-turn pot, this adjustment range is narrow — ¾ turn should carry you all the way through.

Leaving the pot set at the middle of the active region, short circuit terminal B to terminal C. Couple the dip oscillator to the input through a 3-turn link at the end of a short length of RG-58/U cable.

Set the dip oscillator to 4 MHz. When the oscillator is switched on, there should be another jump in current to perhaps 7 or 8 mA with a 12-volt supply. No further adjustment is necessary unless the supply voltage is changed by an appreciable amount. Should the output voltage vary appreciably across any single output range, either R2 is not set right or else more coupling to the oscillator is needed. Keep in mind, though, that there are about 4 or 5 pF of shunt capacitance at the rectifier and it's not always negligible (compared, in this case, with the resistance of R3). At 2-MHz output, for instance, the open-circuit voltage will be quite low. However, when a tuned circuit is connected, this shunt capacitance is simply absorbed into the tuning capacitance. At these frequencies, the error should not be serious.

Once the device is functioning properly, connect the probe across a marked i-f transformer. Output voltage should fall toward zero. To find the resonant frequency, start from *above* the expected frequency and tune down. When you get close to the target, the output should peak up nicely. After locating the proper resonance point, keep tuning down the spectrum. You'll find peaks (considerably lower in voltage than at resonance) at regular odd submultiples of the resonant frequency. This is why it's easiest to start hunting for resonance from the high end. It also provides a graphic illustration of just what the corners of square waves are made of.

You can use inductive coupling for resonance checking (but not for Q or impedance). Simply connect a multiturn link directly across the probe terminals. Couple this link to the circuit in question. Output will still be a peak at resonance. Expect to use a lot of turns at these low frequencies.

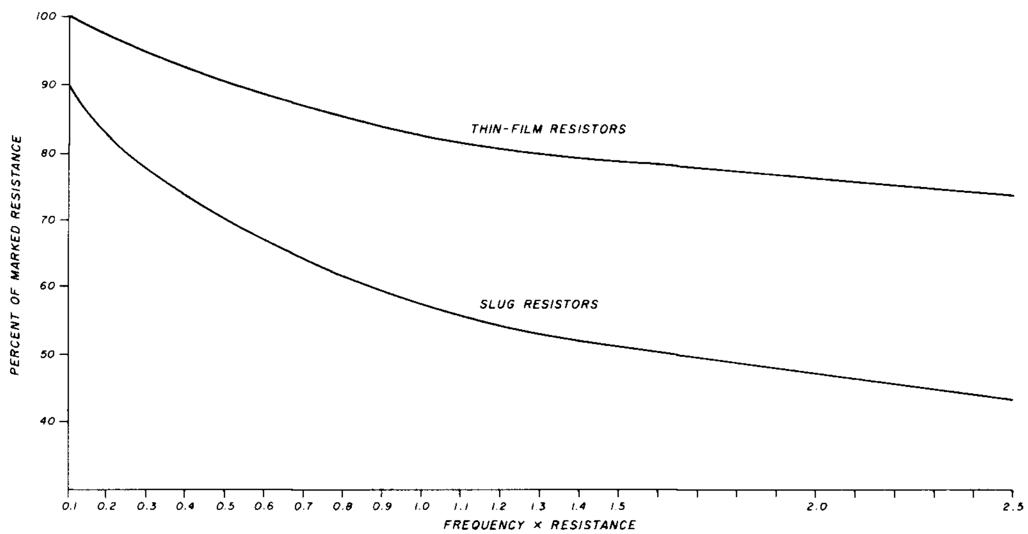


fig. 2. The product of frequency times resistance is shown on the horizontal axis. Frequency should be in MHz; resistance in megohms. The thin film resistors are clearly superior at radio frequencies.

operation

You can use the 20 kilohms of R3 by itself for routine frequency checking, with a short in the R4 position. Measuring circuit Q and resonant impedance is slightly more complicated. You have to make one or two voltage readings and do a little arithmetic.

The divider chip itself can be viewed as a generator with a low internal resistance. Shunting such a low resistance across a parallel-tuned circuit would greatly lower the apparent Q. The simplest way of avoiding this is to use a couple of megohms for R4 and make your measurements with a millivoltmeter.

If yours is a standard analog electronic voltmeter with a lowest range of 1½ volts, you can't do this. The rectifier response would be somewhere between linear and square law, but you wouldn't know where. The voltage readings would be completely unreliable. It's better in this case to keep the voltage to the rectifier high, assume that it's more or less linear, and make a correction for the shunting resistance. Here's how to do it.

Short the square-wave output terminal directly to the probe terminal. With no loads connected, switch the output to its lowest frequency range. Observe the voltage reading (use the dc scale). This should be around 4½ volts with a 12-volt supply. Call this voltage E.

Remove the short. Connect a suitable resistor in the R4 position. 50 kilohms would be a good value to start with. Now connect the probe to the tuned circuit and measure the voltage reading at resonance. Call this V_0. For best accuracy, V_0 should be somewhere around half to three-fourths of E. You may have to hunt a bit to get a resistor that brings V_0 within these limits. The amount of resistance required varies according to the resonant impedance of the circuit. If it's very low, you may have to use the minimum (R3 alone).

Once you get V_0 within the proper limits, measure the Q in the usual manner by detuning the oscillator until you get $0.707\ V_0$ either side of resonance.

$$Q_a = \frac{F_{resonant}}{F_{high} - F_{low}} \quad (1)$$

Q_a is the apparent Q not the true Q. To find true Q:

$$Q = Q_a \left[\frac{1}{1 - \frac{V_0}{1.27E}} \right] \quad (2)$$

The factor 1.27 comes about because the E you measure is a square wave and includes harmonics. Some of them tend to cancel the peak of the fundamental waveform. When the tuned circuit is connected, it bypasses these harmonics and they no longer affect things. (To be precise, 1.27 happens to be the coefficient of the first ac term in the Fourier series expansion of the squarewave after being normalized to the dc term.)

To find the tuned-circuit resonant impedance, you can use the formula

$$Z_0 = (R3 + R4) \left[\frac{1}{\frac{1.27E}{V_0} - 1} \right] \quad (3)$$

These results should be accurate to within about 10 per cent or so, assuming you're using 5 per cent resistors properly derated. Frequency readings will be a few per cent on the low side because of the parasitic shunt capacitances. Decoupling the test circuit by feeding it through a large resistor will greatly reduce this error, but the peaks are harder to locate.

By the way, if you're accustomed to using a dip meter, you'll notice something rather odd when measuring with this device. The precise peak at resonance seems somehow more elusive than the dip used to be. This is not just imagination. With the dip meter, the oscillator frequency tends to lock in with the test-circuit resonant frequency. This produces a sort of "slot" that holds the dip down over a certain tuning range and makes it more easy to observe. The effect is quite pronounced with very tight coupling to a very high-Q circuit. Such grabbing of control by what you're trying to measure is entirely absent with this gadget. The result is a somewhat different "feel."

conclusion

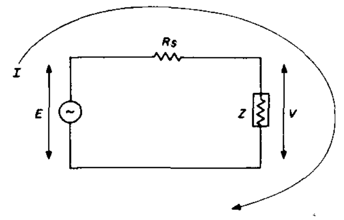
Despite its simplicity, this little indicator should be a big help in getting started at vlf. Now you *can* reach for your trusty dip meter — with the attachment — when working at 100 kHz. Or even 1 kHz!

reference

1. Keith Henney, *Radio Engineering Handbook*, McGraw-Hill, New York, 1959.

appendix

An approximate equivalent circuit, neglecting the internal resistance of the chip and the parasitic capacitances, looks something like this



$$E = I(R_s + Z)$$

$$V = IZ$$

At resonance $E_0/V_0 = (R_s + Z_0)/Z_0$

Hence $Z_0 = R_s/(E_0/V_0 - 1)$

As measured, E and V are real. Z is, in general, complex, which leads to complex equations. However, for Qs greater than about 10, the following reasoning is far simpler and leads to the same practical results.

First, define the true Q.

$$Q = Z_0/X_{L0}$$

When R_s is in parallel with Z_0 (through the generator), the effective parallel resistance is

$$(R_s Z_0)/(R_s + Z_0)$$

$$Q_a = [R_s Z_0/(R_s + Z_0)][1/X_{L0}]$$

$$= [R_s/(R_s + Z_0)]\,Q$$

Hence $Q = Q_a[(R_s + Z_0)/R_s]$

After substituting for Z_0 and some fiddling, you get the formula given. This notation is for sine-wave voltages. If E is a square wave some adjustment must be made, as indicated in the text.

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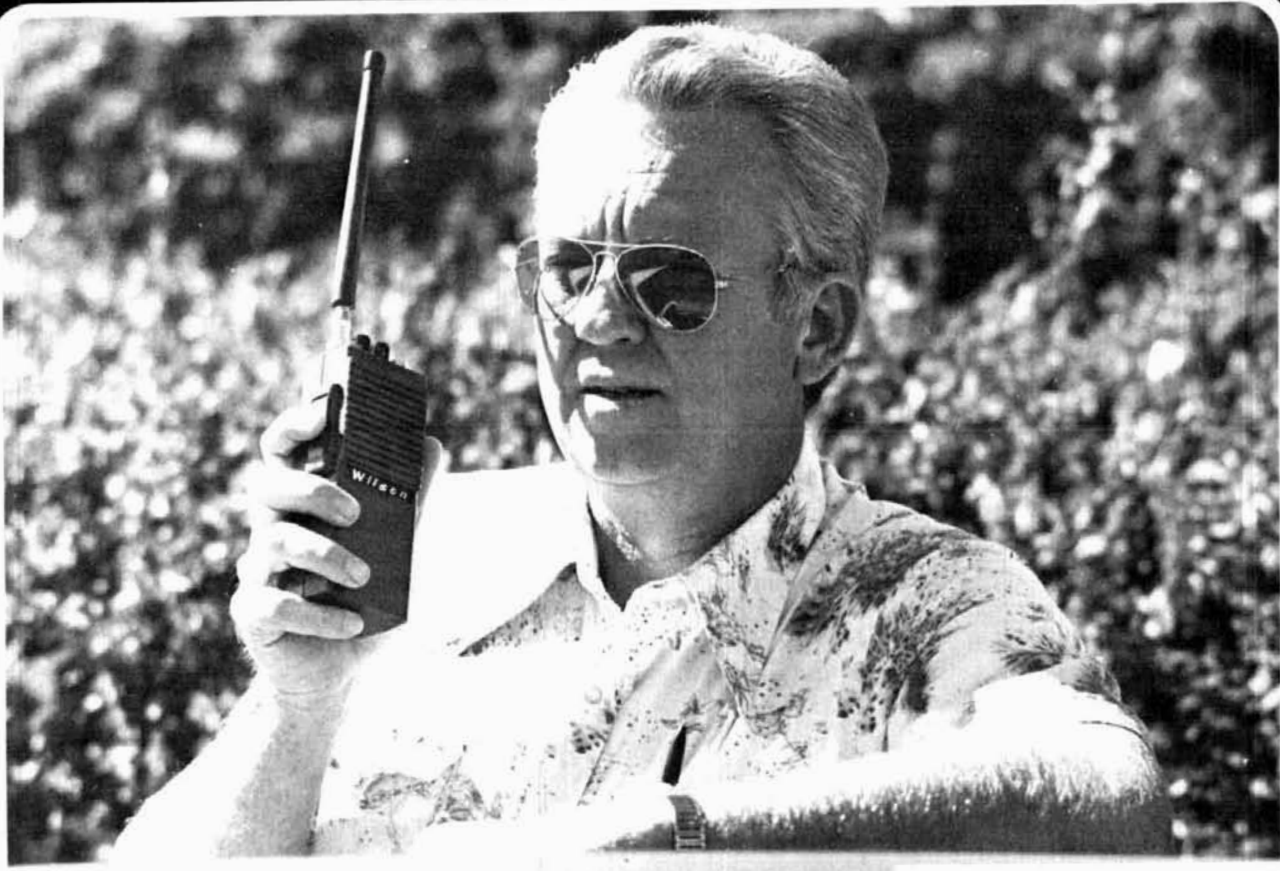

More Details? CHECK—OFF Page 110

ground systems for vertical antennas

Data to help you select the most efficient ground system for your vertical antenna

Over the past few years I've read and enjoyed the many articles about vertical antennas that have appeared in the Amateur magazines. Several of these articles refer to a very old research paper considered to be a classic in the field of ground system design.[1] I finally located this paper, which was written in 1937 by three engineers who worked for RCA in New Jersey. Several of their main points are summarized in this article, and the important results presented given in graphical form.

Using several different antenna heights, the RCA engineers measured the transmitted field strength at ground level, while varying the number and length of the radial ground wires. The radials were buried at about 15 cm (6 inches), with a test frequency of 3.0 MHz. One test, using radials laid on the surface of the earth, gave essentially the same field strength readings as when the radials were buried.

interpreting the graphs

First let's look at **fig. 1**. The actual measured field strength is plotted as a percentage of the maximum theoretical field strength for antenna heights from 10 to 90 degrees. Remember that one wavelength consists of 360 electrical degrees, so that 90 degrees equals 1/4 wavelength, while 45 degrees is 1/8 wavelength. Antennas taller than 1/4 wavelength were not used because of excessive height requirements. In **fig. 1A** each radial is 41 meters (135 feet) long, which amounts to 0.412 wavelength at 3 MHz. In **fig. 1B** each radial is 27 meters (90 feet) long (0.274 wavelength), while **fig. 1C** was plotted for 13.7-meter (45-foot or 0.137-wavelength) radials. **Figs. 2A** through **2D** show field strength as a function of antenna height for three radial lengths with the number of radials held constant.

What do these graphs mean? First, for any number of radials of any length, making the antenna higher will make it radiate more efficiently, although the graphs tend to flatten out in most cases once the antenna height reaches 1/8 wavelength or so. **Fig. 1C** shows that, even if many radials are used, the field strength doesn't exceed 80 per cent of the theoretical maximum value because the radials (just over 1/8 wavelength) are simply too short. Using only 15 radials in this case gives results almost as good as using 113 radials. This holds true even if the antenna itself is very short.

If you use radials of about 1/4 wavelength (as in **fig. 1B**), the measured field strength increases to about 92 per cent of the theoretical maximum if 113 radials are installed. Increasing the length of the radials still further, to about 0.4 wavelength, as in **fig. 1A**, brings the measured field strength to 98 per cent of the theoretical maximum, if you again use 113 radials.

Looking at **figs. 1A**, **1B**, and **1C**, you can see that if you use only two radials for your ground system, the field strength will be *virtually identical* no matter how long the radials. Even if you use a full-size, 1/4-wavelength vertical, the field strength will be less than 65 per cent of the theoretical value. As the number of radials increases, the improvement in field strength is progressively greater (the curves become further apart) as the length of the radials is increased. As you've already discovered from **fig. 1C**, putting down more radials may not yield much improvement if the radials are *too short.* Similarly, using very long radials is a waste of time if they are too few in number, as shown in **fig. 2A. Fig. 2D** illustrates the benefits that can be gained by using long radials if you can install a lot of them.

examples

1. Suppose you have a 15-meter (50-foot) tower section that's base loaded with a low-loss inductor, and the system is resonant in the 160-meter "DX window" at 1825 kHz. The antenna height works out to be slightly less than 1/10 wavelength, or about 35 electrical degrees. Thinking that you'll probably need lots of radials to get good efficiency with such a short antenna, take a look at **fig. 2D**, which is for a ground system of 113 radials. Using 0.137-wavelength radials (about 22.5 meters or 74 feet) the efficiency is about 68 per cent; it is 87 per cent for 0.274-

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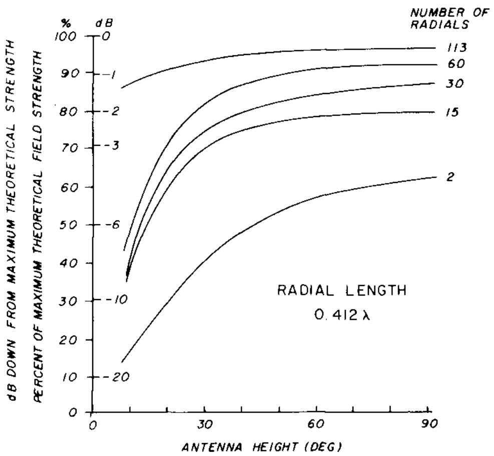
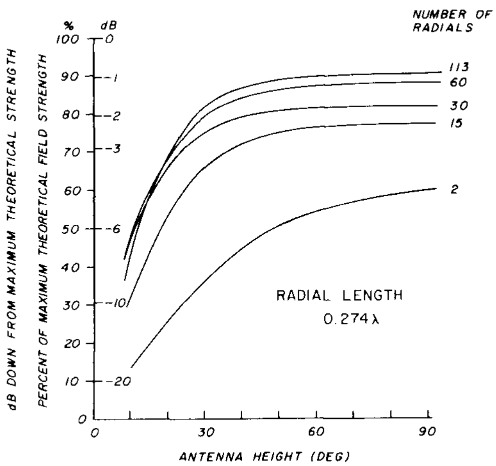
wavelength radials (45 meters, or 148 feet), and 96 per cent for 0.412-wavelength radials (68 meters, or 222 feet). By interpolation, 90 per cent efficiency would require 113 radials with lengths of about 0.32 wavelength (53 meters, or 173 feet).

Another approach is to use **fig. 1A**. About 96 per cent efficiency can be achieved by using 113 radials 0.412 wavelength long, as mentioned above. Using 60 of these radials yields 86 per cent efficiency; and, by interpolation, 90 per cent efficiency is attained by using 81 of these long radials. The first scheme requires 5948 meters (19,500 feet) of wire, while the second approach uses almost 5490 meters (18,000 feet).



A

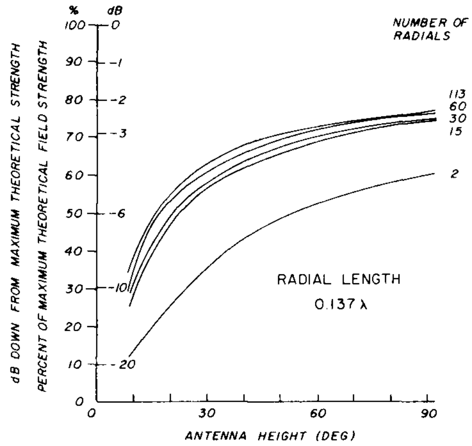


B

2. Suppose you have a phased array of 1/4-wavelength verticals on 40 meters, and want 90 per cent efficiency. From **fig. 1B**, it seems that 60 radials, each 0.274 wavelength (12 meters, or 38 feet) will give the desired result. Or you can use **fig. 1A** to determine that 38 radials, each 0.412 wavelength (17 meters, or 57 feet), will also do the trick. Total wire length is 695 meters versus 662 meters (2280 versus 2170 feet)

3. Suppose you have a four-band trap vertical (40 to 10 meters) and your yard is such that the radials can't be any longer than 5.8 meters (19 feet). This amounts to about 0.137 wavelength at 7150 kHz, so **fig. 1C** applies.

Now it looks like it would be a waste of time to put in more than fifteen radials, because very little field strength is gained by adding extra ones. But this is a multi-band antenna, and those 5.8-meter (19-foot) radials are 0.274 wavelength at 14.2 MHz and 0.412 wavelength at 21.34 MHz, so **fig. 1B** applies for 20 meters, and **fig. 1A** applies for 15 meters. If you use sixty radials, each 5.8 meters (19 feet) long, you won't get much improvement on 40 meters, but the increase from 15 to 60 radials yields a gain in efficiency from 79 per cent to 91 per cent on 20 meters and from 77 per cent to 94 per cent on 15 meters. The results on 10 meters are better yet. Radials that are "short" on one band may be quite "long" on another higher band.



C

fig. 1. Design data for ground radial systems. Graphs A, B, and C show actual measured field strength as a percentage of maximum theoretical field strength for various numbers of radials 0.412, 0.274, and 0.137 wavelength long.

A tall antenna will have a broader bandwidth than a shorter antenna of the same diameter, so if a short antenna *must* be used, make it "fat." Instead of aluminum tubing or pipe, make the vertical radiator from tower sections. Alternatively, a wooden telephone pole can be used to support a wire cage built around it. A short, fat antenna may have a bandwidth as great as, or greater than, that of a tall, thin one. A top hat can be used to capacitively load a vertical and make it seem taller. Experiments by W2FMI show that a top hat of diameter D will increase the effective height of the antenna by $2D$.[2] A taller antenna will also have a higher radiation resistance.

There's nothing sacred about a 1/4-wavelength vertical, but an antenna of this height will have zero reactance, and therefore may be easier to match to the transmission line because its base impedance will be purely resistive. As the antenna is made taller, up to a maximum of about 5/8 wavelength, the elevation angle of the major lobe of radiation becomes lower, which should improve the DX capabilities of the antenna. If a very tall antenna is erected, vertical stacking through the use of a coaxial sleeve or other means may be used to achieve extremely low radiation angles.[3]

conclusion

Remember that these graphs were drawn from data taken at a specific location in New Jersey, and results may vary somewhat depending on local soil conductivity. However, the general results are still useful and may be used as a guide. It's important to note that for any given length of radials there comes a point at which it's useless to install any more of them.

If the radials are short compared with the operating wavelength, radiation efficiency will be low and relatively few radials will be needed to reach this point. If the radials are quite long, then many can be installed before reaching the point of diminishing returns. The "classic" ground system used by a-m broadcast stations consists of 120 radials, each 1/2-wavelength long, which gives a radiation efficiency on the order of 95-98 per cent.[4]

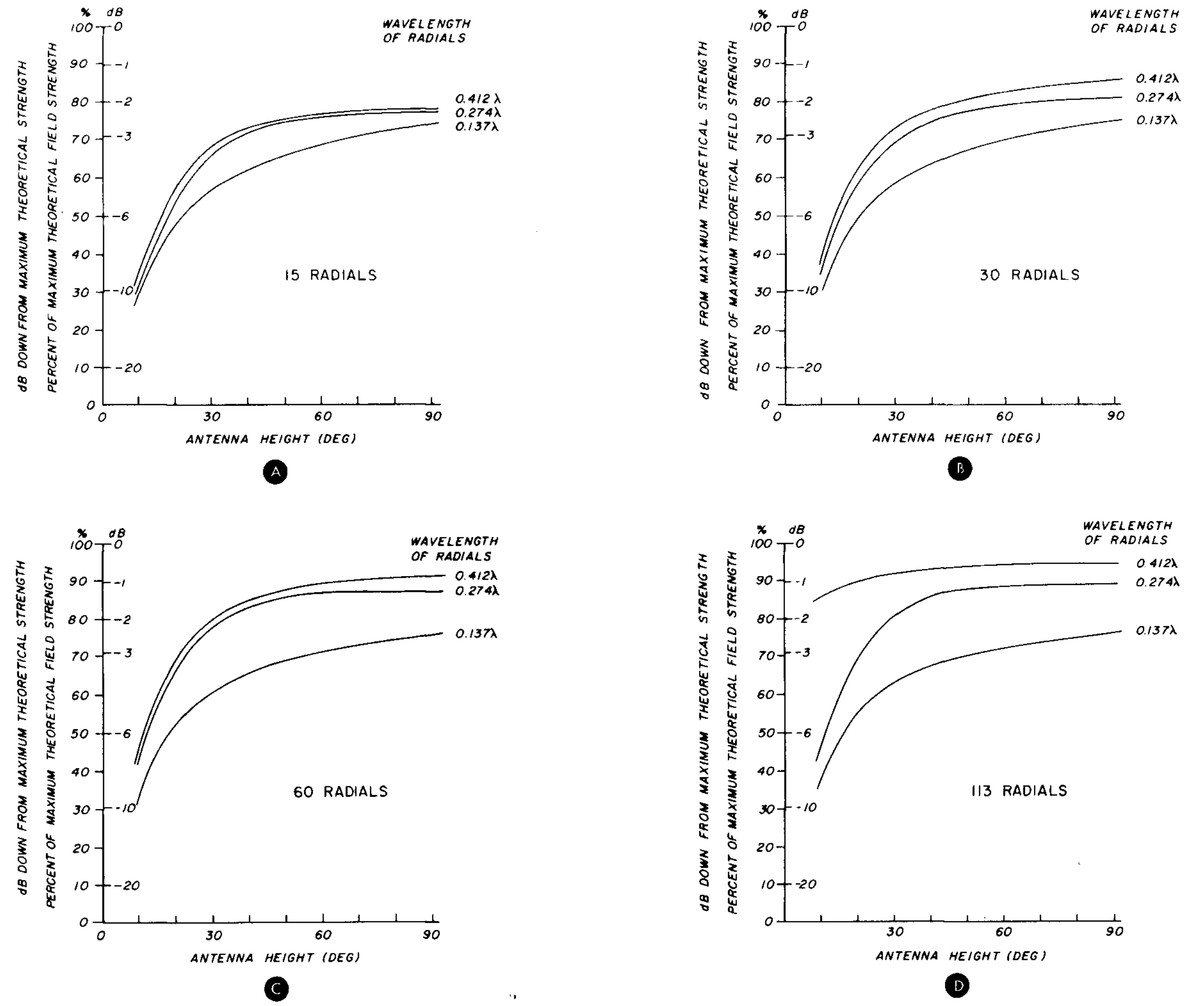


fig. 2. Performance comparison of fixed numbers of ground radials of various lengths. These graphs show measured field strength as a percentage of maximum theoretical field strength for 15, 30, 60, and 113 radials.

references

1. Brown, Lewis, and Epstein, "Ground Systems as a Factor in Antenna Efficiency," *Proceedings of the Institute of Radio Engineers*, June, 1937, page 753.
2. Jerry Sevick, "Short Ground-Radial Systems for Short Verticals," *QST*, April, 1978, page 30.
3. Paul Lee, "Theoretical Aspects of Vertical Stacking," *The Amateur Radio Vertical Antenna Handbook*, Cowan, 1974, page 43.
4. Keith Henney, *Radio Engineering Handbook*, McGraw-Hill, New York, 5th edition, page 20.

ham radio

all about traps and trap antennas

These days, almost everyone who enters the Amateur Radio hobby purchases or builds a bandswitching transmitter or transceiver covering 80 to 10 meters, allowing a degree of operating flexibility unknown in the days of single-band finals and plug-in coils. A logical extension of the bandswitching transmitter is an equally flexible antenna, capable of "instant" operation over the same bands the transmitter covers. Hence the trend to efficient, automatic, multiband antennas. One of the most popular, and technically sound, multiband antenna systems is the trapped antenna, both in its vertical and horizontal forms. Unfortunately, if ever there was confusion surrounding antennas, there's confusion about trap antennas; a great deal of mumbo-jumbo has been written about them.

In this article, I will attempt to set things straight with a discussion of some of the basic antenna concepts necessary to put traps in perspective, then I'll proceed to talk about both the trap dipole and the trap vertical. I'll also make some suggestions on how to feed, match, and tune the trap antenna, and discuss some possible problems you may encounter with harmonic radiation and television interference (TVI).

basic concepts

Many beginners do not realize the importance of using a good antenna, and, as a result, waste much of their transmitter power and spend much of their time unsuccessfully trying to make contacts. While virtually any piece of wire can be "loaded up" using a wide-range antenna coupler on any band, the performance of such a makeshift antenna will not likely set any DX records. Far better for single-band operation is the dipole, or "doublet," antenna, which is usually the simplest and most trouble-free kind you can use. The dipole is normally cut for the center of the desired band and fed with 50- or 75-ohm coaxial cable. A coax-fed dipole that is high and in the clear will usually work well over a range of ± 2 per cent of the center frequency before the mismatch even goes above 2:1.

A simple half-wave dipole is cut to frequency using the formula $F\ (in\ feet) = 468/frequency\ (in\ MHz)$.

Whereas the impedance at the ends of the antenna is quite high, approaching 3000 ohms or more, the center impedance of a high-frequency dipole at moderate heights runs about 50-75 ohms. This presents a good match for easy-to-handle coaxial cable. The other end of the transmission line (which may be of any reasonable length) is connected to the output connector of the transmitter or transceiver. Thus, a good match is also effected between the transmission line and the transmitter, which normally has a pi network output circuit designed to handle line impedances under about 100 ohms.

Problems arise when you try to use a dipole far from its design frequency: For example, using one cut for the center of the relatively wide 80-meter band (3750 kHz) at the high end, 4000 kHz. The impedance will then be reactive, since the antenna is no longer perfectly resonant, and it may result in a moderately high SWR and loading problems at the transmitter. Also, if you try to use a dipole that's cut for one band on another band, you may develop a severe transmission line mismatch (SWR) of up to 20 to 1 or higher. If you were to load up an 80-meter dipole with 40-meter rf from your transmitter, for example, you would find that the antenna no longer acts like an ordinary dipole, but rather like two half-wave antennas fed at their endpoints. The impedance might be around 3000 ohms, resulting in a mismatch to 75-ohm coax of about 40 to 1!

Thus, the dipole is essentially a single-band antenna, although there is an exception. At odd harmonics of its fundamental frequency the antenna's center impedance is low, so that it can be fed with low-impedance coax and work on certain higher-frequency bands. A 40-meter dipole, for example, can be used on 15 meters (21 MHz being an odd harmonic of 7 MHz); this fact is also made use of by trap manu-

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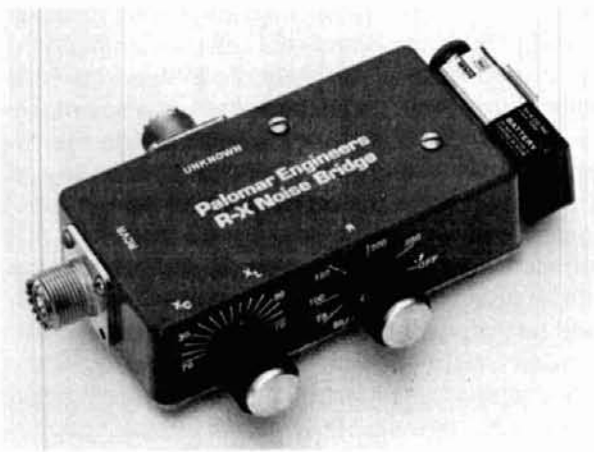
facturers to make possible operation on several bands using a minimum number of separate traps. In fact, the horizontal trap dipole is really an ingenious and versatile adaptation of the basic dipole or doublet.

What about verticals? I'll cover trap verticals later, but first I want to discuss basic vertical antenna concepts. The vertical is popular on all the high-frequency bands, and especially on the three highest bands (20, 15, and 10) for DX work. The simplest vertical is a quarter-wavelength long, fed "against ground" or connected to "artificial" groundplane radials tied to the base of the antenna. The groundplane, or earth, acts as a sort of mirror image for the antenna, allowing it to be a quarter-wavelength long rather than a full half-wavelength. The vertical's feedpoint impedance is usually between 25 and 40 ohms, so it offers a fair match to 50-ohm coax.

The vertical's popularity stems from two factors. The first is that it is a space saver; all one needs is vertical space, rather than a long horizontal antenna "run." If buried ground radials rather than aboveground radials are used, no horizontal space at all is required. (Of course, to be effective, the vertical should be installed as far as possible from other objects, such as house and utility wiring, and the ground system should be as extensive as possible.)

The second factor promoting the popularity of the vertical antenna for high-frequency work is that it produces a low angle of radiation, which places maximum signal near the horizon for good effect when working DX. When compared with a horizontal antenna mounted 10 to 15 meters (30 to 50 feet) high, the vertical will usually perform better over longer hauls, roughly 950 to 1300 km (600 to 800 miles) and beyond. On the other hand, the horizontal will usually give a better account of itself over shorter distances. The choice of vertical versus horizontal antennas for the high frequencies depends a great deal on what you want to use them for — and also on individual preference. Overall, I prefer the horizontal on 80 and 40 meters (for short- and medium-haul work), and the vertical on 20, 15, and 10 for longer-path DX.

Traps and completed trap antennas may be fine tuned to resonance using an rf noise bridge such as the one shown here. The traps may also be adjusted using a grid-dip oscillator, and overall antenna performance may be checked with the aid of an SWR (standing wave ratio) bridge (*photo courtesy Palomar Engineers*).



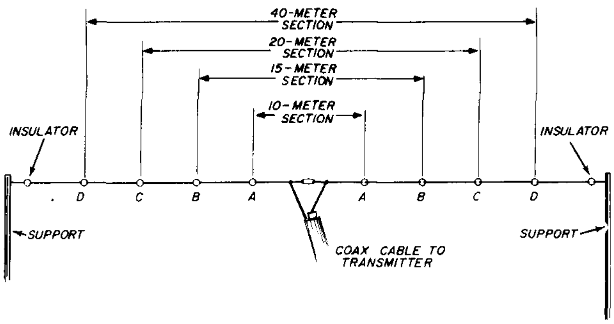
variations on a dipole

Lack of space has prevented many an Amateur from putting up any satisfactory antenna for the high-frequency bands, let alone install multiple antennas for each band on which he might want to operate. In many cases, an antenna length of about 30 meters (100 feet) is all that can be managed on a small city or suburban lot, not quite enough for operation on 75 and 80 meters. The trap antenna offers promise in this case, since its traps act as loading coils to "shorten" the required length to between 30 and 35 meters (100 and 110 feet) for 80-meter operation, and the electrical characteristics allow the antenna to be fed easily on the higher bands by an untuned (coax) feedline.

Trap operation is actually quite simple. Each is a parallel-tuned LC coil and capacitor circuit which is installed in the antenna to "divorce" the remainder of the antenna from the section on the "inside" of the traps. The principle involved is that an inductor and capacitor in parallel, when tuned to a given frequency and installed in a line, present a near-infinite impedance to rf current at that frequency. In effect, the parallel circuit acts to "trap" that particular frequency, acting as though it were the end of the antenna for that frequency. At all other frequencies (both above and below the trap's resonant frequency), the trap is a short circuit so that rf passes through it as though is were not there.

Several trap dipole configurations are popular. In a simple trap scheme, only one pair of traps is required for operation from 80 through 10 meters. In this case, a basic flat-top length of about 32.4 meters (108 feet) is used for 80-meter operation, the shortening being due to the electrical loading caused by the traps. On 40 meters, the traps insulate, or "divorce," the outside wire sections so that the antenna looks electrically like a 40-meter dipole. On the higher bands — 20, 15, and 10 meters — the trap dipole works out to electrical lengths that are roughly odd multiples of half-wavelengths (such as three half-waves on 20, five half-waves on 15, and seven half-waves on 10). Thus, use is made of the same principle that allows a simple 40-meter dipole to work on 15 meters.

In a more complex trap arrangement, a pair of traps (one on each side of antenna center) is required



selected trap and trap antenna suppliers

Antenna Supermarket, Post Office Box 1682, Largo, Florida 335450

Butternut Electronics Co., Route 1, Lake Crystal, Minnesota 56005

Cushcraft Corp., Box 4680, Manchester, New Hampshire 03108

Electrospace Systems, Inc., Post Office Box 1359, Richardson, Texas 75080

Hy-Gain Electronics Corp., 8601 Northeast Hwy. 6, Lincoln, Nebraska 68505

Mosley Electronics, Inc., 4610 Lindbergh Blvd., Bridgeton, Missouri 63044

New-Tronics Corp., 15800 Commerce Park Drive, Brookpark, Ohio 44142

Pace-Traps, Box 234, Middlebury, Connecticut 06762

Unadilla-Reyco Div., 6743 Kinne Street, East Syracuse, New York 13057

Western Radio, Box 400, Kearney, Nebraska 68847

Wilson Electronics, 4288 S. Polaris Avenue, Las Vegas, Nevada 89119

fig. 1. Typical 80-10 meter multiple trap antenna using four pairs of traps. Section A-A forms the 10-meter antenna; the traps at the end of this section consist of resonant inductor/capacitor circuits which isolate the rest of the antenna when operating on 10. Sections B-B, C-C, and D-D work similarly on 15, 20, and 40 meters. The full antenna resonates on the 80-meter band, but is slightly shorter than a full-size dipole due to the loading effect of the coils. Antennas can also be constructed using fewer traps, as explained in the text. The antenna should be installed at least 10 meters (30 feet) above ground; plastic clothesline or rope can be used as halyards. The trap antenna can be fed with either coaxial cable or with 72-ohm twinlead, which should be run from the antenna at right angles as far as possible; slight tension on the feedline will minimize swing.

for each band (except the lowest). For example, to cover 80, 40, and 20 meters, you would need two pairs of traps — one for 40 and another for 20. A pair is not required for 80, since the antenna itself resonates on that band. For five-band coverage from 80 through 10 meters, you would use four pairs of traps. In this scheme, the antenna is resonated by the single-band traps as a "true" half-wavelength dipole on each band, rather than as some multiple of a half-wavelength as in the simpler arrangement. Any combination of traps can be selected to make a "custom" multiple-band trap antenna, such as one covering 160 and 20 meters, or 80, 20, and 15 meters, to cite but two of many possible examples. **Fig. 1** shows *trap arrangement in a multiple-trap antenna.*

Either trap scheme is capable of delivering good results. In the single-trap version, you can adjust the antenna length for the two lowest bands, but exact resonance on the higher bands (such as 20, 15, and 10) may not fall where you want it to fall and a high SWR may result. On the other hand, single trap antennas are lightweight; if matching becomes awkward, the feedline length can be adjusted to allow the antenna to take power, or an antenna coupler to be used. The multiple trap kind has the advantage that it can be adjusted for a low SWR on each band, but interaction between the traps can make adjustment tricky. Also, the many traps involved can introduce some system loss, and the antenna is heavy. In either case, trap antennas are not broad-band antennas, and they will show an increasing SWR as they are operated farther away from the center frequencies. Usable bandwidth is typically several hundred kHz, depending on the band, the design of the traps, and the physical antenna length involved. Although the ARRL *Radio Amateur's Handbook* and *Antenna Book*, as well as numerous Amateur magazine articles, describe trap construction, in some respects it's a good idea to purchase commercial traps, because the required low-loss construction and weatherproofing can be tricky.

Antenna installation is more critical with trap antennas than single-banders, especially since trap resonances are set assuming a high and clear antenna and they can easily be upset if these conditions aren't met. It's worthwhile to mount the trap dipole as high as possible, at least 10 meters (30 feet). If possible, the antenna should be a wavelength or more away from buildings and other obstructions, especially metallic towers and utility lines. It should also be well clear of tree limbs. Plastic clothesline (the kind without a metallic core) or rope can be used to support the antenna ends; the transmission line should be run away from the antenna at right angles for as far as practical and can be stapled directly to the house siding or run through TV-type standoff insulators in the shack. Do not try to use a trap dipole in a very limited space by bending down the ends at right angles; this will usually upset trap operation and detune the antenna, as well as unpredictably distorting the radiation pattern.

If space is a problem, however, you can run the flat-top in a horizontal-V or inverted-V shape with good results; many Amateurs actually prefer the V, believing that there is some apparent gain on the higher bands, directivity is enhanced, and the angle of radiation (for DX) is lowered. Inverted-V configurations have the advantage that the antenna requires only one high center mast, as the ends are sloped downward and can be suspended from convenient lower supports. There is no hard and fast rule about the angle of the V, but 90-120 degrees is normally used; it should not be less than about 75 degrees. Such arrangements are perhaps the best way to get on the air on several bands from a small city lot, yet allow for some directivity and gain which can be helpful in competing on the higher bands. **Fig. 2** shows some popular V configurations.

What about antenna placement and directivity? Generally speaking, since the trap dipole is, essentially, a dipole, the signal pattern will be bi-directional and roughly doughnut shaped, with maximum signal perpendicular to the wire direction (90 degrees). Maximum radiation angle will be about 30 degrees from the horizontal. These figures assume an antenna height of about a half-wavelength, although fairly similar patterns will result if the antenna is at least an eighth to a quarter wavelength high. As a practical matter, directivity will not be pronounced on 80 meters and will be only slightly noticeable on 40. On the higher bands (20, 15, and 10), however, the antenna becomes much more directional, and optimum radiation departs from the doughnut-shaped pattern to become more of a cloverleaf, with maximum radiation lying about 30 degrees off the ends. This is especially true of single trap dipoles where the antenna operates at some multiple of a half-wavelength.

Thus, if you were to run your antenna east and west, maximum signal would be radiated southwest, northwest, northeast, and southeast. If possible, orient the antenna so that the four main lobes of the cloverleaf lie in the most favorable directions from your particular location for working DX on these bands. If you use the V or inverted-V configuration, the antenna becomes more sharply directional, with some gain apparent on the higher frequencies. Some typical radiation patterns are shown in **fig. 3**.

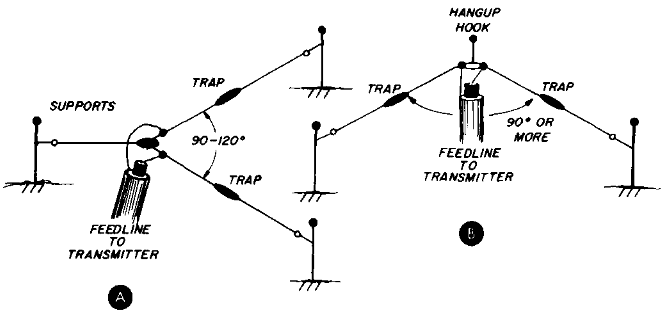


fig. 2. Diagram at (A) shows a V trap dipole, which can allow relatively long antennas to fit on small city and suburban lots. Three supports are required; the antenna is more directional than a straight dipole and may exhibit a few dB gain, particularly on the higher frequency bands. Diagram (B) shows an inverted-V trap dipole, which can be hung from a high center mast and the ends run to lower supports to form an approximate 90-degree angle at the apex. This arrangement is a favorite with DXers for improved low-angle radiation characteristic. The two configurations may be combined to form a so-called sloping-inverted V but the radiation pattern may become rather unpredictable.

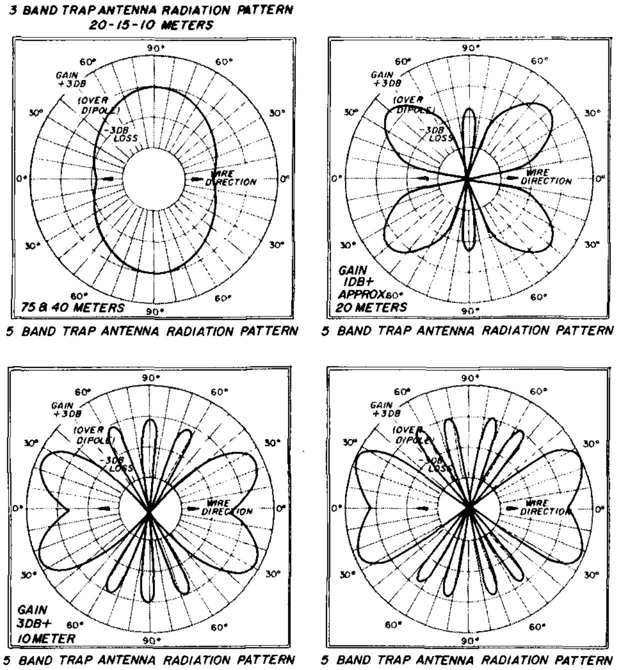


fig. 3. Typical trap dipole radiation patterns. The familiar doughnut-shaped patterns tend to become cloverleaf-shaped on the higher bands, where directivity is much more pronounced. The radiation pattern will vary from the patterns shown for V and inverted-V configurations. Vertical radiation patterns depend largely on the antenna's height above the ground or the structure on which the antenna is mounted. For best results, the antenna should be installed at a height of about 10 meters (30 feet) or more.

A logical extension of the trap antenna is the multiband rotatable beam, usually in the form of a tribander covering 20, 15, and 10 meters. The tribander uses the same trap principles in resonating the director and reflector elements of the beam to give the antenna its directionality, front-to-back ratio, and gain figure. Few commercial trap beam antennas are available for 80 and 40 meter operation due to their unwieldy size, but for the high-frequency DXer, the three-band trap beam is probably a "best bet" if separate, full-size beams can't be installed.

trap verticals

The trap vertical's operation is very similar to that of the trap dipole; it works on the same principle.

As I've indicated, the quarter-wave vertical is a single-band antenna. But, like the dipole, it can be put to use on odd harmonics of its resonant frequency, so you can use the same antenna on, say 40 and 15

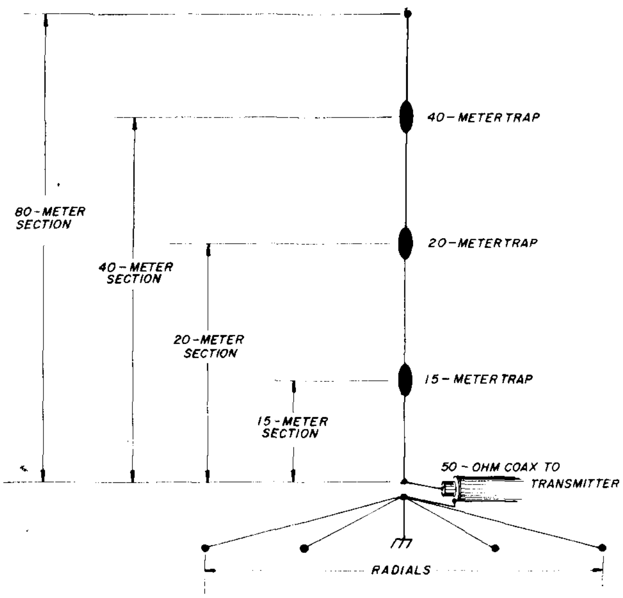


fig. 4. Typical trap vertical antenna configuration. The example shown operates on four bands, 80 through 15 meters, and uses three traps; many other variations are possible. Each trap isolates the higher sections as required to simulate a resonant quarter-wavelength at the operating frequency. A good radial ground system or groundplane is essential for good efficiency in the vertical antenna.

meters because of this special relationship. Besides the fact that the vertical is essentially a one-band antenna, its length for the lower bands, such as 160 and 80 meters, is much too long for most tastes. Many hams feel comfortable working with a length up to about 15 meters (50 feet), but not the 19.5 meters (65 feet) of an 80-meter vertical or the 39 meters (130 feet) of a full-sized 160-meter "skypole." As in the case of the dipole, the addition of the traps has a shortening effect on the antenna, so that the typical 40-10 meter trap vertical is somewhat shorter than 10 meters (33 feet). Verticals that are to be used on 80 or 160 also are longer for good efficiency on these bands, but shorter sticks can be used by installing add-on base loading coils at the expense of radiation efficiency. One trap per band (for all bands except the lowest) is usually installed to cause each section of the antenna to act as a quarter-wave vertical (although fewer traps may be used in certain designs). Thus, an 80 through 15 meter antenna is about 15 meters (50 feet) high and uses three traps in order to get four-band performance, as shown in **fig. 4**; sometimes 160 meters is added by means of a base loading coil or "resonator." The ground radials effectively provide the "missing half" of the antenna.

Like the standard single-band vertical, the trap radiates most of its power omnidirectionally at low angles above the horizon, and thus is a good choice for DX work. Unfortunately, many beginners have had poor results using trap verticals, but this is usually the result of mounting the antenna too close to signal-robbing obstructions, or not using a good ground system, or trying to work with a "too-compact," highly shortened vertical (especially on the lower bands, such as 80 and 160).

The trap vertical is a bit more sensitive to mounting position and grounding than single-band types; trap operation is easily upset by proximity effects. The antenna should be installed well clear of buildings, rain gutters, trees, and utility wires for good operation and low SWR. A good ground is extremely important for efficient performance. This means using six to twelve radials buried at least 15 cm (6 inches) in the ground, one or two ground rods at the base of the antenna, and possibly a direct connection to the house's cold-water piping. Without a good ground, much of the transmitter's power will be dissipated as heat, and the ground will not provide the proper mirror effect necessary for good results. If it is impossible to get a good ground connection, or if there are too many power-absorbing objects near the antenna when mounted at ground level, you can construct an artificial ground system, known as a groundplane, using at least four wires, or radials, connected together at the base of the antenna and running away from it like the spokes of a wheel. Usually, four quarter-wavelength wires are used, but, in the case of the multiband trap vertical, these would only be a quarter-wavelength for one band. In this case, you could run several quarter-wavelength wires for the lowest band to be used, and add several shorter "random" lengths which would take care of the higher bands. Using an artificial groundplane with a trap vertical is necessary in some congested locations and when the antenna must be installed atop a high building. In any case, be sure to carefully follow the antenna manufacturer's suggestions for mounting and grounding whenever installing a trap vertical, since the ground system is an integral part of the antenna.

You should also be aware that there is another type of multiband vertical that is technically related to the trap but is a good deal less expensive due to its much simpler mechanical construction. This is the base-loaded vertical, which uses a section of aluminum tubing usually between 4.8 and 10 meters (16 and 33 feet) in length; it has a tapped loading coil connected to it at the ground end. By making adjustments to the coil, the antenna can be resonated and matched closely on each band. However, since there are no traps, the antenna does not automatically switch bands, but requires that the operator change tap settings outdoors at the antenna when switching bands. (Remote switching arrangements are possible using relays controlled from the radio shack; these can become quite complex, however, for five-band operation.)

feeding, matching, tuning, and harmonics

The trap dipole can be fed with 50- to 75-ohm coaxial cable (using either RG-58/U or RG-59/U for moderate power levels — RG-8/U or RG-11/U if you're running a full kilowatt); the antenna impedance at resonance will usually fall in this range. The larger coax will also have the lowest loss, and, if you use a cable having a polyfoam center insulating material, it will have about 30 per cent greater power-handling capacity and a similar reduction in signal loss. If you must use a long feedline, use the larger-size cable with foam insulation.

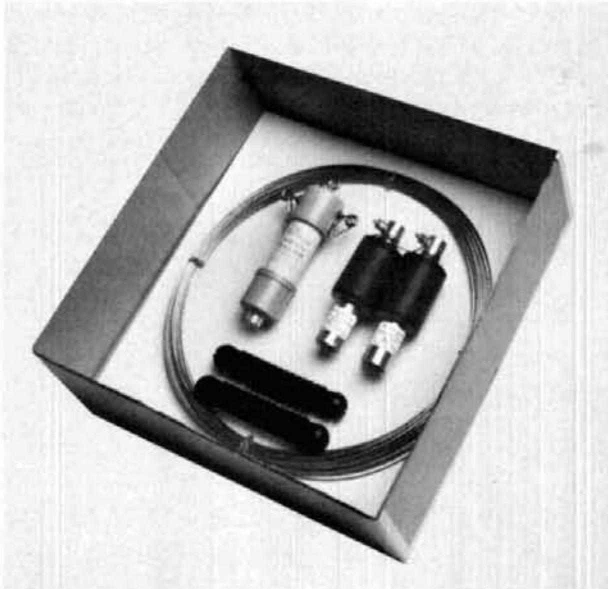
Since the dipole antenna is a balanced, or symmetrical, type, if you are using coax feed you may want to use a 1:1 balun transformer as the center insulator; this is not absolutely necessary, but using a balun can help equalize rf flow and prevent antenna current from flowing down the outside of the coaxial cable, causing distortion of the radiation pattern and possibly TVI. Commercial baluns are small devices resembling center insulators; most of them also have a convenient hang-up hook for V configurations and a coaxial connector.

You can also use 72-ohm twinline as the lead-in; it is less expensive than coax, and, since it is balanced, it does not require the use of a balun at the antenna — although you may still want to use one at the transmitter to mate with the coax output of most transmitters and transceivers. This type of line is frequently "lossier" than coax, however, and it should not be used on long runs, say over 45 meters (150 feet), unless special low-loss, transmitting-type twinline is used.

The vertical trap antenna should be fed with 50-ohm coax, and, if the cable is to be buried, the heavier RG-8/U type is preferred. A balun is not used with the vertical since it is an "unbalanced" type of antenna and works quite well when fed directly by coax.

I should point out that any multiband antenna, trap types included, involves compromises to allow it to cover several bands. It is not possible to get a perfect match on each and every band, or from band edge to band edge. Some advertising literature leads one to believe that the trap "match" is perfect over all bands, but this is not so. In most cases, it is necessary to adjust the traps, shorten or lengthen sections of the antenna flat-top, or even change transmission line length to get uniform transmitter loading on all bands.

What is important is to get a reasonable match across all the bands that you want to use; if the feedline isn't too long, losses will not be excessive and the antenna will work well even on the higher bands with SWRs of 4:1 or 5:1, although you may want to use an antenna tuner to facilitate loading.



Representative trap multiband antenna coils. The coils electrically isolate portions of the antenna flat-top depending on their resonant frequency. Electrically similar but mechanically different coils can also be used in connection with vertical antennas for multiband operation (*photo courtesy Unadilla/Reyco*).

When using traps, you may find that one or more bands show a higher SWR than desired. Since most commercial traps are pre-tuned and sealed, this means that you must adjust antenna section lengths to "tweak" the SWR into shape. Reyco, in its product literature, gives a simple procedure for adjusting the traps in a dipole: After constructing the antenna according to the recommended dimensions, each band is checked for SWR (starting with highest band) and the point of lowest SWR is noted. If the resonant frequency is too high, the center sections are increased slightly in length until the SWR is lowest at the desired operating frequency; if too low, the lengths are decreased. The same procedure is followed on each band, working from the high to low, adjusting the wire sections between traps. Using the one-pair type system, you can use this procedure for the two lowest bands, but adjusting the lengths for best operation on, say 80 and 40 meters may "throw out" the SWR on one of the higher bands. These effects can't be overcome, but they can be minimized by cutting the feedline to certain lengths. Doing this will not affect the true SWR, but can help the transmitter to "see" a good match. You should find that starting with coax lengths of about 13.5, 25.5, 33, and 40.5 meters (45, 85, 110, and 135 feet), or twinlead lengths of 22.5, 30, 33, and 39 meters (75, 100, 110, or 130 feet) should reduce loading problems on the higher bands; the feedline can be lengthened or shortened as necessary to get a good compromise match on all bands. It may not be possible to get a perfect match on all bands, however, and trying to get the match down from, say, 2:1 to 1:1 on each and every band can be extremely frustrating and is probably just not worth the effort in terms of improved ability to get out.

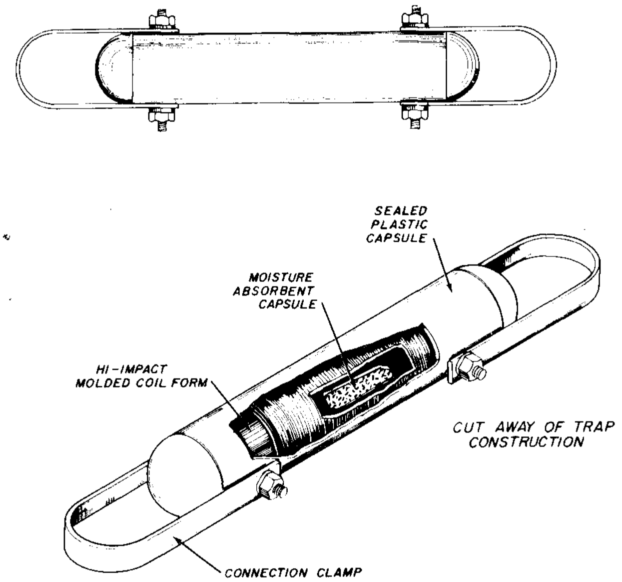


fig. 5. Representative exterior sealed trap construction is shown at (A). In this case, the trap itself is encapsulated in high-impact plastic which offers protection against the elements. The antenna wires are attached to the trap by means of two metal U-clamps. An interior view of the same trap is shown at (B). Traps designed for multiband beams and verticals are electrically similar, but are usually encased in or wound over fiberglass forms for added strength. For lowest loss, there should be no metal inside the rf field of the trap coil.

Trap verticals are tuned in similar fashion, but instead involve either sliding the aluminum element lengths, tuning the traps themselves, or adjusting a special top-hat section. In most cases, you can get good results using nothing more than your SWR bridge in adjusting commercial trap antennas, but if you build your own traps (whether for dipole or vertical use) you will have to first adjust them for resonance using a grid-dip oscillator or rf noise bridge, then seal them against weather before installation. **Fig. 5** shows typical trap construction.

There is a potential problem in using multiband trap antennas that should be carefully considered, and that is the problem of harmonics. While a single-band antenna will reject even harmonics of the operating frequency, that rejection just isn't there in the trap antenna, and, in fact, any harmonics present are efficiently radiated. This is an especially critical problem when using a five-band antenna system, since harmonics of even 80-meter signals will be radiated nicely through at least ten meters; this problem has caused many unsuspecting Novices operating on 80 and 40 to receive FCC citations for radiating out-of-band signals. While most pi network output circuits have good harmonic suppression, if they are loaded too heavily (such as when trying to get a high-SWR antenna to take power), their harmonic rejection can be destroyed and second-, third-, or higher-order harmonics are passed on to the antenna and radiated.

You can make a rough check on your own harmonics by having a friend listen to your signal on harmonically related frequencies; if he is located a short distance from your home, your signal should be received very weakly, if at all, on harmonics. This is not an infallible test, however, and a more certain approach to harmonic suppression is to use an antenna coupler or tuner in the transmission line between your transmitter and the antenna. The tuner will add a great deal of selectivity to the antenna system, causing harmonics to be reduced to an acceptable level. In addition, the tuner also helps the transmitter to "see" a near-perfect 50- to 75-ohm match and thereby load more consistently from band to band. This is a real plus when operating with a moderately high SWR on the transmission line, frequently the case when using multiband antennas. In addition if the coupler is installed so as to be in the circuit on receive (automatically the case when using a transceiver), it will add a good deal of front-end receiving selectivity as well, helping to prevent i-f image signals and very strong local stations on other bands from coming through and cross-modulating the receiver's front end.

Not to be overlooked is the increased potential for TVI (television interference) when using multiband antennas. Certain conditions may cause the antenna to radiate vhf harmonics of your high-frequency signal, particularly on the lower TV channels (2 through 6). The short, well-matched transmission line between the transmitter and antenna coupler or tuner makes an ideal spot to install a lowpass filter, as shown in **fig. 6**; placing it there prevents any possible danger to the filter from high SWRs or upsetting its operation by SWR mismatches. The use of a good lowpass filter (which in itself can provide 60 dB or more harmonic attenuation) in connection with an antenna tuner should keep you out of trouble with both the FCC and your neighbors.

summary

Trap antennas, both horizontals and verticals, offer much to the ham who has space limitations and cannot erect separate antennas for each band. Traps are capable of excellent performance if installed and adjusted properly, but one should keep in mind that certain trade-offs are involved in their design; this fact must be recognized when interpreting their performance.

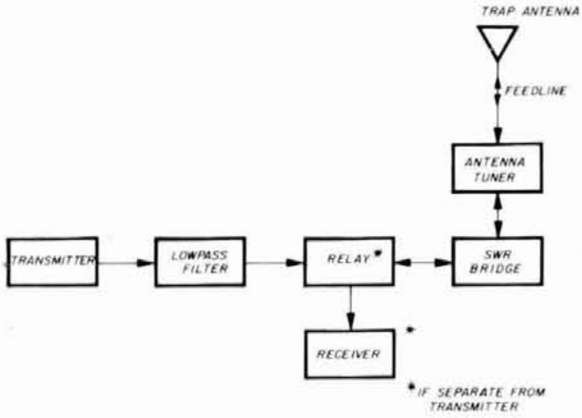


fig. 6. Suggested multiband trap antenna system feeding arrangement. Due to the inherent nature of trap and other multiband antennas, harmonics are easily radiated. For this reason, you should use a lowpass filter and antenna coupler to suppress these harmonics. The antenna relay shown is required only if a transmitter is used, that is, if you are not using a transceiver. If you use a separate receiver, by placing the antenna relay as shown the antenna coupler is used to good advantage on receiving as well. While either 72-ohm twinlead or coax may be used to feed the trap antenna, coax is usually the best choice. In adjusting the antenna length, move the SWR bridge to the antenna side of the coupler; once the adjustments are made, place the bridge as shown for routine tuneup.

Trap antennas can take the place of five or more individual antennas. Remember that your trap is doing a big job for you, so install and treat it right. If you do, you can expect excellent performance from it.

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ham radio

More Details? CHECK—OFF Page 110

curing frequency drift

in the Swan 350 transceiver

A frequency counter, some deliberation, and a handful of capacitors will help tame frequency drift in this popular rig

I recently undertook the task of reducing the more than 1-kHz frequency drift in K6OWA's Swan 350C transceiver. Since then I've had several queries from others who own these reliable rigs. The availability of a frequency counter made this project easy to implement. This article summarizes the techniques I used so that other Swan 350 owners can reduce frequency drift to a tolerable level. The final drift (or lack of it) achieved by this electronic surgery depends on your determination and patience.

analysis

Most VFOs drift to a lower frequency. However, K6OWA's Swan 350 had a positive frequency drift. Most drift occurs in the VFO coil, caused by changes in coil dimensions with temperature. Drift in the Swan 350 is likely aggravated by the seven tubes clustered around the VFO box. Lack of ventilation traps the heat inside, thus extending the time before drift levels off. On-off cycling over a period of years will gradually stretch the coil wire to the point where it will not return to normal — something like the "set" of a fishing pole. Compensation originally found adequate will no longer keep the drift within reason.

It's interesting to compare specifications of maximum frequency drift in present-day rigs. Several well-known units list 1 kHz, some less than 300 Hz, and a very few 100 Hz. My TS-520, rated at 2-kHz, came out with 75 Hz. Both the Alda 103 and the Swan 100MX are rated at less than 100 Hz. The ARRL's *Amateur Radio Handbook* (1976), on pages 166 and 169, shows homebrew VFOs. One stabilizes in 1½ *minutes* at 15 Hz, while the other levels off in only 30 *seconds* with a 25-Hz drift. Truly amazing.

mechanical considerations

Since mechanical ruggedness is synonymous with low frequency drift, begin by tightening *all* nuts and bolts around and in the VFO compartment, including the five screws holding the band coils to the chassis. In some cases the VFO circuit board is underneath the chassis and not in the can. Then apply Lubriplate to the bandswitch bearings to reduce torsion on

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these parts. Thoroughly clean all eight wafers with contact cleaner and remove lint and dirt from the variable cap plates with a pipe cleaner.

compensation

The next step, compensation, will be facilitated by the use of a 7- or 8-digit frequency counter. Absolute accuracy isn't imperative because the counter records approximate drift only. Begin with the chassis lying on its final-amplifier side, and connect a short piece of wire to pin 1 of the VFO amplifier, V1, (see your schematic). This will permit attachment of a counter probe with less chance of short circuits to other leads.

Set the bandswitch to 20M and the dial to 14,200 kHz. When the set is turned on, the counter will read roughly 8700 kHz, as noted on page 14 of the Swan manual. During the first run, connect a voltmeter to read the −10 volt bus from zener diode 1N2974. If this voltage is steady during a 45-minute test the zener need not be replaced. (A faulty diode will cause shift, however.) Leave the cover on the VFO box to simulate normal conditions. Have a sheet of paper ready to log data each five minutes from the moment the set is turned on. At least 30 minutes should elapse — certainly long enough to see a leveling off or maximum drift.

Turn off the Swan 350 and let it cool for the next run. Meanwhile make a graph of the first run as in **fig. 2**, curve A. K6OWA's Swan 350 was still increasing in frequency after 45 minutes (past 1200 Hz). If experience convinces you that drift occurs on only *one* band, refer to your schematic and **fig. 1**, noting capacitors 1711, 1713, 1718, 1720, and 1723. These negative temperature coefficient caps compensate each band, the idea being that each coil needs individual compensation, and C1709 in series with the variable cap takes care of things in general. Most likely this won't be the case — cap C1709 will be removed and replaced, thereby compensating all bands.

You're now ready to make a substitution for C1709. Remove the VFO cover plate, probe, and voltmeter leads. Unsolder the rf and dc leads from beneath the chassis. (Two nuts and washers under the chassis and two nuts, washers, and two spacers hold the PC board to the chassis.) With the Swan 350 lying on its side, remove the PC board. This will position the PC board horizontally and will make board removal and replacement easier because the hardware won't get lost in the equipment innards. The spacers especially have a nasty habit of getting lost if removed with the board in a vertical position. Unsolder C1709 at the variable cap (C1706) and carefully pull the PC board from the compartment.

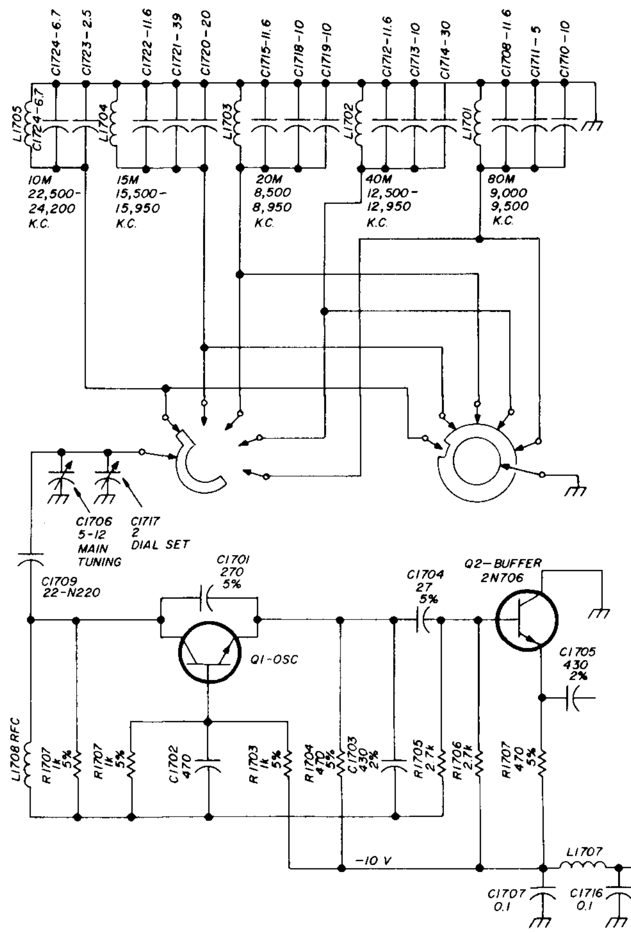

fig. 1. Partial schematic of the Swan 350 transceiver showing the VFO section. Capacitor C1709 is the subject of the modifications in this article.

compensating capacitors

Capacitor C1709 is really an unknown and is suspect. Discard it since it's incapable of compensating for the inherent frequency drift. The Swan manual specifies C1709 as a 22-pF capacitor with an N220 temperature coefficient, meaning 220 parts per million. (Capacitor C1709 in K6OWA's rig was an *N150*, obviously tailored to compensate *that* unit.)

A second trial run must now be made. I chose a parallel combination of 10-pF/N150 and 12-pF/NPO.

The *N* value of this new combination is

$$N_{eq} = \frac{10}{22} \times 150 = N68 \qquad (1)$$

Put everything back, tighten the board securely, reconnect the counter, and begin anew with another run.

Fig. 2, curve C, shows a *negative* drift (more than 300 Hz). The next, and you hope final, attempt must

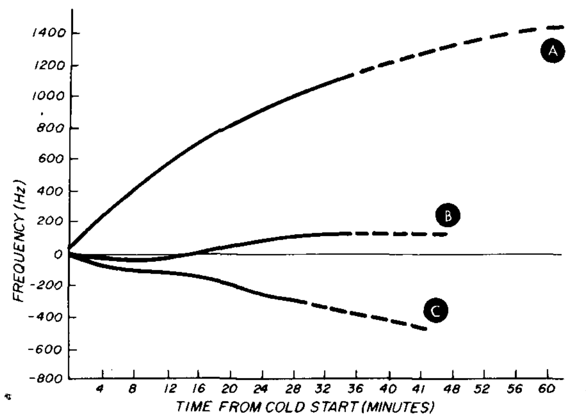

fig. 2. *Test data showing frequency drift as a function of time for several test runs on the Swan 350 transceiver. Capacitor C1709 must be tailored for individual cases. Naturally, any long-term drift will approach zero. (A): Frequency drift of the as-built Swan 350 transceiver extrapolated to 1500 Hz after a warm-up period of one hour. C1709 was a 22-pF/N150 compensating capacitor. (B): The third test run, using an N120 capacitor for C1709. The measured frequency drift is 105 Hz after 35 minutes from a cold start. (C): A trial run using substitute N68 capacitor for C1709. The measured frequency drift is 335 Hz after 30 minutes from a cold start.*

have C1709 with an N between 68 and 150. I tried a 12-pF/N220 and a 10-pF/NPO resulting in N120.

Out comes the oscillator board; again watch out you don't lose hardware. Replace the VFO top cover and connect the counter after soldering the N120 combination in place. The set will have cooled off sufficiently during this process for the next run to be from a cold start. Somewhere in this operation you'll take out time for lunch, so let the Swan 350 cool off — too much time and effort will have been expended to take chances on a set that hasn't reached room temperature.

The last run will perhaps be what you'll settle for in performance. Ralph, K6OWA, and I were quite elated when we finished the third run and plotted curve B (**fig. 2**), ending up with frequency drift close to 100 Hz. Any set that stabilizes in 30 minutes or so with that amount of drift is a pleasure to operate. This Swan 350 certainly takes no back seat to many new sets off the assembly line. Perhaps at some convenient time, another trial could be made using a 12-pF/NPO and 10-pF/N220 combination:

$$N_{eq} = \frac{10}{22} \times 220 = N100 \qquad \textbf{(2)}$$

Mathematically, any VFO can be compensated to achieve no drift. This particular Swan 350 might need an N105 or perhaps an N95; this must be determined experimentally. Generally you must weigh the advantages gained with close-to-zero drift and the effort expended.

When you've made mods to satisfy your standards, you must refer to the *Swan* manual, page 14. With the counter reading the VFO frequency, adjust the trimmers for each band to correspond with the dial-frequency/oscillator-frequency table. Follow manual instructions.

obtaining parts

If you live near an electronics emporium procurement of capacitors to conduct the tests will be simple; if you're on a Pacific atoll, you must provide yourself with enough NEG caps to experiment with. In our case, it seemed logical to use half of the 22-pF total value in an NPO (thus the 10- or 12-pF values), while the other half can be used with negative N values to suit. One of each of N220, N150, and N110 would be a starter and would probably bring the frequency drift within reason. This evaluation must be made on the second trial with a new cap value.

The direction of drift would dictate whether higher or lower N values will work. Two or three attempts should give a good idea of the necessary value. If a supplier has a poor selection, combinations other than 10 pF and 12 pF could be tried. Eight pF and 14 pF could be combined in a ratio that might do the job.

closing remarks

The technique outlined applies to any VFO, tube or transistor, in which an increase in temperature causes a frequency change. Getting rid of the heat in a Swan 350 is impossible; the set is already quite well ventilated, so an extra muffin-pan blower won't suffice! Thermal insulation of the outside VFO walls from the heat of adjacent tubes might help. However, I feel that the lack of circulation in the VFO itself is the cause of excessive frequency drift. A perforated chassis and sidewalls would allow heat to escape, whereas the Swan 350s, as designed, trap heat inside the box.

Further suggestions on drift problems are covered in many articles in the Amateur Radio literature: The ARRL handbooks and the new *Solid State Basics* from ARRL also elaborate on design of VFOs to minimize frequency drift.

acknowledgment

Neither K6OWA nor I have a frequency counter, so credit must be given to Reed Craven, WB6BFK, for the use of his counter, thus making this interesting project possible.

ham radio

More Details? CHECK—OFF Page 110

close look at amateur fm

Should the FCC regulations that combine F3 and A3 emissions be changed? Here's one Amateur's viewpoint

Casual observers of Amateur Radio practice have found that operators seldom use more than three types of emission and frequency bands, even though Amateurs are allowed as many as thirteen emission types on seven bands, twelve types on six bands, eleven types on two bands, six types on four bands, five types on one band, and two types on one band (160 meters). Most Amateurs use two types of emission: CW (type A1) and a-m or SSB phone (type A3), on several of the bands listed and largely ignore frequency and phase modulation (type F3). Mobile operators, however, make good use of fm on the vhf and uhf Amateur bands. Fixed-station operators have little use for fm on the high-frequency (3-30 MHz) bands, even though A3 and F3 emissions are listed together on virtually all subbands except 160 meters.[1]

amateur fm

The disuse of fm on the 15-, 20-, 40-, and 80-meter bands is because of deterrents such as lack of suitable transmitters and receivers and the FCC's bandwidth limitation. Paragraph 97.65c, under the heading of *Emission Limitations*, reads: "On frequencies below 29.0 MHz and between 50.1 and 52.5 MHz, the bandwidth of an F3 emission (frequency or phase modulation) shall not exceed that of an A3 emission having the same audio characteristics; and the purity and stability of emissions shall comply with the requirements of 97.73[1]." This paragraph deserves special attention.

Amplitude modulation contains only one pair of sidebands. The audio-frequency limit for voice communications is nominally 3 kHz; therefore, the a-m bandwidth can't exceed 6 kHz. However, fm contains one or more pairs of sidebands, equally spaced from the carrier frequency or adjacent sidebands. Therefore the fm bandwidth can't be less than, and may greatly exceed, the a-m bandwidth.

We note that FCC specifies *fm bandwidth*, not frequency deviation, which is not proportional, although some Amateur publications[1] give a simple rule of thumb that fm bandwidth equals twice the maximum frequency deviation plus the maximum audio frequency. One book[1] states that this rule of thumb doesn't hold for narrowband fm, and defines sliver-band, narrowband, and wideband deviations as 2.5, 5, and 15 kHz, for which bandwidths are 6, 13, and 33 kHz approximately. The last two of these bandwidths are far below accurate values of 16, 22, and 48 kHz, respectively, which further analysis has proved.

bandwidth

Bandwidth is a complex function of deviation and audio frequency, not of deviation alone. It depends on a factor known as modulation index or deviation ratio — the ratio of maximum deviation to maximum audio frequency, which is a pure number. There's no simple relationship, such as a direct proportion between bandwidth and deviation, although bandwidth generally increases with deviation in a nonlinear manner for a fixed audio frequency. An increase in audio amplitude at any audio frequency increases the deviation, the number of sideband pairs, and the bandwidth. Also, an increase in audio frequency at any given deviation increases the spacing between the

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sidebands, which increases the bandwidth. The overall effect of changes in audio amplitude and frequency on bandwidth is often hard to evaluate, as, for example, the case of complex speech waves where the amplitude of the various frequency components varies somewhat inversely with the frequency.[2]

deviation

The fact that bandwidth is not a function of deviation alone is shown by the following example. Assume two cases with the same deviation of 10 kHz but different audio frequencies of 5 and 10 kHz respectively. In the first case, four pairs of significant sidebands (at least 1 per cent of carrier amplitude) are 5 kHz apart, so the bandwidth is 4 × 2 × 5 kHz, or 40 kHz. In the second case, only three pairs of significant sidebands occur but are twice as far apart, so the bandwidth is greater (3 × 2 × 10 kHz). Since $60/40 = 1.5$, it appears that bandwidth is not in direct proportion to audio frequency for a fixed deviation.[3]

In fm broadcasting, the maximum permissible deviation is 75 kHz and the maximum audio frequency (for high-fidelity music) is 15 kHz, so the modulation index might approach 5 (75/15) if both values occur simultaneously. Similarly, in Amateur wideband fm, the deviation may be 15 kHz and the audio frequency may be limited to 3 kHz (for speech only); so the same modulation index would occur. A ratio of five signifies eight sideband pairs; hence bandwidths of 240 (8 × 2 × 15) and 48 kHz respectively are indicated. These values are extremes, which are not realized in practice because complex music and speech waves have smaller amplitudes at the higher frequencies. So less deviation and fewer sideband pairs occur than the indicated values.

narrow-bandwidth case

If we consider a narrow bandwidth of 6 kHz with a 3-kHz audio-frequency limit, as in Amateur a-m, there can be only one pair of significant fm sidebands. This corresponds to a modulation index of no more than 0.4 and a deviation of no more than 1.2 kHz $(1.2/3.0 = 0.4)$. Under these conditions, the fm carrier retains 96 per cent of its unmodulated amplitude, and the sidebands have only 4 per cent of the amplitude they would have at a modulation index of 2.4 (or 5.5) — the ideal condition wherein all carrier power is converted to sideband power.

If the FCC had specified a 3-kHz deviation limit instead of an a-m bandwidth limit, a better condition would prevail. A modulation index of unity (3/3) would yield three pairs of sidebands, 18 kHz bandwidth (3 × 2 × 3 kHz), 76.5 per cent carrier amplitude, and 23.5 per cent sideband amplitude.[4]

Even the latter imaginary case wouldn't offer much of an advantage over the former real case, because power is proportional to the square of the amplitude (voltage or current), hence the sideband power is only 5.5 per cent (100×0.235^2) of the ideal power.

From this discussion it follows that Amateurs can't make much use of narrowband fm wherein the bandwidth may not exceed 6 kHz. Accordingly, the FCC listing of type F3 along with type A3 emissions on bands below 29.0 MHz is misleading and serves no useful purpose, so it should be dropped. On the other hand, if a deviation of 5 kHz or 22 kHz bandwidth were permitted on certain Amateur bands, as on certain commercial frequencies, fm operation would be quite feasible, because the carrier amplitude would be only 41 per cent, and the total sideband amplitude would be 59 per cent.

table 1. Amateur fm characteristics.

M	%F	P	ΔF	(BW)
0-0.4	100-96	1	0-1.2	0-6
0.5	94	2	1.5	12
0.83	83	—	2.5	16
1.00	77	3	3.0	18
1.67	41	—	5.0	22
2.00	22	4	6.0	24
2.40	0	5	7.2	30
3.00	26	6	9.0	36
3.33	34	—	10.0	38
4.00	40	7	12.0	42
5.00	18	8	15.0	48
5.50	0	—	16.5	51
6.00	15	9	18.0	54
6.67	25	10	20.0	60
7.00	30	11	21.0	66

Notes:

f = 3 kHz, fixed

M = modulation index = ΔF/f = ΔF/3, so ΔF = 3M

%F = carrier amplitude in per cent from reference 2

P = pairs of sidebands of 1% minimum amplitude (reference 2)

ΔF = deviation (±) = fM = 3M

BW = bandwidth — 2fP = 6P

(BW ranges from 1.4 to 2.0 times rule-of-thumb bandwidth, 2 ΔF + 3 and 1.5 to 4.0 times 2 ΔF.)

These points may be emphasized by reference to **table 1**, which may be converted to a series of curves if desired.

references

1. *The Radio Amateur's License Manual*, ARRL, Newington, Connecticut, 1977, pages 66-67 and 92.
2. August Hund, *Frequency Modulation*, McGraw-Hill, New York, 1942, pages 22 and 23.
3. Ed Noll, W3FQJ, *First-Class Radiotelephone License Handbook*, Sams and Bobbs-Merrill, New York, 1970, pages 139 and 140.
4. *FM and Repeaters for the Radio Amateur*, ARRL, Newington, Connecticut, 1972, pages 50 and 169.

ham radio

More Details? CHECK — OFF Page 110

high-current regulated dc power supply

A high-current, regulated power supply incorporating rf protection, current limiting, and over-voltage protection

The present popularity of the two-meter fm band has attracted many Amateurs to that portion of the spectrum. Many hams use two-meter rigs in double-duty service, both in mobile and fixed-station applications. In either case, 12 Vdc is required for input power. For mobile use, the automotive electrical system provides input power; however, in fixed station use the rig requires a power supply which converts ac power to nominal 12 Vdc with current capacities ranging from about 3 to 10 amperes. Such a power supply should contain the following features:

1. Voltage Regulation — For steady-state regulation, the output voltage should remain within 1 per cent of the desired value over the full range of output current capability. Instantaneous load changes, or dynamic regulation, commonly encountered when keying or unkeying the transmitter, should not produce excessive voltage overshoot or undershoot. Additionally, the settling time required for return to steady-state regulation conditions should be minimal, on the order of milliseconds.

2. Current Limiting — The power supply should be protected against excessive output current. The current should be automatically limited to a preselected safe value.

3. High-voltage shutdown — In case of a power supply fault, which would apply unregulated dc to the rig, a protection circuit is required to disable the power supply output within milliseconds after fault condition detection. The radio being powered is thus protected against excessively high voltages which could permanently damage semiconductors or other components.

4. Rf protection — The voltage regulation and other control circuits should be rf bypassed to eliminate the possibility of voltage instability or other adverse effects caused by strong rf fields.

The power supply described in this article incorporates the outlined features. By using the specified components you can construct a power supply which is totally adequate for 30- or 40-watt transmitters.

circuit description

This power supply uses a standard series-pass circuit controlled by a 723 monolithic IC regulator. The high-voltage shutdown circuit is controlled by a μA741 operational amplifier. All regulation and control circuits are contained on one circuit card, compatible with a 15-contact edge connector.

The power circuit consists of a transformer, bridge rectifier, pi-section filter, and series-pass transistors. This is a standard circuit commonly used in many regulated power supplies.

Operator controls consist of an ON/OFF toggle switch, a pushbutton switch to reset the high-voltage shutdown circuit, and appropriate indicators.

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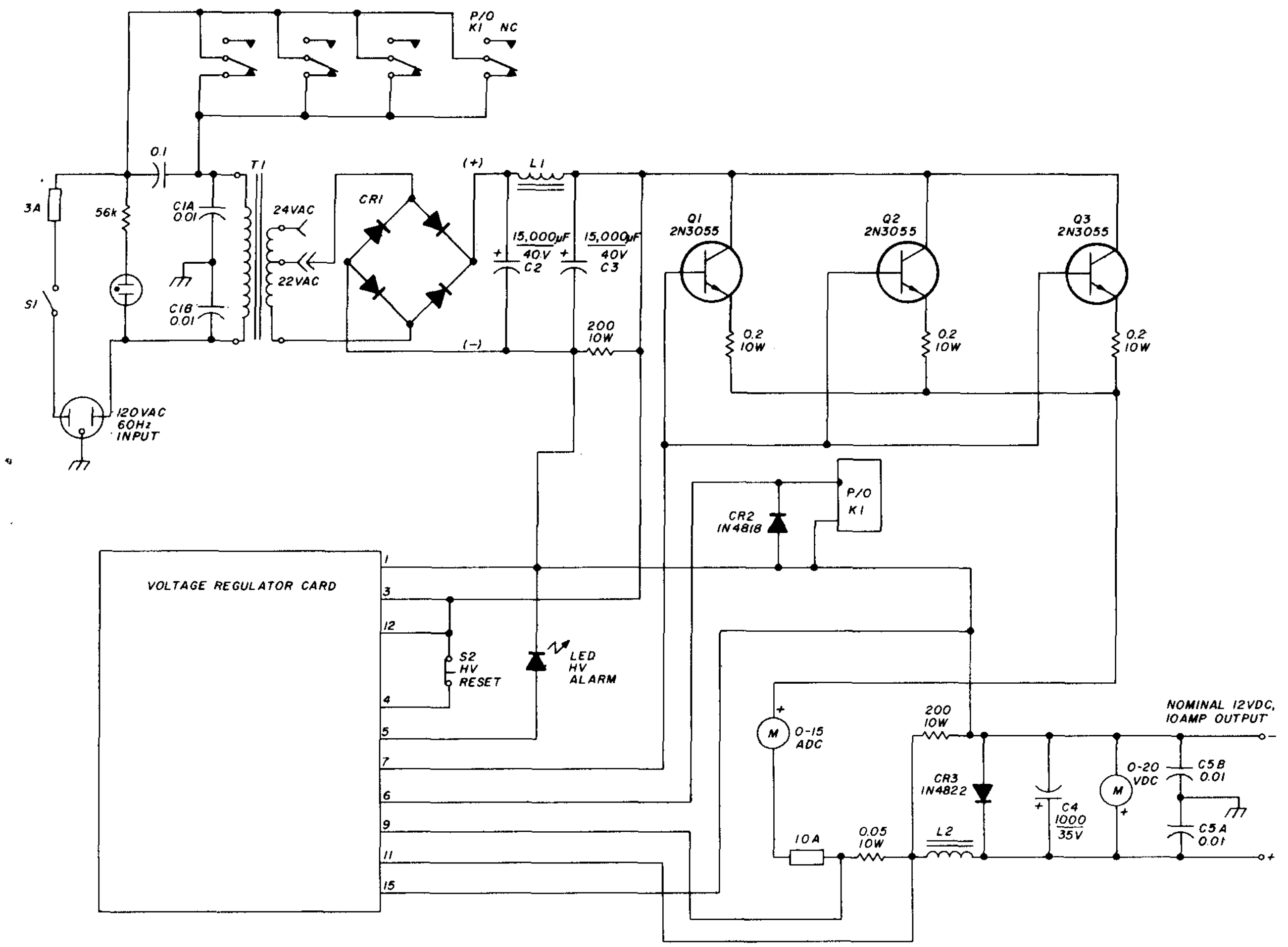


fig. 1. Schematic diagram of the chassis-mounted components. CR1 is a 15-amp, 50-PRV bridge rectifier; CR2 a 1.5-amp, 200-PRV diode (1N4818); and CR3 a 1.5-amp, 600-PRV silicon diode (1N4822). K1, a 4pdt, 24-VDC relay, is available from Potter and Brumfield as type KHP17D11 or Allied Control type T163X-147. The choke, L1, is a Stancor C-2688 with a 10-mH, 12.5-amp rating. The rf choke, L2, is wound with fifteen turns of number 14 AWG (1.6-mm) stranded insulated wire on a Genelex G49S/191 toroid. The power transformer, manufactured by Triad (F-79U), supplies 24 Vac at 10 amps. The bridge rectifier, CR1, and the pass transistors, Q1 through Q3, are mounted on finned heatsinks on the rear of the enclosure. For CR1, use Termalloy part 6169, and for the pass transistors part 6423.

The panel-mounted meters allow the operator to monitor output voltage and current. Voltage and shutdown level adjustment potentiometers on the circuit card are accessible through the front panel.

Power Circuit. The power circuit handles ac input, rectification, filtering, and dc-output functions (see **fig. 1**). The ac-input circuit contains ON/OFF switch S1, input fuse, and power transformer T1 as major functional components. The indicator assembly, connected across the primary of T1, illuminates when input power is applied. C1A and C1B provide noise and rf suppression at the primary of T1. The relay contacts of K1 are normally closed to allow current flow through the primary of T1. If the high voltage shutdown circuit activates at any time, the contacts of K1 open to interrupt power to T1, thereby protecting the dc load from high output voltage.

CR1 rectifies the low-voltage ac supplied by the secondary winding of T1. The resultant pulsating dc is filtered by C2, C3, and L1. The filtered, unregulated dc supplies power to components on the circuit card and is applied to the collectors of series-pass transistors Q1-Q3.

The series-pass transistors perform the regulation function in the power circuit, under control of the regulator circuit. Under changing line and load conditions, the drive signal applied to the base-emitter circuit of transistors Q1-Q3 varies automatically. The changing drive signal serves to increase or decrease the collector-emitter voltage on Q1-Q3 as output voltage, output load, and ac input voltage levels dictate. The result of automatically varying the collector-emitter voltage on Q1-Q3 is to hold the emitter output voltage at a nearly constant level. This emitter output voltage is used as the regulated dc output.

The dc output circuits comprise metering, fusing, and suppression functions. A dc ammeter and voltmeter provide output current and voltage level monitoring capability. L2, wound on a toroid core, serves as an rf choke to decouple the power supply from any stray rf which may appear on the dc leads. C5A and C5B provide further rf suppression at the power supply output terminals. CR3 and C4 suppress voltage spikes generated by instantaneous load changes that could falsely trigger the high-voltage shutdown circuit.

Control Circuits. The control circuits, located on the circuit card (see **fig. 2**), comprise voltage regulation, current limiting, and high-voltage shutdown circuits. Various functions of the control circuits are described as follows.

Voltage regulation and current limiting functions are performed by U1, a monolithic IC voltage regulator. A voltage divider, R2, R3, and R4, is essentially connected across the power supply output. The setting of R3 primarily determines supply output voltage. R5 and R6 provide temperature compensation for U1, with C2 and C4 providing rf bypassing. Operating power for U1 is derived from the unregulated dc through isolation diode CR1, while C3 provides input power filtering. The output of U1 is applied to driver transistor Q1 through the normally closed contacts of K1. Q1 essentially increases the current-handling capability of U1. The output of Q1, as derived from the emitter circuit, drives the series-pass transistors in the power circuit.

The current limiting point is determined by the value of R6. When a voltage drop of 0.6 volt appears across R6, U1 begins current-limiting action.

The high-voltage shutdown circuit is composed of the comparator and relay-driver circuits. U2 is used as a comparator. The reference input of approximately 7.3 volts is derived through R12, CR2, and CR3. CR2 provides a stable, regulated voltage for the reference input applied to the inverting input of U2. CR3, in series with CR2, provides temperature compensation for the comparator circuit. The output voltage of the power supply is sampled in a voltage divider composed of R9, R10, and R11. A portion of the sampled output voltage is applied to the noninverting input of U2 through the wiper contact of R10. During normal operation, the reference voltage at the inverting input of U2 is higher than the sampled voltage at the noninverting input; therefore, the output of U2 is low and Q2 is biased into cutoff. In the event power supply output voltage rises to a sufficiently high level, the sampled voltage becomes higher than the reference voltage. The output of U2 changes to a high level, which biases Q2 into conduction. The resulting voltage developed across R17 triggers CR6 through steering diode CR7. When CR6 is triggered into conduction, K1 in the power circuit and K1 on the circuit card are energized and the following actions occur:

1. The output of U1 is disconnected from Q1, and the base of Q1 is grounded to drive it and the series-pass transistors into cutoff.

2. Power is applied to an LED, giving visual indication of a high-voltage shutdown condition.

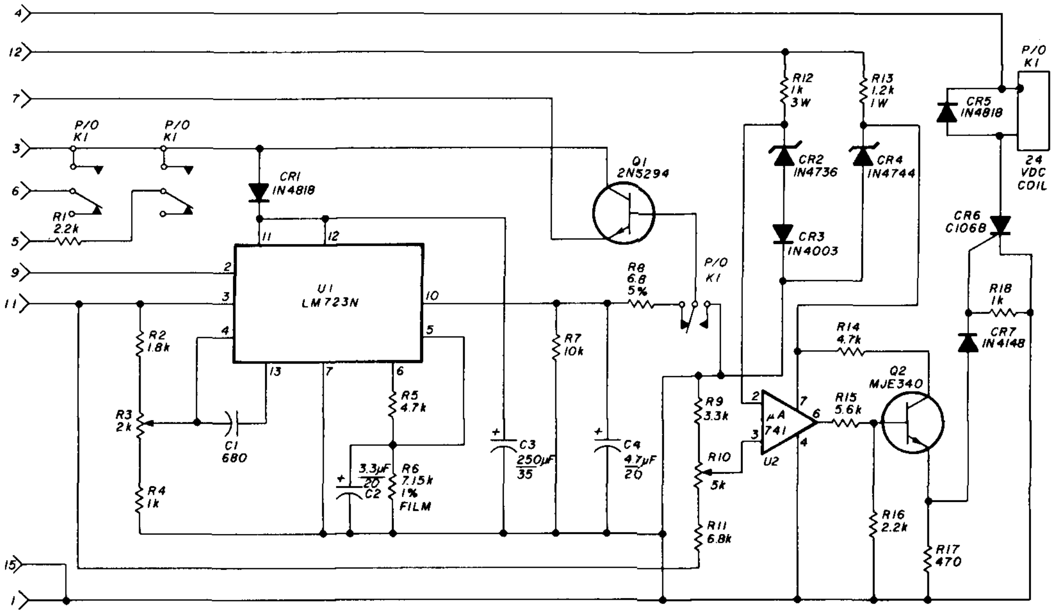
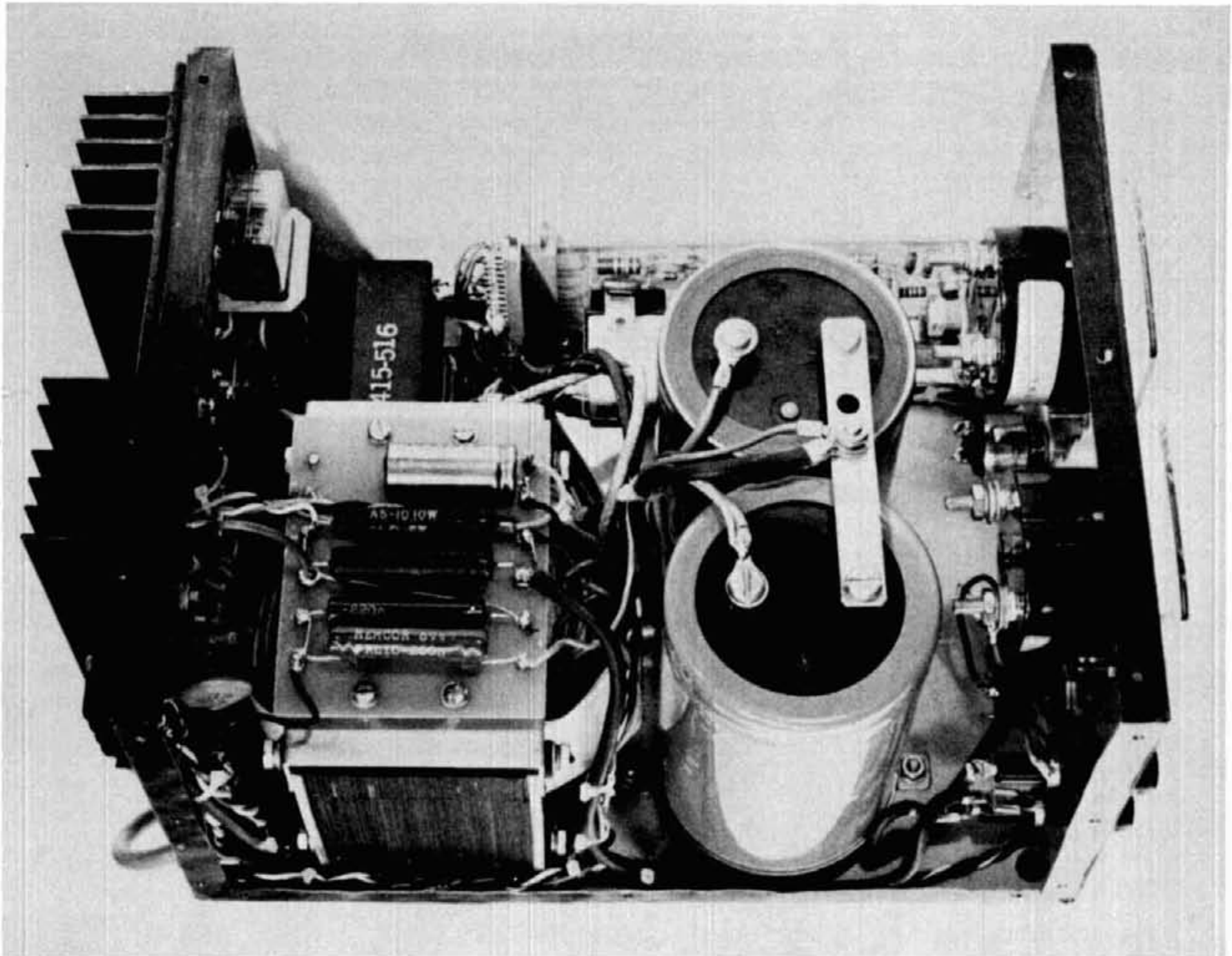


fig. 2. Schematic diagram of the voltage regulator and high-voltage shutdown circuits. CR2 is a 6.8-volt, 1-watt zener diode; CR3 is a 1N4003 (1 amp, 400 PRV); CR4 is another zener (15 volts, 1 watt); and CR6, the SCR, is rated at 4 amps, 200 PRV (C106B). The relay, K1, is the same type of relay used in the chassis-mounted components. The circuit card accepts a Potter and Brumfield relay socket, type 9KH2, for a KHP17D11 relay. Except as marked, all resistors are 10 per cent tolerance, ½ watt.



View of the author's power supply. The capped access holes, in the lower righthand corner of the front panel, allow access to the high voltage shutdown level and voltage adjustment controls mounted on the circuit board.

3. The primary circuit of the power transformer is opened to remove input power from the supply.

The approximate time from detection of a high voltage condition to supply shutdown is 3 milliseconds.

construction

Parts placement and general layout of the power supply are not critical; however, standard construction techniques and practices should be used when building the supply. Particular care should be taken in one area — lead lengths of rf bypass and decoupling components on the output terminals should be as short as possible. Additionally, meters should not be located near the power transformer or filter choke.

The particular construction technique chosen is at the discretion of the builder, but the power supply should be totally enclosed and shielded when assembly is complete. The supply shown in the accompanying photographs was built in a homemade cabinet to reduce construction cost.

Adequate ventilation must be provided for the power semiconductors, especially the series-pass transistors. The heatsinks specified in the parts list are adequate to handle device dissipation, but heatsinks of smaller size are not recommended. The series-pass transistor heatsink should be mounted outside of the power supply cabinet, on the rear panel, to ensure adequate ventilation. A thin coating of silicone grease, or other suitable thermal joint compound, must be applied to the mounting surfaces of all power semiconductors and insulating washers.

A circuit card pattern for the control circuits is shown in **fig. 3**. Pads are provided to make the circuit card compatible with a standard 15-contact edge connector; however, the circuit card can be permanently mounted and hardwired into the complete circuit.

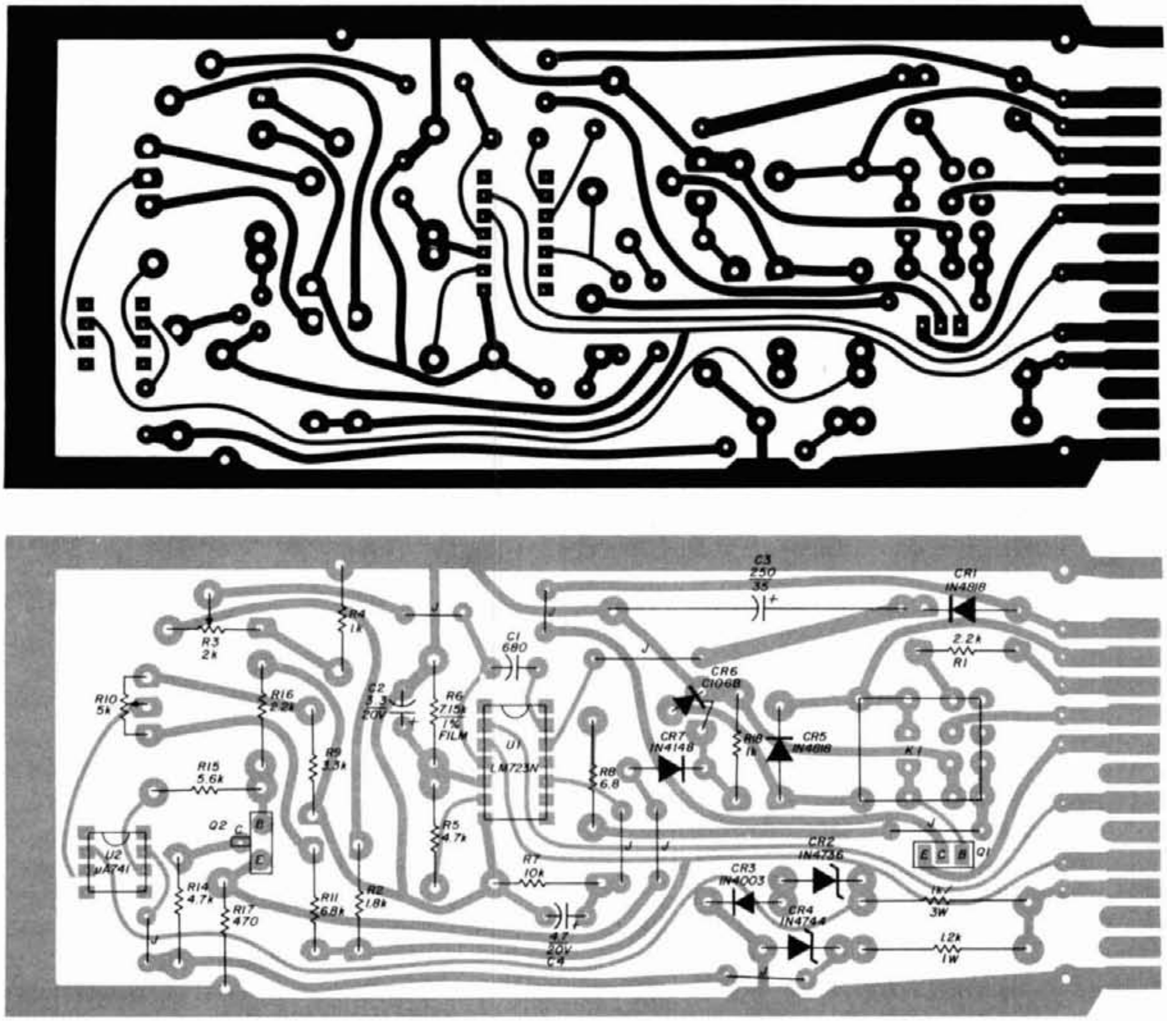


fig. 3. The circuit-board layout for the voltage regulator is shown above, with the parts placement diagram shown below. The edge pins will mate with a 15-contact circuit card connector, Amphenol 225-21531-101.

initial startup and adjustment

1. Before initial power supply startup, verify that all wiring is correct. If a tapped power transformer is used, ensure that the secondary voltage is no higher than 24 Vac.

2. On the regulator circuit card, adjust R3 and R10 fully clockwise.

3. Close S1 to start the power supply. Output voltage should be 10 Vdc or slightly less.

4. Adjust R3 on the regulator circuit card to 15 Vdc with no load at the output terminals. Turning the adjustment screw counterclockwise increases output voltage.

5. Slowly turn the adjustment screw of potentiometer R10 counterclockwise until the high voltage shutdown relays close. The LED should illuminate at this time, and supply output voltage should drop to zero.

6. Adjust R3 one turn clockwise, then press S2 to reset the shutdown circuits. Output voltage should now be present at the output terminals.

7. Slowly adjust R3 counterclockwise while noting the voltage at which the shutdown relays close. This voltage should be approximately 15 Vdc; if not, adjust R10 as necessary. The shutdown level can generally be adjusted to any desired level within the range of 13-16 Vdc. Individual operating requirements will determine the exact level.

8. Repeat Steps 6 and 7 if necessary to obtain the desired high voltage shutdown level.

9. Adjust R3 one or two turns clockwise, then reset the shutdown circuits by pressing S2.

10. Adjust R3 for the desired power supply output voltage. Adjustment is now complete.

ham radio

More Details? CHECK — OFF Page 110

TS-520SE

"Cents-ability" in a quality HF Rig!

The TS-520SE is an economical new version of the TS-520S...the world's most popular 160-10 meter Amateur transceiver. Now anyone can easily afford a high quality HF transceiver, providing 200 watts PEP input on SSB and 160 watts DC on CW!

The TS-520SE is a high-quality 160-10 meter SSB/CW transceiver intended for ham-shack use. The following changes were made to produce the new "SE" model:

- Replaced the heater switch with a CW WIDE/NARROW bandwidth switch, for use with the optional CW-520 500-Hz CW filter. A big improvement for the CW operator!
- Removed DC converter terminals. Now it operates strictly on 120 VAC and is not intended for mobile use.
- Removed transverter terminals. Now it is strictly a 160-10 meter SSB/CW transceiver.

All other proven features and high quality of the TS-520S have been retained in the TS-520SE, including:

- Effective noise blanker.
- Three-position (OFF, FAST, SLOW) amplified-type AGC circuit.
- RIT control.
- Eight-pole crystal filter.
- Built-in 25 kHz calibrator.
- Front-panel carrier level control.
- Semi-break-in CW with sidetone.
- VOX/PTT/MANUAL operation.
- TUNE position for low-power tune up.
- Built-in speaker.
- Built-in cooling fan.
- 20-dB RF attenuator.
- Provisions for four fixed channels.
- Speech processor consisting of a very effective audio compression amplifier.

The TS-520SE functions with many popular accessories, including:

- DG-5 digital frequency display/counter.
- VFO-520S remote VFO.
- SP-520 external speaker.
- CW-520 500-Hz CW filter.
- AT-200 antenna tuner/SWR and RF power meter/antenna switch.
- TL-922A linear amplifier.
- MC-50 dynamic microphone.
- SM-220 Station Monitor with BS-5 pan display module.

SPECIFICATIONS FOR THE TS-520SE

GENERAL:	
Frequency Range:	1.8- 2.0 MHz (160 m) 3.5- 4.0 MHz (80/75 m) 7.0- 7.3 MHz (40 m) 14.0-14.35 MHz (20 m) 21.0-21.45 MHz (15 m) 28.0-28.5 MHz, 28.5-29.1 MHz, 29.1-29.7 MHz (10 m) 15.0 MHz, receive only (WWV)
Modes:	SSB (USB, LSB), CW
Antenna Impedance:	50-75 ohms
Frequency Stability:	Within ±1 kHz during one hour after one minute of warm-up, and within 100 Hz during any 30-minute period thereafter.
Power Requirements:	120 VAC, 50/60 Hz; 280 W (transmit)
Dimensions:	13-1/8 inches wide, 6 inches high, 13-3/16 inches deep
Weight:	35.2 pounds
TRANSMITTER:	
Input Power:	200 W PEP (SSB), 160 W DC (CW)
Carrier Suppression:	Better than 40 dB
Unwanted Sideband Suppression:	Better than 50 dB
Spurious Radiation:	Better than -40 dB
Microphone Impedance:	50 k ohms
AF Response:	400-2,600 Hz
RECEIVER:	
Sensitivity:	0.25 μV for 10 dB (S + N)/N
Selectivity:	SSB: 2.4 kHz/-6 dB; 4.4 kHz/-60 dB CW: 0.5 kHz/-6 dB; 1.5 kHz/-60 dB (with optional CW filter)
Image Ratio:	Better than 50 dB
IF Rejection:	Better than 50 dB
Audio Output:	1.0 W (8-ohm load with less than 10% distortion)
AF Output Impedance:	4-16 ohms

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design considerations for linear amplifiers

Building a high-power, high-frequency linear amplifier and companion power supply is an interesting, challenging, and constructive project. And don't let anybody tell you that you can't do it! Many new hams approach equipment construction with great timidity. Be assured it isn't all that difficult. The toughest part of the work, in fact, is finding the necessary components. This is where flea markets, classified advertisements, surplus stores, and the junk box of neighboring Amateurs play an important part. You can find all the stuff you need, it just takes a little perseverance.

Before you begin bending metal, punching holes, and wiring, you should have the amplifier completely designed on paper, as outlined in the previous articles of this series. Once this task is done, you can make a parts list and start rounding up the components. You should also start thinking about the physical layout and assembly of the amplifier.

amplifier layout and assembly

Modern design indicates that the linear amplifier be enclosed in a metal cabinet, or box, that is shockproof, rf radiation-proof, compact, and easy to build. Many people build their linear amplifiers on a readily available aluminum chassis and then box up the chassis with aluminum sides and top to form a complete enclosure. This is not a bad idea. The cost is low and the chassis forms a platform and underchassis area that is hard to duplicate with simple tools. Once the enclosure is built, holes are drilled in it for leads and cables, control shafts, and for cooling air to enter and escape. Components within the box are positioned so that rf leads are short and direct and power wires are not coupled to the strong rf field within the box (see **fig. 1**). By paying attention to mechanical detail and armed with a knowledge of circuit design and a dose of common sense, the average Amateur can build a linear amplifier that looks good and works as well as the book says it should.

The object of using an all-metal amplifier enclosure is to keep the strong rf currents and subsequent harmonics within the box. Since these currents travel only on the surface of metal, the box can be made "electrically tight." Whenever a hole is made in the box, or a conductor brought into it, a leakage point is established through which rf energy can escape. It is important that these "rf holes" be reduced to a minimum in number and size, and that their effect upon circuit operation be controlled.

openings into the enclosure

Holes, leads, and shafts break the rf-tight amplifier box. Large holes for ventilation can be used without harm, provided they are screened so that air can enter and leave but rf energy cannot escape. Perforated metal sheet, having many closely spaced holes, is the best screening material to place over the openings. Copper wire window screen is not as effective because of wire corrosion which produces a film of insulating oxidation between the individual wires at the crossover points.

If a perforated sheet is to be used, it may be made by drilling lots of holes in the enclosure wall. Or the hole pattern can be drilled in an auxiliary plate placed over the ventilation hole. If such a plate is used, it should be bolted or riveted to the enclosure with a bolt-to-bolt spacing of about 2.5 cm (1 inch) so that rf energy cannot leak out through the crack between the surfaces. Mating surfaces between the metals should be clean and free of paint (**fig. 2**). A screened ventilation opening should be about three times the size of an equivalent unscreened opening, since the screening material reduces the area of air passage.

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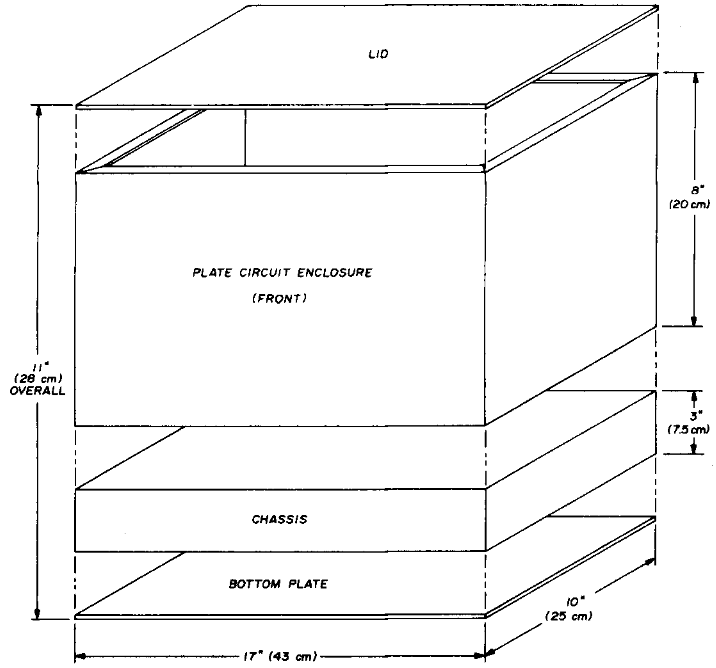


fig. 1. A representative amplifier enclosure. Basic unit is an aluminum chassis with bottom plate. The plate circuit enclosure is made of aluminum stock. For ease in assembly, aluminum channel angle stock is pop-riveted around outer edge of chassis to mate with the bottom of plate circuit enclosure. Angle stock is run up each corner and riveted to the four plates. Additional angle stock runs around the inside edge of the top of the enclosure and is tapped for 6-32 (M3.5) screws, which hold the lid on. Lid may be made of perforated metal for ventilation or may be modified from a solid aluminum sheet as discussed in the text. Additional angle stock may be required to hold bottom plate in place and to make the under-chassis area relatively air-tight. Blower to cool the tubes is mounted on the rear apron of the chassis. The completed enclosure is mounted behind a relay rack panel for appearance.

Control shafts passing into an rf-tight box should be made either of phenolic-insulating rod or of metal, grounded at the point of entry by means of a spring contact (**fig. 3**).

Long, narrow slots in the enclosure should be avoided, or else shunted with a ground strap every few inches; otherwise the opening tends to act as a "slot antenna" through which harmonic energy can readily pass — more easily than through a much larger circular hole, in fact.

Meters mounted in a wall of the shielded box pose a problem, as they are a source of prolific rf leakage. Unless the body of the meter is shielded and the leads well bypassed, it is more prudent and less time consuming to mount the meters outside the enclosure and to filter the meter leads running into the box.

pass-through leads

Careful attention must be paid to power and meter

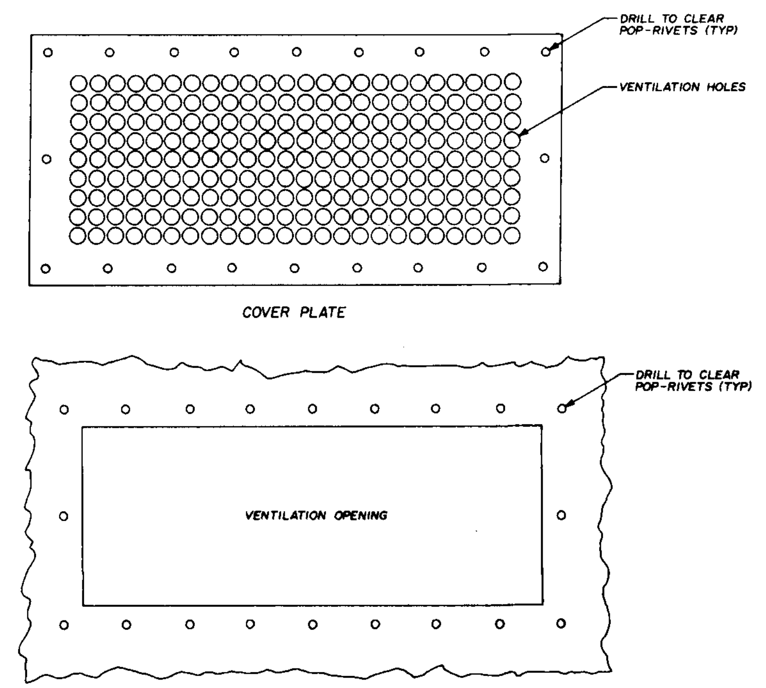


fig. 2. Ventilation holes are cut in sheet aluminum by means of a nibbling tool. Cover plate is cut slightly larger and drilled for ventilation holes. Plate and sheet aluminum are then drilled together for holes to place pop-rivets. If it is necessary to remove the cover plate for insertion of tubes, the plate may be held in position with sheet metal screws or by 6-32 (M3.5) nuts and bolts (provided assembly is such that you can get your hand inside the enclosure to hold the nut in place). Most side ventilation plates are fixed in position; top cover plates are removable.

leads entering and leaving the rf-tight box. Harmonic currents inside the box can easily flow out of the enclosure on these leads or even on the outer shield of a coaxial line if the shield is not properly grounded at the point of entry (**fig. 4**). Unshielded leads entering the box must be carefully bypassed and filtered at the point of entry to prevent rf energy from escaping from the box and flowing down the leads. A combination of bypass capacitors and small filter inductors will close off this escape route. The inductor must have ample capacity to carry the current flowing in the lead. Feedthrough-style capacitors are often used in low-voltage power and metering leads.

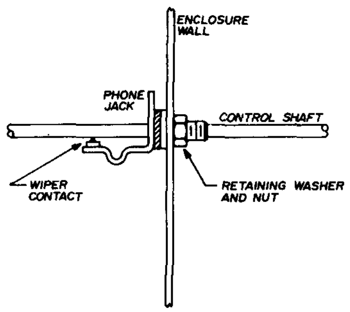


fig. 3. A single-circuit phone jack makes a good grounding device for a 6.5-mm (¼-inch) diameter shaft. The jack is mounted in the shaft hole, which is drilled out to accept the jack. The wiper contact of the jack rides on the shaft as it is rotated. The contact arm of the jack is grounded to the enclosure wall. Jack is positioned so that wiper arm is inside amplifier box.

amplifier wiring within the enclosure

Wiring within the rf-tight box can couple to rf energy because of the storing field within the box. Any lead in the box can pick up fundamental and harmonic energy and feed it outside the enclosure (**fig. 5**). On the other hand, the lead can pick up rf energy from an outside source (your exciter, for example) and leak it into the box causing amplifier instability. The solution for this problem is to bypass or filter all internal power and control leads at each end, dress them close to the chassis, and keep them physically remote from areas of high rf energy.

All these precautions may seem more complicated and time-consuming than they really are. Unfortunately, most circuit diagrams leave off much of the important rf bypassing circuitry since it tends to clutter up the diagram; its existence may be only briefly mentioned in the text. And the filter circuitry is often left out of commercially produced units as a cost-cutting measure.

When you build your own amplifier, you can afford to take the time and do things the right way. Always remember that holes, shafts, and leads are sources of rf leakage from an rf-tight enclosure and, unless protected, are a direct invitation to TVI, harmonic radiation, and amplifier instability. Sadly enough, many modern amplifiers on the market look like they're in an rf-tight enclosure, but, in reality, they are only sitting in an attractive dust cover.

practical amplifier layout

A simple to understand and practical parts layout for a representative high-frequency linear amplifier using two 3-500Z tubes is shown in **fig. 6**. The layout can be adapted to other tubes. The assembly consists of an aluminum box made up from a standard chassis. A bottom plate pressurizes the underside of the chassis and a blower is mounted on the rear apron of the chassis. Air is introduced under the chassis and is expelled through the tube sockets and air chimneys. The heated air from the tubes escapes through the perforated top and side areas of the plate circuit compartment.

The meter and control circuits are placed outside the shielded enclosure. Wiring for these circuits is not critical, and is done with 600-volt insulation hookup wire. High voltage wiring is done with test-

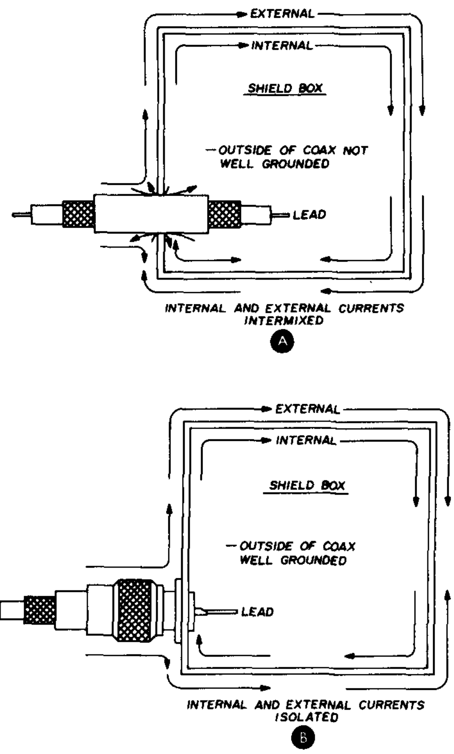
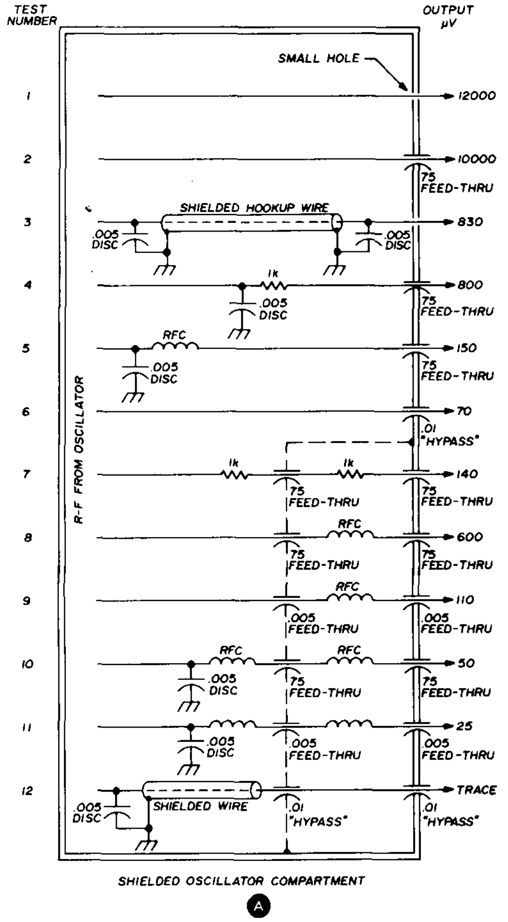


fig. 4. Improper termination of coaxial line can destroy effectiveness of the shield (A). Rf currents within the enclosure can escape via the outside shield of the line as it passes through the hole. Properly grounding the shield of the coaxial line to the box (B) ensures isolation of currents within the box. Rf currents outside the box are also prevented from entering the box.

prod wire of the type used for instrument test leads (10-kV insulating rating) or equivalent high-voltage cable. TV-type capacitors are used for lead filtering (**fig. 7**).

Low voltage leads enter the amplifier enclosure via 1-kV feedthrough capacitors, which are also shunted at the point of entry with a larger value of capacitance to suppress low-frequency rf energy and transients which can pass through most feedthrough capacitors with little attenuation. A simple homemade rf choke and bypass capacitor are placed on each lead inside the enclosure. Note that all capacitors used on the 120-volt ac power line should be rated at 1.6 kV in accordance with the Electrical Underwriter's Code. Don't use run-of-the-mill disc bypass capacitors on the power line, as it is a source of random voltage transients which can easily puncture the standard 600-volt-working capacitor.



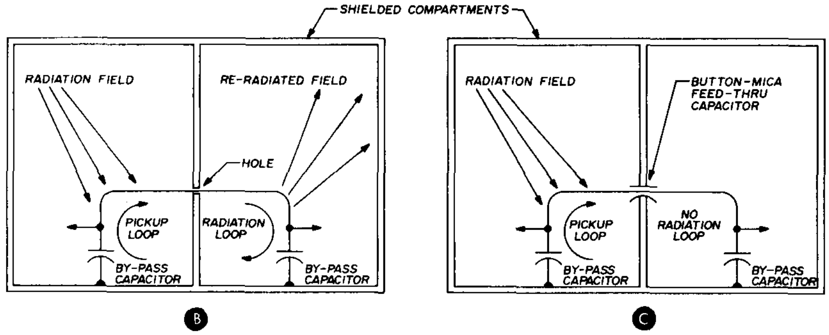


fig. 5. Tests of lead-filtering techniques (A). A signal generator having an output of 12,000 µV was placed in a metal box and rf leakage via various paths was measured. Very complex shielding was required to remove the last vestige of signal from the power lead. A combination of rf choke and capacitors, such as tests 8 or 9, does the job in adequate fashion. A very effective filter (not shown here), consists of a 0.001-µF feedthrough capacitor with a series rf choke. Both ends of the choke are additionally bypassed with a 0.01-µF disc capacitor. Energy can be conducted from one area to another as this test shows. Lead-through hole in partition (B) conducts energy from one compartment to the other. Proper bypassing (C) attenuates leakage. (Courtesy Radio Publications, Inc.)

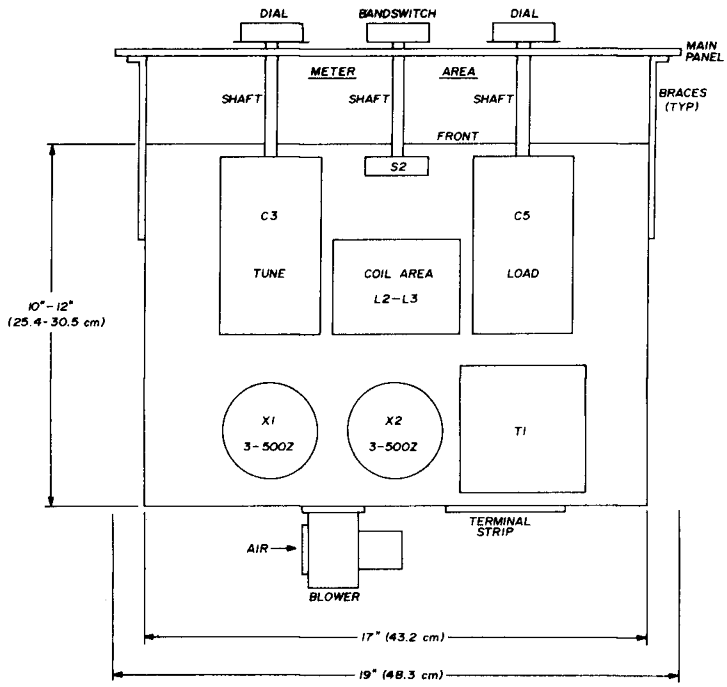
Power leads from the panel controls to the terminal strip on the rear of the amplifier must either pass through the box or go around it. It is easy to pass through the enclosure without breaking the rf seal with a short section of 1.3-cm (0.5-inch) diameter thin-wall electrical conduit with wall fittings on each end of the section (**fig. 8**). An rf tight passageway through the amplifier for various wires is formed by the conduit. Coaxial fittings are used for the input and output rf connections and are mounted to the wall of the box.

The mouth of the blower is covered with a small piece of copper window screen. While not the best material, this screen doesn't reduce the air flow as much as a perforated metal sheet would do.

While all this hum-drum filtering and bypassing might seem like overkill, it is the *only* way to achieve an amplifier that is rf radiation proof and one that keeps rf energy where it belongs. The rf energy leaves the box only via the output circuit where harmonics can be suppressed by means of a suitable lowpass filter before they reach the antenna. Without the filtering and bypassing, the harmonics suppressed in the antenna circuit would pass down the power leads or be radiated directly from the amplifier circuitry.

B-plus safety switch

A quick way to kill yourself is to remove the amplifier cover and fiddle around inside the box when the high voltage is turned on. Even the best of us might forget to turn things off and disconnect the amplifier from the supply before work is performed. A B-plus shorting switch will pay big dividends in operator longevity. It is simple to make (**fig. 9**). The shorting ring is made of spring brass and is depressed when the amplifier lid is in place. When the lid is removed, pressure is taken off the shorting ring and it makes a direct contact between the high voltage circuit and the chassis. This short circuit results in a blown line fuse if the amplifier is inadvertently turned on when fig. 6. A practical layout for a linear amplifier using two 3-500Z tubes. This is representative of a layout using any popular tube or tubes available for the Amateur service. A 43-cm (17-inch) chassis is used, with depth chosen to allow proper placement of components. Tuning and loading capacitors are mounted symmetrically on the main panel with the plate bandswitch between them. Panel meters are placed across lower portion of the panel. An area for the plate coils lies between the two capacitors, immediately behind the bandswitch. The 3-500Z tubes, air system sockets, and chimneys are near one rear corner of the chassis with the air blower placed on the rear apron between the sockets. To the side of the tubes is the filament transformer. To reduce transformer heating caused by infra-red radiation from the tubes, the transformer (which is normally black in color) is given a coat of white stove enamel. This reflects the heat from the tubes and reduces transformer operating temperature. The fixed-tuned cathode input circuit and bandswitch are located beneath the chassis, and the switch control shaft is brought out to the panel. Some Amateurs gang the input and output circuit band-change switches, but this is not necessary. The bottom of the amplifier is sealed with a metal plate, and the top area is made up of perforated aluminum sheets to permit ample tube ventilation.



the lid is removed. It also makes sure the filter capacitors are discharged before hands can be poked inside the amplifier.

metering circuits

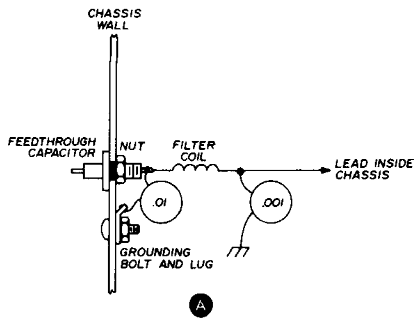
When you have power tubes in your linear amplifier that may cost upwards of $100, it is a smart and thrifty idea to take good care of them. As far as metering goes, it is wise to monitor both grid and plate current (and screen current if a tetrode tube is used) plus filament voltage. And a plate voltmeter is a handy thing and necessary if you run close to the maximum power level.

The meters are mounted outside the rf-tight box to remove them from the strong rf field of the amplifier. A single meter may be used as a matter of thrift to measure either grid or plate current if an appropriate switching circuit is employed, such as shown in **fig. 10**, where one meter does the work of two.

For economy and simplicity, a 0-1 mA dc meter is used. The scale will read 0 to 100 mA for grid current and 0 to 1000 mA for plate current. The scale need not be re-inked, since the user merely adds zeros to the reading to get the exact current value.

The meter is converted into a simple voltmeter circuit by a series-connected resistor. This voltmeter then reads the voltage drop across a shunt resistor placed in the circuit to be monitored. The whole circuit is inexpensive, accurate, and easy to make up. It does not require precision resistors — inexpensive one-percent metal film resistors will do (or carbon resistors in pinch).

As an example, suppose a 3.9-kilohm series resistor (a standard value) is used. The 0-1 mA meter is now turned into a voltmeter which reads 3.9 volts full



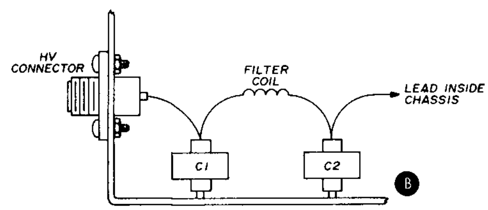


fig. 7. A simple filter circuit (A) for low voltage leads is made up of a 1000-volt feedthrough capacitor (Nytronics CP09A3 style, 0.01-μF, with case grounded and mounting stud). These, or similar capacitors can often be found in surplus stores. The disc capacitors are 1 kV (Sprague 5GA-D10, or equivalent). The filter coil is ten turns of no. 16 AWG (1.3 mm), 1.3-cm (½-inch) diameter spaced to 3.2 cm (1¼ inches) long. The coil and capacitors are placed inside the chassis. High-voltage filter circuit (B). A high-voltage chassis connector (Millen or equivalent) is used. The capacitors are 500-pF, 10-kV TV-type, with stud mounts. Some Amateurs use a high-voltage coaxial connector for the B-plus lead and run the high voltage in RG-8/U coaxial cable with the outer sheath grounded as a safety factor.

scale. All that is necessary now is to design a shunt which will produce a 3.9 volt drop across it at the desired full scale reading of the meter. Let's say we want 100 mA (0.1 amp) full-scale deflection for grid-current measurement. The shunt resistor (by Ohm's law) is:

$$\textit{Shunt resistor (ohms)} = \frac{E}{I} = \frac{3.9}{0.1} = 39\,ohms$$

This, also, is a standard resistance value. If you want

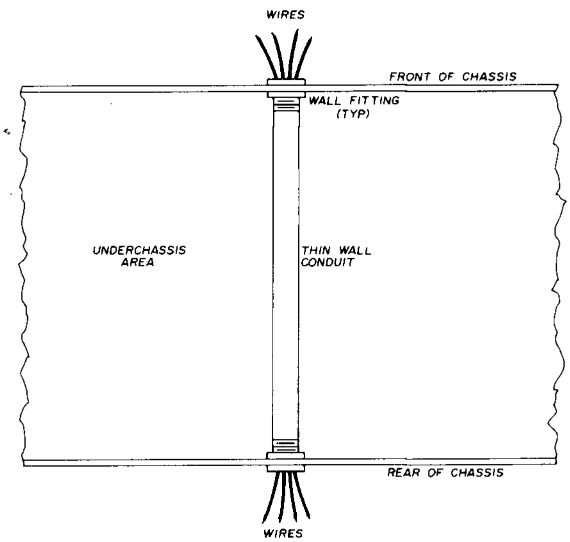


fig. 8. Wires can be passed through an underchassis area by using a short length of thin wall electrical conduit as a passageway. Conduit is attached to the chassis walls by means of metal wall fittings. Conduit and fittings can be purchased at electrical contractor or large home improvement store.

to read plate current at 1000 mA (1 amp) full-scale, the appropriate shunt resistor is:

$$\textit{Shunt resistor (ohms)} = \frac{3.9}{1}$$

$= 3.9\,ohms$ (a standard resistance value)

Simple, isn't it? No expensive precision resistors are needed and everything is figured out by simple mathematics. Other full-scale meter readings can be worked out by changing the value of the shunt resistor.

inexpensive perforated metal sheet

A good way to make a ventilated rf-tight metal box is to use perforated aluminum sheet stock found in many hardware stores and home improvement centers. Ideally, the holes should be small and closely spaced so that it seems as if there is more open space than solid metal. As an alternative, you can make your own perforated sheet from solid aluminum

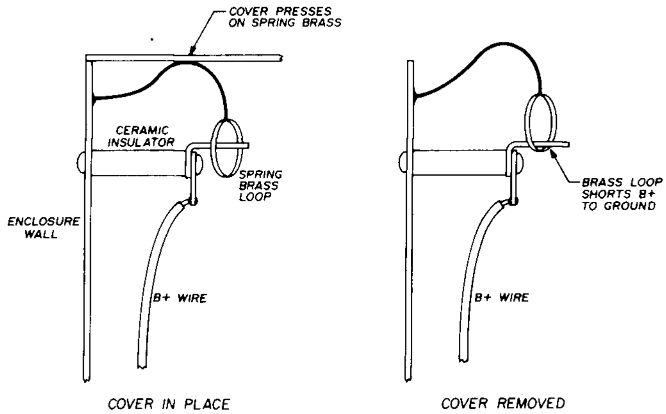


fig. 9. Inexpensive high-voltage shorting switch. The B-plus lead is connected to a ceramic standoff insulator. A short length of brass rod projects out from the insulator. A shorting ring made of spring brass loop encircles the rod as shown in the left illustration. When the lid is in place, the loop is centered around the rod. When the cover is removed the spring brass straightens out and the loop is offset, shorting the B-plus wire to ground.

sheet and an electric drill. The trick is to make up a drilling jig out of a small steel plate (**fig. 11**). This sounds like doing it the hard way, but once the jig is made, it can be used rapidly and can be reused time and time again. It is a worthwhile addition to the home workshop. The jig is held in position on the sheet with a pair of C-clamps and the holes easily and quickly drilled with an electric drill to the pattern you wish.

amplifier layout

If you look through the various Amateur magazines and handbooks (particularly those of the pre-1970 era) you'll see plenty of homebrew linear amplifiers. They bear a remarkable similarity as far as layout goes. Indeed, so do most of the linear amplifiers currently on the market. Time spent in seeing how others solved their problems is a big asset when

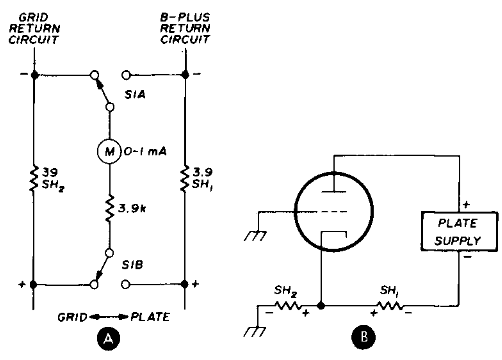


fig. 10. Meter-switching circuit (A), using an inexpensive 0-1 mA dc meter to measure either grid or plate current. In the grid position, the full-scale reading of the meter is 100 mA. In the plate position, the full-scale reading is 1000 mA. A simplified amplifier circuit (B) showing the dc current paths of the meter circuit. Note that the B-plus supply is "above ground" by virtue of the meter shunts.

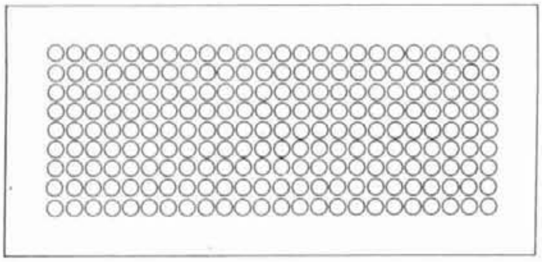


fig. 11. A drilling jig made of sheet metal 3.2-mm (1/8-inch) thick is handy for making your own perforated stock for areas requiring ventilation. Jig is about 20 cm (8 inches) long and 7.5 cm (3 inches) wide. Holes should be about 6.5 mm (1/4 inch) in diameter.

it comes to laying out the components for your own linear amplifier.

You should lay the parts out on the chassis before you start drilling holes and bending metal. Some Amateurs make a cardboard mock-up of their amplifier and slide the components around in a three dimensional layout to make sure that one part does not mechanically interfere with another and that the dials fall on the panel in a symmetrical pattern.

Once general parts placement has been ascertained, the sides, back, bottom, and top of the enclosure can be laid out and cut from sheet aluminum. The finished parts can be held together by means of bent-over edges on the sheets or by means of aluminum angle stock cut to fit. Some people use nuts and bolts to hold everything together, while others use sheet metal screws or pop-rivets. The top of the enclosure is held in position with removable screws so that it can be taken off for tube installation.

The amplifier box is supported from the panel by spacer rods cut long enough to leave space for the meters between panel and amplifier. Shaft extensions can be used to couple the panel controls to the control shafts extending from the amplifier wall.

If your assembly is completely knock-down and the chassis plate is replaceable, the amplifier circuitry and tube complement can be changed at will while still retaining the panel, circuitry, and main body of the amplifier. But you'll never need this, since hams rarely rebuild their equipment!

recommended reading

The new 21st edition of the *Radio Handbook* is now available and has a greatly expanded section on design and construction of linear amplifiers. Photographs show many different designs using popular power tubes. The new *Radio Handbook* is available from Ham Radio's Bookstore. Also read "A Beginner's 50 Watt Rig" by Bill Wildenhein, W8YFB, in the July and August, 1978, issues of *Ham Radio Horizons*. This is a goldmine of design, construction, and layout information. You should also read "Custom Design and Construction Techniques for Linear Amplifiers Using the 8877," by Merle Parten, K6DC, in the September, 1971, issue of *QST*. A reprint of this article can be obtained at no cost from the Amateur Service Dept., EIMAC, Varian Division, 301 Industrial Way, San Carlos, California 94070. Ask for bulletin AS-45.

ham radio

DIGITAL TECHNIQUES

counters and weights

Counting in the digital sense is really a sequence of flip-flop state changes. The sequence repeats and the number of state changes required for one sequence is termed the division ratio. Thinking in terms of state changes is a clue in understanding counter operation. To make sense of certain flip-flop counters, the bit weight system is used.

states and weights

Each flip-flop in an array represents a bit of data. A counter always has the same number of bits, but each bit may be 1 or 0 depending on the sequence. A chain, or cascade, of flip-flops will have an orderly sequence of bit state changes, but it is still difficult to interpret the changes into decimal notation.

Assume four flip-flops in cascade. The maximum number of states is sixteen. Weights are assigned to each bit. The least-significant bit, or LSB, will have a weight of one; it represents the input flip-flop, which changes the fastest. The next bit has a weight of two; the next four. The most-significant bit, or MSB, has a weight of eight. Mathematically, the bit weight is 2^n, where n is the bit significance.

Converting binary states to decimal notation involves adding up the weights of any bit that is a 1. Forget any 0 bits. **Table 1** has four-bit binary states with equivalent decimal weights. Note that the maximum decimal number is fifteen. What happened to sixteen? Simple. An all-zero binary state is decimal zero, so all sixteen are accounted for. A decimal sixteen would require five binary bits with the MSB at 1, the remainder at 0.

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Table 1 also gives hexadecimal notation. This is common in microprocessor state designation, and some four-stage counter packages are called hexadecimal counters.

simple counter chain

Fig. 1 has three negative-edge, clocked, JK flip-flops in cascade. J and K inputs of all are tied high, so each stage divides by two. With three in cascade the total division, or count, is eight.

This simple cascade is a ripple-through counter since each successive stage state change is dependent on the previous stage propagation delay. A ripple-through counter should not be used at high speed for selecting a particular state.

Suppose you wanted to select a decimal 2 state. The flip-flop states would be $\overline{A}B\overline{C}$ (A and C low, B high). For a short period of time this same state would occur after the fourth negative clock edge after A had toggled low but B was still high. It is a very short time, but the select gate might pass this "glitch."

A solution is to make the counter synchronous using anticipated carry. Carry in counters is the state change output, that can cause the next stage to toggle. You can see that carry anticipation is possible by examining all previous flip-flop states and the clock before a toggle occurs; they are all high.

table 1. Four-bit binary states with decimal weights.

	binary states				hexadecimal
decimal	MSB			LSB	notation
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	2
3	0	0	1	1	3
4	0	1	0	0	4
5	0	1	0	1	5
6	0	1	1	0	6
7	0	1	1	1	7
8	1	0	0	0	8
9	1	0	0	1	9
10	1	0	1	0	A
11	1	0	1	1	B
12	1	1	0	0	C
13	1	1	0	1	D
14	1	1	1	0	E
15	1	1	1	1	F

Synchronous counter modification is shown in **fig. 2**. Additional AND gates set up the next flip-flop stage so that all change state at the same time. Carry out will have the same width as the high clock state but occurs only every eight clock periods.

Difference in state change time is caused only by differential flip-flop propagation delay (quite small) or the AND gate delay. The latter may be compensated for by adding inverters to the first stage outputs for any state select gating.

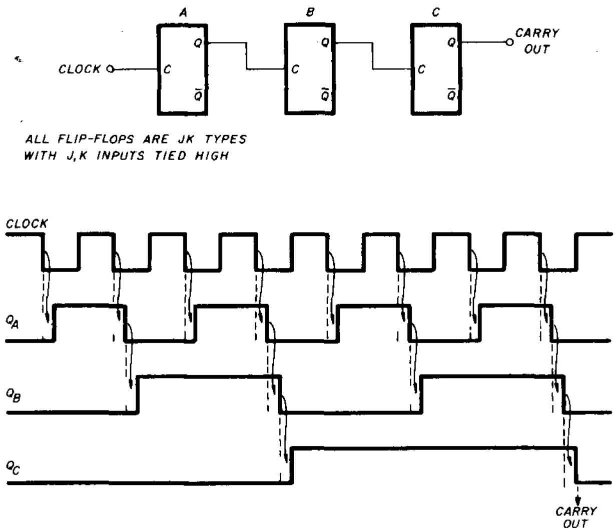


fig. 1. Cascade of three JK flip-flops with waveforms.

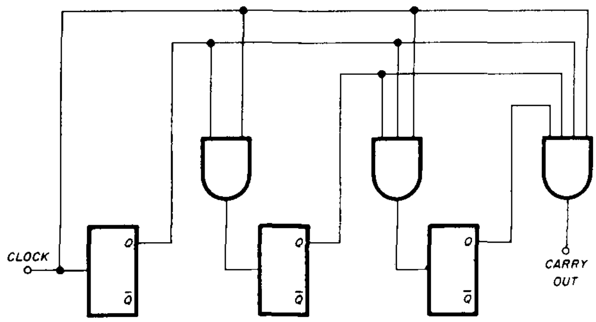


fig. 2. Synchronous three-stage binary counter using anticipatory carry.

decade counting

A minimum of four stages are necessary for division by ten. JK flip-flops can be used, and the control inputs will enable a binary state sequence from decimal 0 through decimal 9. This type of counter is called a binary-coded-decimal, or BCD, and is shown in **fig. 3**.

This is a cascade of divide-by-two (stage A) and a divide-by-five (last three stages). Ten is divisible by two, so state feedback isn't required for the first stage. Note that $\bar{Q}_D$ is made to both J and K inputs of stage B; as long as it is high (Q_D low), B will toggle on every negative edge of Q_A. Stage D will not toggle since G1 holds its J input low until a decimal 7 is reached.

At the decimal 7 state, both J and K of stage D are

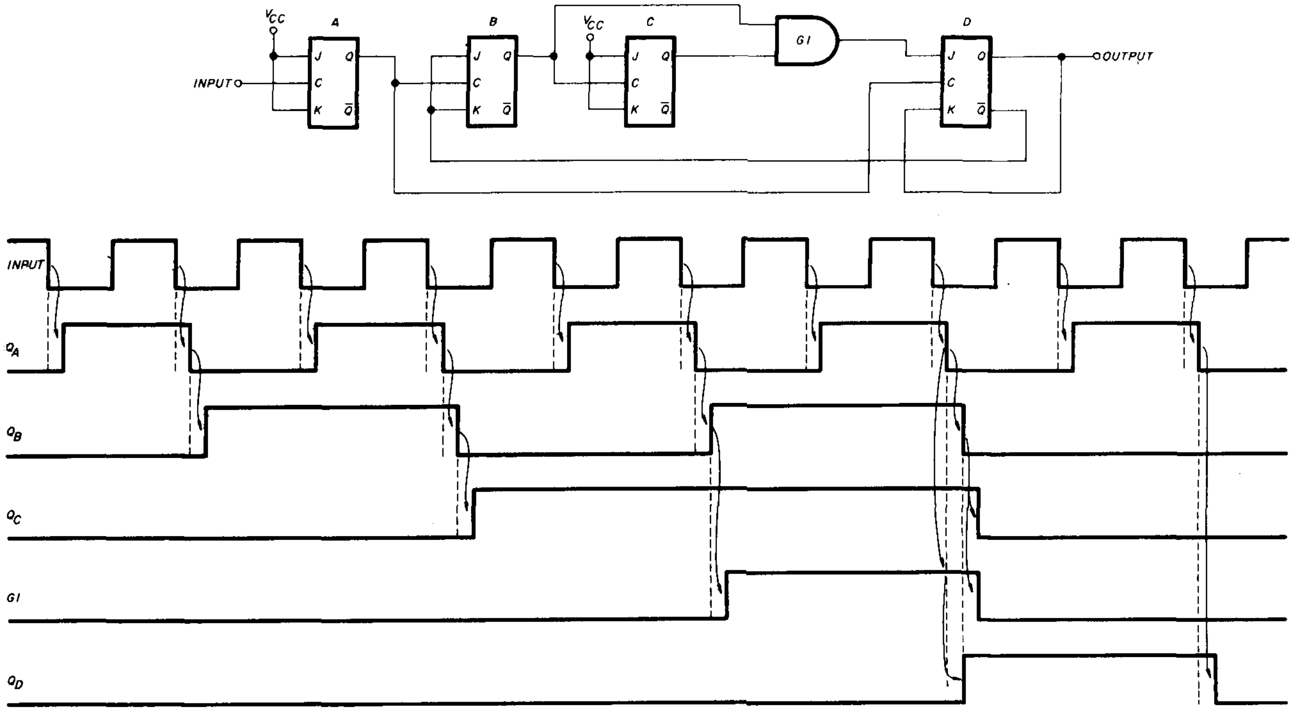
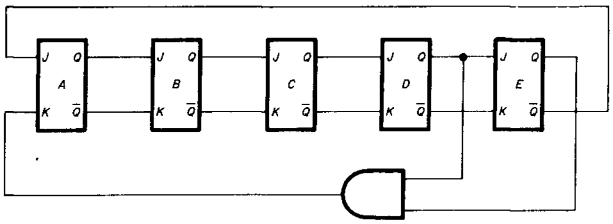


fig. 3. Binary-coded-decimal decade counter.



INPUT IS MADE TO ALL $\bar{C}$
FLIP-FLOP CLOCK INPUTS

TRUTH TABLE

	Q OUTPUTS					
INPUT	A	B	C	D	E	GATE
0	0	0	0	0	0	0
1	1	0	0	0	0	0
2	1	1	0	0	0	0
3	1	1	1	0	0	0
4	1	1	1	1	0	0
5	1	1	1	1	1	1
6	0	1	1	1	1	1
7	0	0	1	1	1	1
8	0	0	0	1	1	1
9	0	0	0	0	1	0
10	0	0	0	0	0	0

fig. 4. Five-stage, self-correcting decade ring counter.

high; D is set up to toggle. It did not toggle when G1 went high, since the control input must be present before a clock arrival. The eighth clock will make A, B, and C all low. D goes high from Q_A, since G1 has set up the toggle condition. Stage B is now inhibited from its J and K inputs made low from $\bar{Q}_D$.

The tenth clock will toggle stage D again, making Q_D low. This action removes B's inhibit, but B does not toggle, since the inhibit was still there when Q_A went low. If this is confusing it won't hurt to review the JK rules given in reference 1.

ring counters

These are shift registers modified by output-to-input state feedback. A shift register is a cascade of JK or D flip-flops with the Q and $\bar{Q}$ of one stage feeding the J and K inputs of the next (Q to D only for D flip-flops). The clock is common to all stages, and any input to the first stage will shift through all stages at each clock edge.

A divide-by-ten ring counter is shown in **fig. 4** with the state truth table. It's common in CMOS and is sometimes called a "Johnson," or "switched-tail," counter. The latter name is from inverted output state feedback. This one is called self-correcting from the AND gate connection.

At power-on you cannot be sure that all flip-flops reach one of the desired ten states. With five stages, the maximum number of states is 32 (2^5), so the counter must be able to shift out of an undesired state. One such pattern is 01101, and you can try it out on scratchpaper with and without and AND gate.*

Ring counters are inherently synchronous and are a bit easier to decode into specific states. **Fig. 4** will decode all ten states into decimal using only two-input gates for each state. A disadvantage is the number of flip-flops, which must be one-half of the count.

odd-modulo ring counters

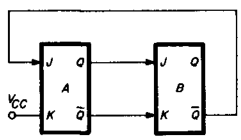
Modulus is another name for division ratio. Odd-modulo ring counters may have advantages over cascades with different state feedback. Divisions of three, five, seven, and nine don't require extra gating for correction. **Fig. 5** shows two counters with state tables.

A modulo-7 counter is created by adding a flip-flop before stage A. A modulo-9 adds two flip-flops. In both cases the Q output is connected to the next J, $\bar{Q}$ to K. The last three stages in divisions of five, seven, and nine will go through the modulo-5 pattern, skipping the 001 state between 011 and 000. All are self-correcting.

ssb quadrature counter

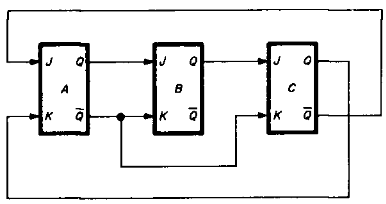
Fig. 6 is a variation of a ring counter and has been used in several phasing-type, single-sideband designs. It's made from one high-speed, dual-D package and uses all four binary states. Quadrature (90-degree) phase is maintained over a wide frequency range.

A disadvantage is that the VFO (clock input) must be four times the output frequency, and differential



DIVIDE BY THREE

INPUT	A	B
0	0	0
1	1	0
2	0	1
3	0	0



DIVIDE BY FIVE

INPUT	A	B	C
0	0	0	0
1	1	0	0
2	1	1	0
3	1	1	1
4	0	1	1
5	0	0	0

INPUT IS MADE TO ALL $\bar{C}$
FLIP-FLOP CLOCK INPUTS

TRUTH TABLE

	Q OUTPUTS					
INPUT	A	B	C	D	E	GATE
0	0	0	0	0	0	0
1	1	0	0	0	0	0
2	1	1	0	0	0	0
3	1	1	1	0	0	0
4	1	1	1	1	0	0
5	1	1	1	1	1	1
6	0	1	1	1	1	1
7	0	0	1	1	1	1
8	0	0	0	1	1	1
9	0	0	0	0	1	0
10	0	0	0	0	0	0

fig. 5. Self-correcting odd-modulo ring counters.

*See appendix

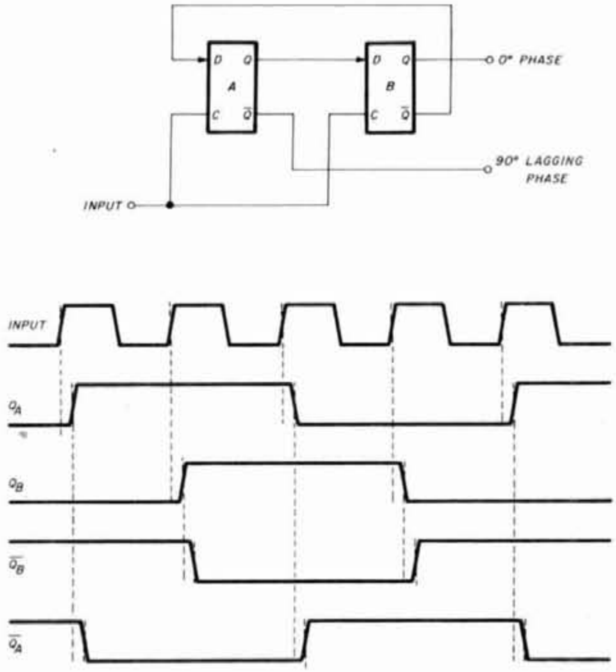


fig. 6. Two-stage SSB quadrature counter.

delay may limit the 90-degree difference. Differential delay in one package is never specified. It must be low since one degree of phase error in only 0.397 nanoseconds at 7 MHz. Output loading should be equal to minimize differential delay, and mixer output filtering must be used to eliminate harmonics.

direct set and clear

Both CMOS and TTL packages have a variety of different flip-flop and counter arrangements. Direct set (or preset) and clear (or reset) may be separate or common or in a combination. Specification sheet data should be studied carefully for each package to make certain all functions and pinouts are understood.

appendix

Starting the decade ring counter without the gate (Q_E directly to K_A) at a state of 01101 will produce this sequence: 00110, 10011, 01001, 00100, 10010, 11001, 01100, 10110, 11011, and back to 01101. It never arrives at a desired state. Adding the gate breaks the sequence at 11001. Both J and K inputs of the first stage are now 0 and it holds at a 1 state; the remaining stages shift through for the next state of 11100, a desired state. Remaining states are in the desired sequence. The worst glitch state is 01100 with the gate. It will go through 10110, 11011, then 01101 for the pattern given above.

reference

1. Leonard Anderson, "Digital Circuits — Propagation Delay and Flip-Flops," *ham radio*, March, 1979, page 82.

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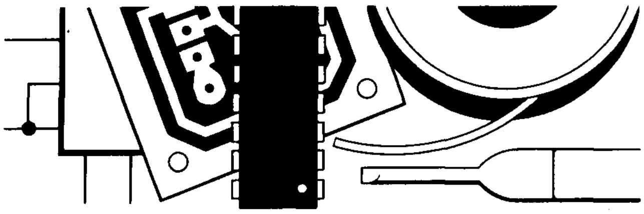
More Details? CHECK—OFF Page 110

the weekender



broadband power-tracking VSWR bridge

One of the problems that most hams have experienced with commercial power and VSWR meters has been the maker's inability to provide adequate isolation between the forward and reflected power sampling ports over a wide bandwidth. There is also the problem of having to recalibrate the VSWR meter when the output power is varied. The power/VSWR meter described in this article has been designed to be truly independent of these problems. My goal was to design a dual-directional coupler with a flat response to at least 55 MHz, and a directivity greater than 30 dB. Three couplers were designed to meet these requirements, with coupling factors of 30, 24, and 20 dB. The 30-dB coupler can be used with transmitting systems having outputs up to 1000 watts. The 24-dB coupler can be used with systems below 200 watts, and the 20-dB coupler can be used with a 100-watt limitation. The 24-dB coupler turns out to be the most practical for average ham use.

circuit description

rf section. The rf sampling and detection circuit shown in **fig. 1** was perfected with the use of a network analyzer having the capability of resolving amplitude variations of less than 0.1 dB over a 1 to 500 MHz frequency range.

In order to obtain the isolation between the forward and reflected power sampling detectors, two properly phased transformers are required. The toroid for the transformers is of "H" type magnetic material with a diameter of 9.5 mm (0.375 inch) and a thickness of 3 mm (0.125 inch), large enough to safely pass 200 watts without saturating the core. The primary of each coupler consists of a 2.5-cm (1-inch) piece of 0.141-inch OD semi-rigid coax with the solid copper outer jacket used as an electrostatic shield. It should be noted that the jacket is soldered to the groundplane of the printed circuit board on only one side of the toroid. Soldering on both sides would result in a shorted turn and actually degrade the performance of the coupler. The secondary of each transformer consists of fifteen turns of no. 31 AWG (0.2-mm) enamelled wire evenly spaced around the core. This provides 24 dB of coupling.

It is very important in winding the secondary of the transformers that the wire be spaced as evenly as possible. I found that having the turns spaced too closely caused the high-end performance to roll off at a much lower frequency than desired. The final design has a coupling response of 23.9 ± 0.1 dB from 1 to 200 MHz, and a roll-off of 0.15 dB at 50 MHz. The insertion loss is negligible. The directivity (isolation between the forward and reflected power ports) is greater than 35 dB from 1 to 30 MHz rolling off to 25 dB at 200 MHz.

The rf detector uses a pair of germanium diodes as a positive halfwave rectifier. The output is then filtered and passed to the analog tracking circuit. In order to avoid large offsets in the rectified voltage, the diodes are matched as closely as possible in the center of the high-frequency band. The setup shown in **fig. 2** allows matching to within 10 mV.

By Hank Perras, K1ZDI, Aglipay Drive, RFD 1, Amherst, New Hampshire 03031

table 1. Values of return loss for different VSWR values.

VSWR	return loss (dB)	P_{out} = 1 kW P_{sec} (mW)	P = 100 watts
1.05:1	32.2	0.6	0.06
1.1:1	26.4	2.3	0.23
1.2:1	20.8	8.3	0.83
1.5:1	14.0	39.8	3.98
2.0:1	9.5	112.0	11.20
3.0:1	6.0	251.0	25.10
4.0:1	4.4	363.0	36.30
infinite	0.0	1000.0	100.00

$$\text{Return loss (dB)} = -10 \log_{10} \left[\frac{VSWR-1}{VSWR+1}\right]^2$$

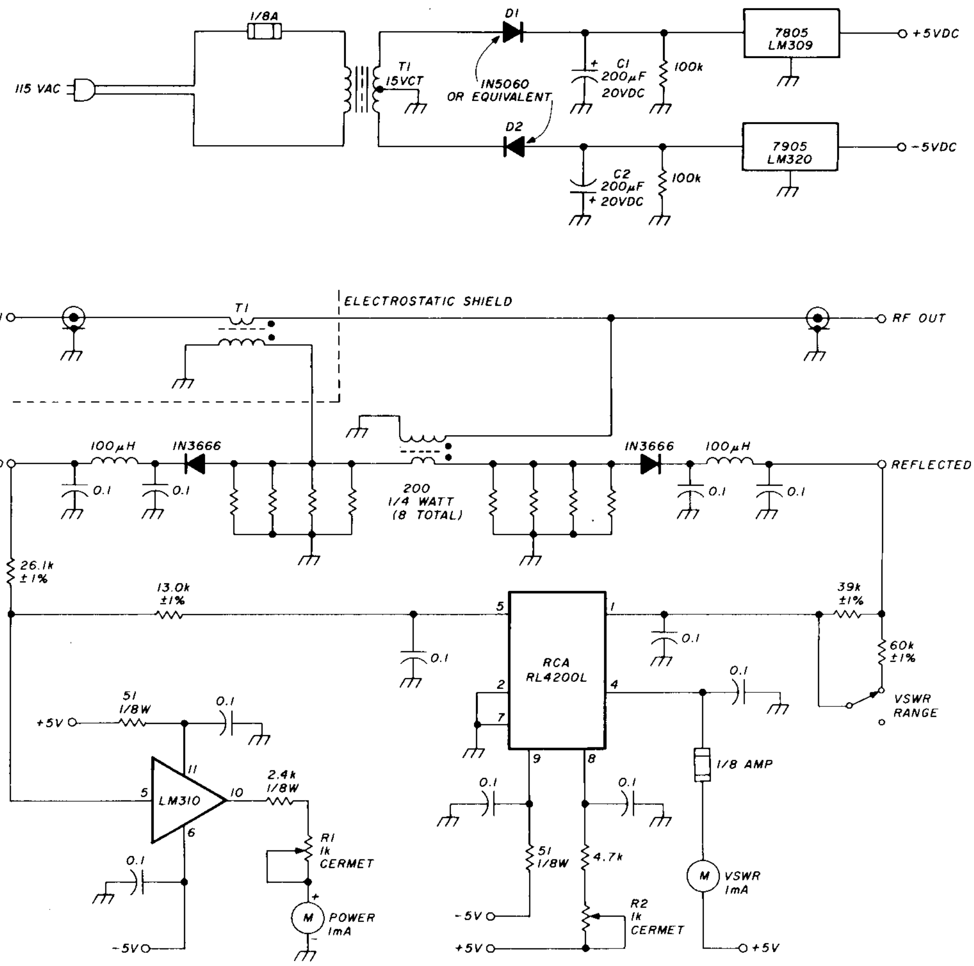


fig. 1. Schematic diagram of the broadband VSWR bridge and power supply. As specified in the text, T1 and T2 are wound to provide a coupling factor of either 24 or 30 dB.

30-dB coupler

This coupler is useful for high-power operation, that is, up to 1000 watts. With this looser coupling, adequate VSWR tracking for very low values of reflected power will be limited to approximately 100 watts of transmitter output. In other words, the VSWR will indicate properly as the power is varied from 100 to 1000 watts. Tracking very low values of VSWR becomes a problem as the output is reduced. The value of power in the reflected wave (see **table 1**) is determined by:

$$P_{sec} = P_{out}\,(dBm) - return\ loss\ (dB) - coupling\ (dB)$$

The only differences in the construction of this coupler are the meter faceplates and the coupling transformers. The transformers consist of the same one-turn primary as the 24-dB coupler, but the secondaries have thirty-one turns of no. 30 AWG (0.25-mm) enamelled wire even spaced around a type-H, magnetic-material toroid 12.5-mm (0.5-inch) diameter by 5-mm (0.188-inch) thick.

It will be necessary to construct the bridge in two sections separated by a shielded compartment. The printed circuit board can be cut in half, separating the coupler from the tracker. The board was designed with this purpose in mind, to obtain greater isolation, if needed, and to operate the coupler at some remote location in the coax.

A word of caution in winding the transformers — be very careful to avoid nicking the enamelled wire. This could result in a short to the outer shell of the semi-rigid coax used as the primary. I would suggest the use of clear epoxy on the entire transformer after assembly.

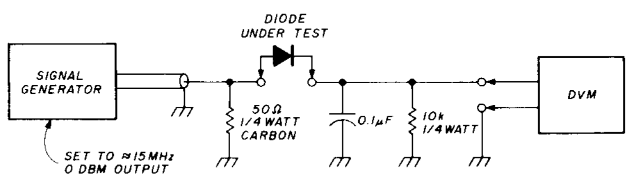
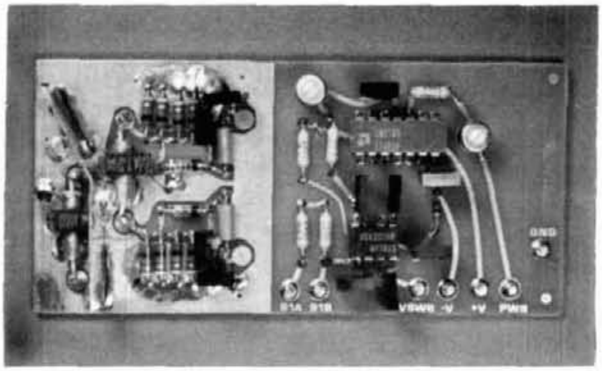


fig. 2. Setup for determining diode characteristics to select closely matched diodes as the detectors.



View of the circuit board used in the broadband VSWR bridge. The board can be cut between the rf and current tracking portions for remote operation.

Current tracker. This portion of the bridge makes the overall performance of the unit truly automatic. It is based upon the RC4200, a four-quadrant multiplier that is used as a current-ratio comparator. A reference current, established at pin 8, is used in the internal bridge portion of the IC. Forward and reflected currents from the diodes are fed to pins 1 and 5 and used internally to track the current ratio by the formula $I_4 = (I_8 I_2)/I_5$. It becomes evident that using this configuration will allow a constant VSWR to be displayed over a fairly wide dynamic power range, the limitation actually being the diode detectors and not the 4200. Thus, VSWR readings remain constant when transmitter power is varied from 200 watts down to 10 watts over the frequency range of 1.8 to 148 MHz.

The forward power is monitored by the use of a voltage follower fed from a 3-to-1 resistive divider. This divider network is necessary to keep the rectified voltage below the +5 volt supply.

I decided to have an expanded range for VSWR with 4:1 full scale being a reasonable choice. This is accomplished by shunting the 39-kilohm resistor with an additional 60 kilohms. The circuit of **fig. 1** can be modified to include a peak rms capability for monitoring the output power. **Fig. 3** shows the modification.

alignment and testing

The VSWR is aligned using the setup in **fig. 4**. The transmitter is first tuned up into a single dummy load. Then, with four loads in parallel, the antenna tuner is adjusted to reestablish a 50-ohm load to the transmitter. With the range switch in the 4:1 position, R2 is adjusted for a full-scale meter reading. Power is then noted on the series power meter, and R1 adjusted for the same reading on the power meter of the bridge.

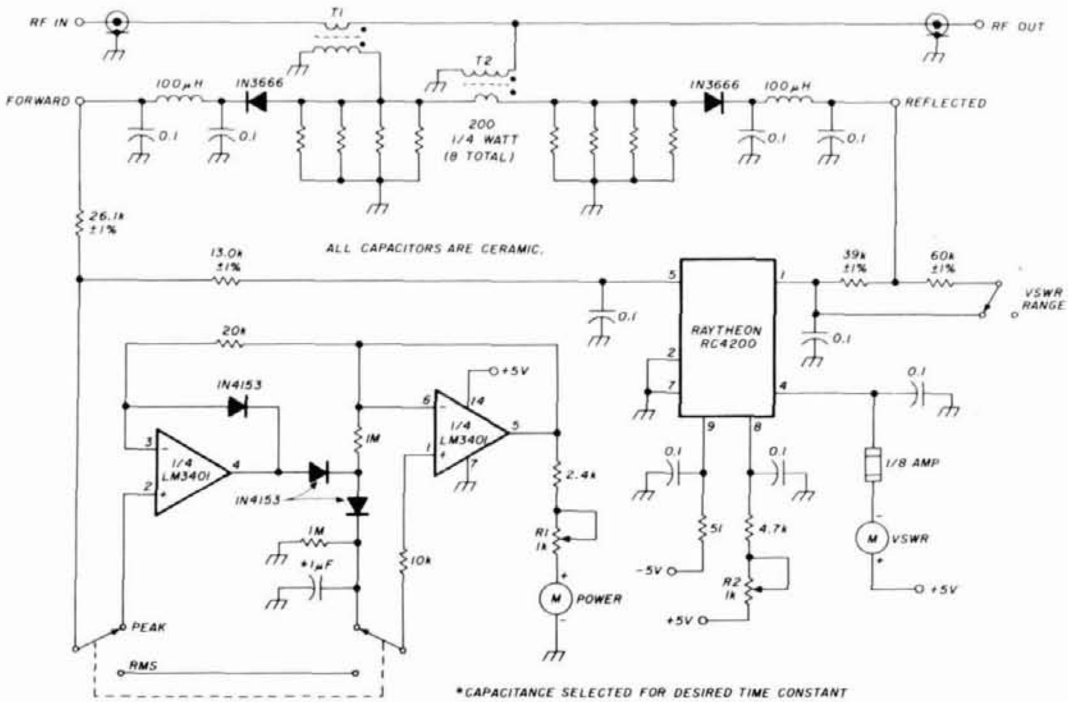


fig. 3. Schematic diagram of a similar VSWR bridge which incorporates a peak-rms power readout.

Next, one of the four loads is removed and VSWR readings are taken using both positions of the switch. The readings should exhibit a ratio of 3:1. This completes the testing and the bridge is now ready to be installed in the line permanently.

construction

This VSWR bridge is constructed on a single 10 × 5 cm (4 × 2 inch) printed circuit board, which is mounted on stand-offs inside an aluminum box. The rf is brought into and out of the box with short pieces of RG-58, stripped on one end for soldering to the terminal and groundplane of the printed circuit board. The other end uses a male BNC connector connected to a bulkhead feedthrough connector. Two feedthroughs are mounted on the back of the main cabinet, one being used for rf in, and the other for rf out.

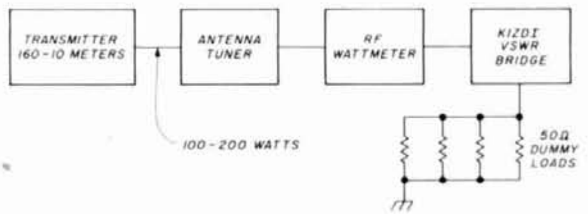


fig. 4. Test set up to calibrate the VSWR bridge.

The meters are 1-mA full-scale movements with custom-designed scales. The face plates were removed and soaked in a solvent to remove the paint. They were then repainted with white spray. The next step was to tape the base plate to a pad of paper, and with the aid of a little geometry and a compass, a new arc was drawn on the white paint. The scale divisions were computed by changing power into a current ratio and finding the antilog.

broadband transformer design

It is very important in broadband torodial transformer design to select a material that has a high permeability. This results in a transformer that, when measured on a vector impedance meter, will display a high real part of the impedance and a small reactive part, as indicated by a small phase angle reading. The low frequency roll-off is determined by the permeability of the material and the number of turns used, with a minimum number being determined by the impedance levels that the transformer will be working into. The high frequency roll-off is determined, for the most part, by the interwinding capacitance of the wires.

acknowledgments

I would like to thank Mark Stevens, WA1WSV, for his original ideas on the toroidal transformer approach, and also Eric Blomberg, N1BF, who helped design the current tracking portion of the bridge.

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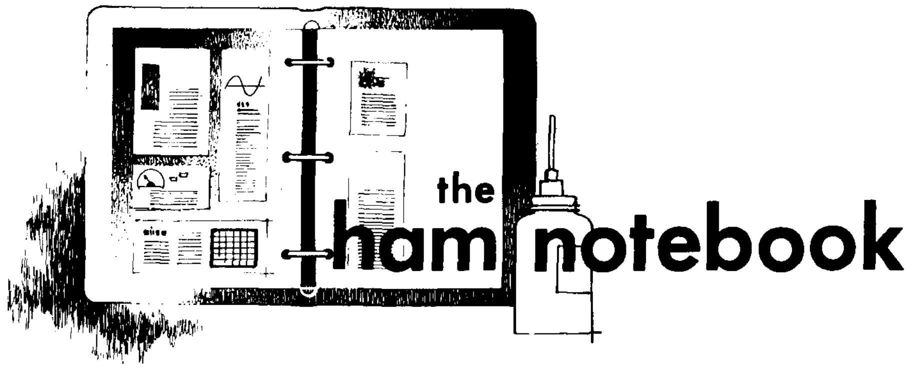

Heathkit Micoder *Touch-Tone* pad adapted to low-impedance input

A quick and easy method of adapting the Micoder to transmitters such as the ICOM 22A, 22S, and 230 is to simply replace the audio-input pot (500 ohms) with a 10-kilohm pot. In the ICOM 22A this pot is R62, which is located behind the microphone connector. In the ICOM 230 it's R34, which is located on module AF.

The Micoder is designed for a 10-kilohm output load. For the ICOM 22A/22S, a Radio Shack 10-kilohm pot (part number 271-218) will work if bent slightly to allow the case to close. I used the 10-kilohm pot (Heath part number 10-1039, R122), which was left over when I converted my HD-1982 to an HD-1984. This conversion, which is available from Heath stores for about $9.00, provides a crystal-controlled oscillator that is quite stable and requires no adjustment or alignment.

Incidentally, there are two levels of Heath conversion kits. One has a zener for regulation and one does not. If yours has the zener, load resistor R105 should be changed from 820 to 470 ohms for the Micoder and to 1200 ohms if used with the Heath HT.

I set the Micoder level control, R103, at 50 per cent range. The new 10-kilohm pot should be set by trial and error with another station while on the air.

I also taped the removed pot (580 ohms) to an inside cover so that it could be easily retrieved for restoration to the original low-impedance microphone input.

E. L. Linde, WB2GXF

off-the-air S-line monitoring

While modifying the S-line for full break in (QSK) may not be desired by many, there are those who wish to monitor the off-the-air CW signal of the 32S-( ) rather than listen to a sidetone. This modification may be made by placing the 75S-( ) FUNCTION switch to OPR. However, this results in a very strong signal. You're then required to constantly adjust the RF GAIN to compensate for this strong signal, as well as the weaker received signal from the desired station. With the addition of two readily available components, off-the-air monitoring can be more pleasant.

Refer to **fig. 1**. With S1 in the NORMAL position receiver operation is normal. In the MONITOR position, R1 (Radio Shack 271-215) is added to the receiver's rf gain circuit. During receive, R1 is shorted by the contacts on the 32S-( ) VOX relay, K1. When the transmitter is keyed, normally closed K1 contacts open, inserting R1. R1's resistance is adjusted only once to provide a comfortable monitoring level in the speaker or headphones; CW SIDETONE is disabled by S1b. If you have difficulty obtaining a pot with a dpdt switch or if only an spst switch is available, S1b may be eliminated and the CW SIDETONE cable can be disconnected.

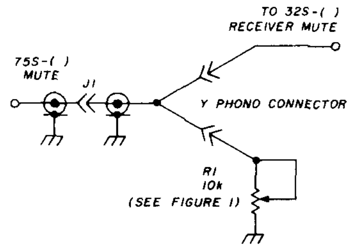

fig. 2. A "no-holes chicken-connection" may be made at the 75S-( ) MUTE jack for those not wanting to make any mods to their S-line gear.

The small size of the Radio Shack

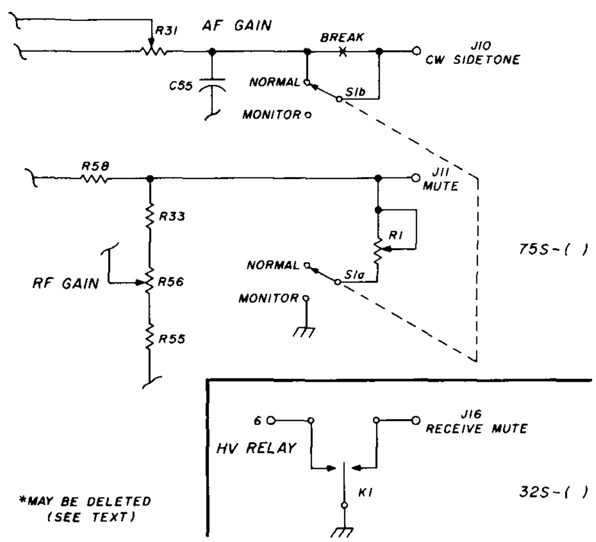

fig. 1. Radio Shack 271-215 pot for off-the-air monitoring level (R1) is added to the 75S-( ) rf gain-control circuit.

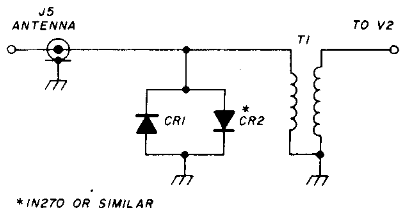

fig. 3. Rf input protection diodes added to the 75S-( ) antenna jack.

pot permits mounting it on the front panel between the MODE switch and the RF/AF GAIN control. The mounting hole should be centered laterally and located 79 mm (3-3/32 inches) from the top of the front panel. If a larger pot is used, it may not fit in that location but may be mounted on a small aluminum bracket and secured behind the PTO control by one of the PTO mounting screws. With front-panel mounting the adjacent chassis hole may be used for the leads. Shielded wire should be used for the CW SIDETONE lead to prevent hum pickup.

For those who may be hesitant to apply *any* modification to their S-line (or who may want to check the effectiveness of the addition), the added pot may be "chicken connected" by using a Y-type phone connector at the 75S-( ) MUTE jack, J-11 (**fig. 2**).

I recommend the addition of two germanium diodes across the receiver antenna jack, J5, as rf protection devices (**fig. 3**).

Paul K. Pagel, N1FB

improved memory for the Yaesu FT-227R Memorizer

I like the FT-227R. It has all the features I enjoy in a 2-meter rig: It's fully synthesized over 4 MHz; it has 5-kHz offset tuning; it operates either up or down 600 kHz (or on so-called oddball splits); and, of course, it has simplex capability. Its power is also right: 10 watts for repeater operation or you can run 1 watt for local contacts. Included are tone-burst circuitry and provisions for CTSS and full-tone access.

After six months of operation I found that the rig will also work in Teletype service. We have a net that runs AFSK at 170 Hz in the New York City area. (Nothing gives as good an indication of how well a rig works as 20 minutes of key-down operation.)

Everything seemed to be what I wanted. But — when I closed down for the night I found that the Memorizer *forgets*! Whenever I took the rig into the house, or just out of the car, I found this to be true. I looked into the instruction manual one evening, and out came the answer.

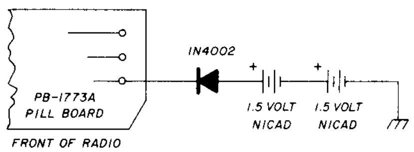

fig. 4. Mods to the Yaesu FT-227R Memorizer 2-meter rig to store a frequency after the radio is disconnected from its power source.

Remembering that my LED watch could remember time with just a low-power battery, I thought perhaps the same idea would work in the FT-227R. A check of the schematic shows that when the rig is connected to a battery, as in an automobile, and the memory switch is pressed, 5 Vdc is constantly applied to the phase-locked-loop (PLL) unit. This is the PB-1773A unit in the book. The 5 Vdc was derived from the 13.5-volt line from the auto battery. A further check showed that the ICs in the PLL were of the CMOS type and would probably work on very little voltage if pushed. The solution to the problem was simply adding 3 Vdc and a 1N4002 diode (**fig. 4**). These mods allow a small voltage on the PLL circuit through a diode to prevent higher voltage from ruining the two AA cells. It's that simple.

construction

The first step in making the addition is to remove the five screws and put aside the bottom cover (this is the one with the speaker). Looking into the unit you'll see the PLL circuit in back of the front panel. In my unit the PLL circuit was covered by a fiber insulating cover.

Remove the three screws that hold the PLL circuit cover. Remove the cover. With the rig facing to the right, look at the upper left-hand corner of the board. You should see three traces running toward the "bottom," or down the long length of the board. Follow the third trace in from the end. It should go to pin 16 of all the ICs. This is the power trace and the one that we want.

Solder a 100-150 mm (4-6 inch) wire to it. Then find a ground point on the board. Anywhere will do. Solder another wire of the same length to it. Replace the cover and the three screws on the PLL board. Observe good construction practice and use a very small (25-watt or so) soldering iron.

This should leave you with two wires sticking out of the PLL board with the cover on. Next solder two AA batteries in series. Solder the anode of the diode (unbanded end) to the positive side of the "top" battery, and the cathode (banded) side to the wire coming from the PLL board connected to ground. This will put a positive voltage on the PLL at all times.

Now solder the ground wire from the PLL board to the negative end of the batteries. That's all there is to the electrical mods.

I wrapped the batteries and diode with PVC electrical tape and located them in an empty area of the board.

Total drain on the system is only 3 mA, so the batteries should last for quite a while. I've had the system in operation for some months and haven't yet replaced the batteries.

With this system you can have memory for the low, low price of under $0.65. This may be one of the best modifications available for the money. Now, if you have one frequency in memory and another on the dial, the radio will remember both frequencies, even if the power is off and the rig is removed from the automobile.

Stephen Mendelsohn, WA2DHF

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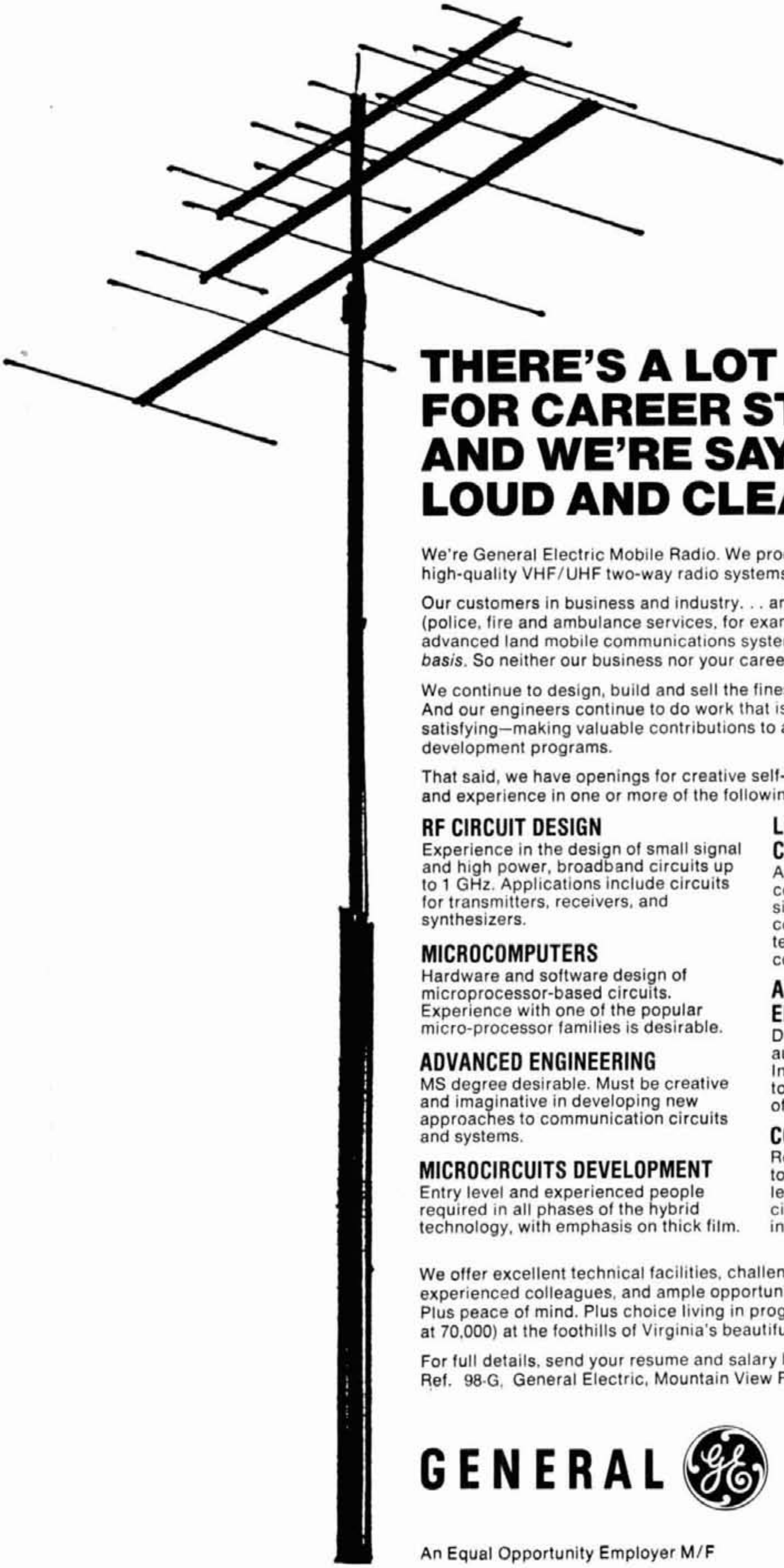

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Ten-Tec Omni hf transceiver

The new Omni high-frequency transceiver by Ten-Tec has just about everything the discriminating Amateur operator could ask for. It's Ten-Tec's top-of-the-line radio — deluxe in every respect from the functional styling to the smallest detail of operating convenience. Truly an engineering masterpiece for those who demand the best.

All-solid-state design is featured, of course. The radio covers 160 through 10 meters and has convertible 10-MHz and AUX band provisions. This means that you can receive WWV and the Omni can transmit between 10-10.5 MHz or 18 MHz should additional Amateur frequencies be granted during the WARC conference. The radio is broad-banded, which means you can change bands without the inconvenience of tune-up and without danger of out-of-resonance damage to the final amplifier.

If you demand operating convenience, the Omni leaves little to be desired. VOX and PTT circuits are built in. A built-in squelch circuit, unusual in hf radios, is also included. It's great for tuning and decreasing band noise while monitoring a frequency for net operation or schedules.

The Omni has a four-position CW/ssb filter. Bandwidth is 150 Hz with three selectable skirt contours for optimum CW reception. The fourth position of the selectivity switch selects the sideband filter, which is an 8-pole crystal lattice design with 2.4-kHz bandwidth and a 1.8-shape factor.

For the CW operator, the Omni features two-speed break-in. A front-panel switch selects either fast or slow speeds. The fast speed is instant, full break-in. Slow speed has a longer mute time before the receiver is activated — useful when working in a crowded band with heavy interference or when operating mobile. The slow setting allows better sidetone readability under adverse conditions. The receiver is totally muted to CW speeds as low as 10 wpm, which is still short enough for full break-in.

Offset tuning is essential in a transceiver. The Omni features two-range offset tuning. One range is ± 0.5 kHz for fine tuning the received signal.

Another offset tuning range allows you to tune the receiver over a ± 5 kHz range for working stations above or below the frequency set by the main tuning control.

Ten-Tec engineers have included a receiver section designed to achieve an ideal balance between dynamic range and sensitivity. This means you can hear loud local stations and weak DX stations without the nuisance of front-end overload. Receiver sensitivity is 2 μV on 160 meters and 0.3 μV on 10 meters: about 85 dB overall. Even greater overload performance can be attained by a switchable PIN diode attenuator on the front-panel rf gain control. Great for eliminating that kilowatt down the street!

WWV is available by switching to the 10-MHz band position. And the Omni is ready to receive on this band (10-10.5 MHz) now. Transmitting capability is available on this band if it becomes available for Amateur Radio later.

Some of the many other Omni features include provision for front-panel control of linear amplifier and antenna systems, phone-patch jacks, "timed" crystal calibrator (Model 545 Omni-A), zero-beat switch, SWR bridge, adjustable alc and sidetone, dual speakers, and plug-in circuit boards.

For planning your new station, here are the dimensions of the Omni and packaging information. The radio measures 14.6 cm high, 36 cm wide, and 35.5 cm deep (5¾ × 14¼ × 14 inches). To blend with any decor the Omni features functional styling: a "clamshell" aluminum case is clad in textured black vinyl with a nonreflective, dark metal front panel surrounded by an extruded satin-finish aluminum trim bezel and tilt bail.

The Ten-Tec Omni is available in two models. The Omni-A with analog dial, sells for $899. The Omni-D, with six 11-mm (0.43-inch) LED digital readouts is $1069. Accessories are also available including model 546 keyer, $85; model 243 remote VFO, $139; model 248 noise blanker, $49; and model 252MO ac power supply, $119.

For a comprehensive look at the Omni, write for the Ten-Tec Omni brochure available from Ten-Tec, Incorporated, Sevierville, Tennessee 37862.

Kantronics morse code teletype reader

Kantronics' Field Day* is a tri-mode microcomputer system that reads and displays Morse code and radioteletype signals and computes Morse code speeds. It is a complete unit that doesn't require peripheral equipment or television monitors for use.

Field Day is lightweight and portable. A movable support arm tilts the unit to four different viewing angles

*"Field Day" is a trademark of Kantronics, Incorporated. All rights reserved.

More Details? CHECK—OFF Page 110

and doubles as a handle for field use. The enclosure is sturdy and durable, but light and compact as well. Front-panel controls include ON/OFF, SPEED (display), EDIT, (word) SPACE, and RESET.

Field Day copies incoming or outgoing signals through the audio output of a receiver. (Outgoing signals are monitored through receiver sidetone provisions.) An internal speaker is enclosed, and volume is adjusted through the receiver audio gain potentiometer. If Morse code is being copied, Field Day screens out unwanted signals with an active 200-Hz bandwidth filter. The 750-Hz center frequency signals are then entered into the microcomputer system, which uses an 8035 chip.

Once signals are converted to alphanumeric text, they are advanced from right to left across ten 14-segment displays. When in the code-speed mode, the two leftmost LEDs display the speed while text advances across the others.

Two Morse copying modes are accessed on the front panel. In the standard copying mode, fairly strict Morse specifications are applied to the incoming code. If spacing or weighting is incorrect, the unit will display a variety of mumbo-jumbo. This mode is good for copying good code, and acts as the perfect "judge" for practicing Morse sending.

When the code editor is engaged, Field Day processes the signals with a relaxed program that effectively analyzes and edits poorly sent code. The corrected version is then displayed. With the code editor in use, a majority of the signals found on the air were edited on 90 per cent accuracy levels in laboratory tests. These tests used random signals from all classes of Amateur bands.

In addition to code editing, a word spacing control is included on the Field Day front panel. This control determines the most likely word breaks and inserts spaces into bunched copy.

Field Day computes code speed with an accurate sampling program. This program is based on the basic Morse element, which is the duration of a single dit. The speed is tracked during the transmission, and changes are conducted and displayed on the LEDs. Morse code speeds are displayed at the touch of a front panel button. When not in use, all ten LEDs are devoted once more to code-text display.

In RTTY mode, which is controlled from the back panel, the standard 60, 67, 75, and 100 words-per-minute Baudot teletype speeds are copied. With no other teletype equipment, the two-tone signals can be read as standard text. Also found on the back panel are terminals for audio input, TTL compatible inputs, TTL compatible demodulator output from the unit, and a phone jack for attaching headphones.

The Field Day enclosure is cream-colored with a brown, tan, and cream front panel. The 14-segment LED displays are red and are protected by a red polylens filter, laminated into the front panel.

For more information, contact Rick Link, WB0KDE, Advertising Manager, Kantronics, Inc., 1202 East 23rd Street, Lawrence, Kansas 66044.

fast-scan ATV transmitter/converter

P.C. Electronics, of Arcadia, California, has put their ATV modules into a single attractive enclosure for those hams who are more interested in operating than building. All that is needed with the TC-1 is a Technician or higher Amateur license, a TV set tuned to channel 2 or 3, a 435-MHz antenna, and a video source. The video source can be a closed-circuit TV camera, computer video, teletype video, or video tape recorder.

The TC-1 ATC transmitter/converter contains a sensitive, varactor-tuneable, 420 to 450 MHz converter with output on TV channel 2 or 3. No modification to your TV set is necessary to receive fast-scan ATV because the same standards are used as in commercial broadcast. The transmitter section of the TC-1 runs 10 watts peak output on 439.25 or 434.0 (or any other ATV frequency by special order).

Computer alphanumerics, graphics, and color can be transmitted because the modulator has a bandwidth of 8 MHz. This allows you to play Star Trek or blackjack over the air.

Price of the TC-1 is only $399 delivered in the U.S. Options include AC/12 Vdc for portable work, $30; off-the-air video detector and monitor driver (to see the actual transmitted picture), $25; and on-carrier audio for those areas with an inband ATV repeater, $50. The 117-Vac, 50-60 Hz power supply is built in. UPS delivery prices are included to save you the trouble of trying to figure out the charges. Direct mail-order sales saves you the cost of dealer markup.

Send an addressed, stamped envelope for a catalog of modules, cameras, and monitors. Write P.C. Electronics, 2522 Paxson Lane, Arcadia, California 91006.

sweepable function generator

The Model 2001 four-waveform function generator, from Continental Specialties, is electronically sweepable over a 10:1 to 100:1 range. The 2001 offers sine, triangle, square, and TTL square waves from 1 Hz to 100 kHz in five pushbutton-selectable overlapping ranges, tuned with a 10:1 vernier dial featuring fifty increments. Accuracy is ±5 per cent of the dial setting. The TTL output will drive ten

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TTL loads with rise and fall times of less than 25 ns.

Sine-, square- and triangle-waveform outputs are variable over a range greater than 40 dB. The high level output is rated 0.1-10 volts p-p into an open circuit; 0.05-5 volts p-p into a 600-ohm load. A separate low level output, 40-dB down from the high level output, is rated at 1-100 mV into an open circuit; 0.5-50 mV into a

600-ohm load. A variable-amplitude control, once set, holds the output signal to within less than ±0.5 dB over the entire frequency range.

The sinusoidal waveform offers less than 2 per cent distortion. The triangular waveform is within less than 1 per cent of linearity error. The standard (not TTL, which is a separate output) square wave features rise and fall times of less than 100 ns and a time symmetry error of less than 2 per cent.

A voltage-controlled sweeping oscillator (sweep VCO) may be zero referenced from any frequency setting. A banana jack input will accept any signal from 0 to ±10 volts and offers a 22k input impedance.

The Model 2001 is calibrated at 25C ±5C, but operates over a 0-50C range. The 25.4 × 7.6 × 17.8 cm (10 × 3 × 7 inch) package weighs 1.0 kg (2.2 pounds). Power requirements are 6 watts at 105/125 Vac, 50/60 Hz. A 220-240 Vac, 50/60-Hz powered version is optionally available. Also available is a 20-dB banana jack adapter output attenuator. Suggested resale price for the Model 2001 is $124.95.

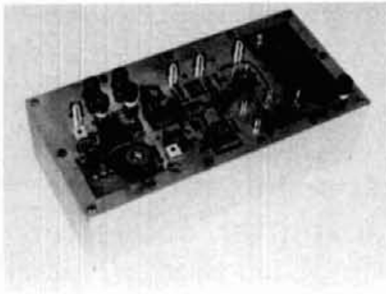
For additional information, contact Continental Specialties Corporation. East Coast: 70 Fulton Terrace, New Haven, Connecticut 06509; (203) 624-3103; TWX (710) 465-1227. West Coast: 351 California Street, San Francisco, California 94104; (415) 421-8872; TWX (910) 372-7992. Overseas: CSC UK LTD, Spur Road, North Feltham Trading Estate, Feltham Middlesex, TWI 40TJ, England; 01-890-0782; International Telex (815) 881-3669.

tunable power amplifier

A tunable master oscillator/power amplifier demonstrating Class-E switching-mode rf power amplifier circuit technology is available from Design Automation, Inc., of Lexington, Massachusetts.

The Design Automation Model E10-3 is a tunable, 10.5-MHz power amplifier that demonstrates Class-E rf operation, while permitting observation of the voltage and current waveforms on a 100-MHz oscilloscope. Four different, and interchangeable, transistors provided with the circuit demonstrate its low sensitivity to variations in transistor characteristics. Load network components adjust over a ±20 per cent range; transistor duty ratio over a 35-60 per cent range.

Deviations from nominal in transistor characteristics, component values, load, frequency, and input drive have little effect on the performance of Design Automation's patented Class-E circuitry. Serving the same function as conventional Class-B and -C circuits, Class-E cir-

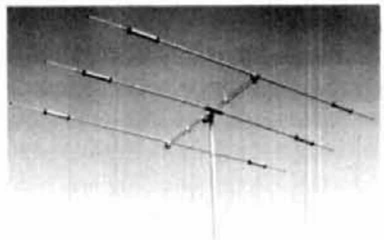


cuits offer 80 per cent or higher efficiency, 20 per cent or lower power dissipation, and lower second-breakdown stress on power output devices, the firm claims.

For more information, contact Design Automation, Inc., Nathan Sokal, 809 Massachusetts Avenue, Lexington, Massachusetts 02173.

system three antenna by wilson

Wilson Electronics is proud to announce the latest in tri-band antennas for 10-15-20 meters. The *System Three* features lightweight design yet



heavy-duty construction materials, low swr across all three bands, boom length of 4.2 meters (14 feet), wind-survival rating of 100 mph, direct feed with 52-ohm coax or with a balun, and power-handling capability of 2000 watts.

The *System Three* is listed at an economical price of $179.95. For more information, see your favorite dealer or contact Wilson Electronics, Consumer Products Division, P.O. Box 19000, Las Vegas, Nevada 89119.

Personal-Size DVOM

A new, 3½-digit, pocket-sized, digital multimeter has just been introduced by The Hickok Electrical Instrument Company for electrical/electronic test, calibration, and field-service applications. The instrument, designated the LX 303, while priced under $75.00, contains features generally found in more expensive units, including auto-polarity, auto-zero, and automatic over-range indication. A rugged, compact unit that fits easily in the palm of the hand, the LX 303 features a large one-half-inch, angle-mounted LCD readout for high readability indoors and out, even in bright sunlight. A reading rate of 3 readings per second makes accurate reading fast and convenient. Battery

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life is 200 hours minimum (300 hours typical) from a single 9-volt alkaline battery. Handy battery check capability is also provided.

Ruggedness is achieved in the LX 303 by combination of light weight, compact size, a high-impact thermoplastic case, and glass-epoxy pc board construction. Ruggedness is further enhanced by a snap-on cover which protects the entire front panel during storage or transit, whether in a briefcase, tool box, or storage bin. The snap-on cover can also be used to store the test-lead set included for a totally self-contained, protected instrument. All input jacks are recessed for operator safety.

Reliability is ensured by the use of LSI circuitry and laser-trimmed, thin-film resistor networks for low parts count. The excellent overload characteristics provide 1000-volt protection on all dc voltage ranges except the 200-mV range, which is protected to 500 volts. All ac ranges are protected to 600 volts. All ohms ranges are protected to 120 volts. Maintainability is also excellent due to the use of sockets for the major components, including the display, and the extensive use of standard components. The unit is covered by a one-year warranty. Suggested user net price is $74.95.

A full complement of accessories is available, including an ac adapter (115 Vac and 220 Vac versions) at $7.50; a padded vinyl carrying case at $7.50; a 10-amp dc current shunt at $14.95; an X10dcV probe adaptor that protects the input to 10 kV at $14.95; and a 40-kV dc probe at $35.00.

For more information, see your local Hickok dealer, or write to The Hickok Electrical Instrument Company, 10514 DuPont Avenue, Cleveland, Ohio 44108.

VHF power amplifier

Mirage Communications is now offering a new solid-state 2-meter amplifier, the B108.

The B108 represents a new generation of all-mode amplifiers for vhf

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use, incorporating features that have not been available before in a single amplifier. It is designed to operate on a-m, fm, ssb, or CW, with a power output of at least 80 watts for 10 watts of drive.

A built-in receive preamp is a standard feature. The preamp utilizes a J310 FET in the latest, low-noise circuit design. It provides at least 10 dB of gain and a 2-2.5 dB noise figure. The preamp may be operated with or without the power amplifier's being turned on. Another standard feature is a rear panel connector for remote-control operation. An optional remote control head, the RC-1, is available with either a 1.8-meter (6-foot) or 5.4-meter (18-foot) cable.

Keying is provided by either the internal rf sensing circuit or the external transmitter. For ssb operation, the relay-drop-out delay is fully adjustable.

The B108 has a list price of $169.95. The RC-1 remote control head lists for $24.95. For further details, contact your local dealer or Mirage Communications, P.O. Box 1393, Gilroy, California 95020.

communications essentials and filters brochure

A new four-page brochure describing essential communications accessories and filters is now available from the J.W. Miller Division, Bell Industries of Compton, California.

Models CN-720 and CN-620 SWR and power meters provide simultaneous direct reading SWR, forward power, and reflected power. Model

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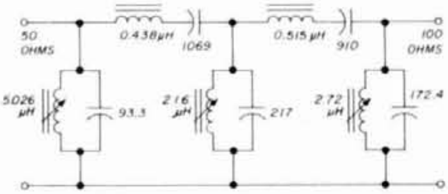
RF-440 rf speech processor increases talk power with splatter-free operation. Models CS-201 and CS-401 coaxial switches ensure high isolation — better than 50 dB at 300 MHz, and better than 45 dB at 450 MHz.

A broad line of interference filters includes highpass, lowpass, audio, and ac power-line filters. For additional information, contact Jerry Hall, Operations Manager, J.W. Miller Division, Bell Industries, 19070 Reyes Avenue, Compton, California 90224. Telephone (213) 537-5200.

short circuits

grounded-grid matching circuit

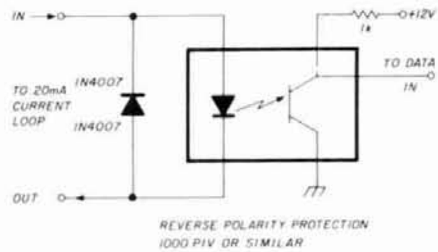
The author inadvertently supplied the wrong schematic for the wide-band grounded-grid matching circuit



published in the March, 1979, issue of *ham radio*. This schematic shows the correct matching network. All inductors are in µH and capacitors in pF.

phase coherent RTTY modulator

The schematic diagram of the phase-coherent RTTY modulator published in the February, 1979, issue of *ham radio* contains an error. The



resistor between pin 7 of U1 and the LOW-ADJUST potentiometer should be 10k. The op-isolator to be used as a current loop interface should be connected as shown here.

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DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N.H. 03048.

EBC 144 Jr. — 2-meter synthesized FM transceiver. Aircraft quality construction throughout. Super sensitive receiver, not prone to interference even in strong RF fields. Transmitter has solid audio, and in excess of 15 watts output. Modified to include lights over synthesizer switches. $200. Craig Clark, P.O. Box 83, Greenville, N. H. 03048.

WANTED: Com-key #416 Western Electric or Amtron handsfree telephones. Bearer. 65 W. 69th, NYC 10023.

RM-300 RTTY MODEM, the complete TU and AFSK generator on one board. This modem featured Sept '78 HAM RADIO. Complete documentation $2.00. RM-300 Modem or RP-400 Power Supply board just $21.25. Complete RM-300 or RP-400 kit less PROM $71.25. PROM programmed with your call $7.00. WA6DNR Eclipse Communications, 5 Westwood Drive, San Rafael, CA 94901.

WANTED: Will pay reasonable price for wired and working E&L's MMD-1 microprocessors. Gearald Malseed; 8102 LaSalle Rd., Towson, MD 825-4266. Leave phone number, will call back.

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FOR SALE: Heath SB-230 Linear, 80 through 10 meters, perfect, factory aligned, $395. Heath IO-4541 Oscilloscope, perfect, factory aligned, with PKW-105 Combination Probe, $130. Sabtronics 2000 DMM, perfect, $45. K2RHK, (212) 877-8539.

BUY-SELL-TRADE. Send $1.00 for catalog. Give name address and call letters. Complete stock of major brands new and reconditioned amateur radio equipment. Call for best deals. We buy Collins, Drake, Swan, etc. Associated Radio, 8012 Conser, Overland Park, KS 66204. (913) 381-5900.

QSL's 24 hour service. Why wait? New, strong designs. Get more action for your money. Send 25¢ for catalogue, samples. DX Majic, Dept. A, 2448 Channing, Berkeley, CA 94704.

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RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

FIBERGLASS VAULTING POLES: Perfect Quad spreaders or VHF/UHF booms. SASE for info. K5WSE, Box 1032H, Cedar Park, TX 78613. (512) 259-2164.

MUSEUM for radio historians and collectors now open. Free admission. Old time amateur (W2AN) and commercial station exhibits, 1925 store and telegraph displays, 15,000 items. Write for details. Antique Wireless Assn., Holcomb, N. Y. 14469.

MOSLEY 10-15 meter beam. If you already have a 20-meter monobander, here's an excellent way to get on 10-15. $75 plus shipping. Would prefer local pickup, however. Craig Clark, P.O. Box 83, Greenville, New Hampshire 03048.

HEATH SB-101 XCVR $350, SB-200 Linear $350, SB-630 Console $95, SB-600 Spkr. $20, HP-23B Pwr $60, Heath CW Filter $30. All mint, satisfaction guaranteed. Also — W4UX type keyboard $90. Want SB-110, SB-610 — W4UKU Jerry Flanders, 411 Urquhart Dr., Beech Island, S. C. 29841. (803) 827-1629.

DRAKE B-LINE w/160M $750. Mint IC211 $750. Johnson KW Matchbox w/swr $165. K4TO, (205) 536-6546.

REWARD: $25.00 for the following technical manuals: Alfred 6551 sweep generator, Micro Power Model 221 sweep generator, Marconi TF 868B LRC bridge. Also I am looking for the following items: Plug-ins for Alfred 6551 and Micro Power sweepers, General Radio: 1607A, 1602-P3, 1209C, 1215B, 900DP, 874LK10L, 874LK20L. If you have any of these manuals or other items please phone collect (503) 327-3827, W7LDO — Cliff.

WANTED: Heath HO-10 monitor scope; please quote price and condition in first letter. Jim Fisk, W1HR, HAM RADIO, Greenville, NH 03048.

MOBILE HF ANTENNA, 3.5-30 MHz inclusive, 750 watts PEP, center loaded coil, tuned from the base, eliminating coil changing or removing from mount. Less than 1.5 to 1 VSWR on all ham bands. $119.95 each — contact your local dealer or order from Anteck, Inc., Box 415, Route 1, Hansen, ID 83334. (208) 423-4100. Master Charge and VISA cards accepted. Dealer inquiries invited.

ATTENTION: UHF and Microwave Amateurs, at last a single source for your state-of-the-art Preamplifier and coaxial components. Send for free catalog. Cascade Microwave Labs, Rt. 1, Box 25, Jefferson, OR 97352.

QSL CARDS 500/$10. 400 illustrations, sample. Bowman Printing, Dept. HR, 743 Harvard, St. Louis, MO 63130.

AUDIO FREQUENCY GENERATOR: Heath IG-1272. Pushbutton plus variable frequency selection. Calibrated output. Brand new condition. $120 new, sell for $75. MFJ random wire antenna tuner, $15. Ameco TX-62 6 & 2 meter AM and CW transmitter. 80 watts. $50. WB8IKJ, Box 246, Portage, MI 49081 or call (616) 375-7469 after 6 EDT.

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RTTY — Bandpass active filter 2125/2295 Hz. kit — $11.95, W/T $16.95. NS-1A PLL Demodulator W/T $26.95; kit — $19.95; board only $4.95. All postpaid. SASE for info. Nat Stinnette Electronics, Tavares, FL 32778.

HEATHKIT SB-200 Like new $385; SB-102 with extra tubes & CW filter $355; HP-23 Power supply $43; SB-600 Spkr. $23; New Shure 444 mic in box $30; Drake L.P. filter new $18; Symtek RF pre-amp $40. All or part — write K3FOD, 120 Embleton Rd., Owings Mills, MD 21117.

WANTED: Hilltop property near Pollock Pines, California. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

MOTOROLA 150 MC desk top FM receiver $20; HP205AG Lab type Audio Generator $75; Factory manuals, RCA, G.E., Motorola — $5.00 each. K6KZT, 2255 Alexander, Los Osos, CA 93402.

CALL TOLL FREE for an EZ deal. 800-247-2476/1793. Iowa call 800-362-2371. See ad elsewhere. WØEZ, Bob Smith Electronics, RFD 3, Fort Dodge, Iowa 50501.

FERRITE BEADS: w/specification and application sheet - 12/$1.00. Assorted PC pots - 10/$1.00. Miniature mica trimmers, 3-40 pF. - 5/$1.00. Postpaid. Includes latest catalog. Stamp for catalog alone. CPO Surplus, Box 189, Braintree, MA 02184.

RTTY AFSK Modulator PC board. See Feb. 79 Ham Radio. Drilled $5.00 F. E. Hinkle, 12412 Mossy Bark, Austin, TX 78750.

EZ deals are the best! Try me and see for Yaesu, Drake, KLM, Swan, Cushcraft, DenTron, VHF Eng., ICOM, CDE, Hustler, Wilson and more. Call, see or write WØEZ, Bob Smith Electronics, RFD 3, Hwy 169 & 7, Fort Dodge, IA 50501. (515) 576-3886.

WANTED: Motorola KXN 1024 and KXN 1052 channel elements. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

THE MEASUREMENT SHOP has used/reconditioned test equipment at sensible prices; catalog. 2 West 22nd St., Baltimore, MD 21218.

MANUALS for most ham gear 1937/1970. Send 25¢ for "Manual Catalog." HI, Inc., Box H864, Council Bluffs, Iowa 51502.

PORTA PAK — Make your FM mobile a self-contained portable. Models in stock for most popular makes. 4.5 amp hr model $80.00. 9 amp hr $103.00. Charger included, shipping extra. P.O. Box 67, Somers, WI 53171.

WANTED — Radio transcription discs. Any size or speed. Larry, W7FIZ. Box 724, Redmond, Washington 98052.

TEST EQUIPMENT CATALOG listing used Tektronix, HP and GR equipment at bargain prices. PTI, Box 8699, White Bear Lake, MN 55110. Price $1.00 refundable with first order.

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PERFECT SSB RECEIVER: Drake R-4, MS-4 matching speaker, 26 extra crystals, manuals. Looks and works like brand new. Will ship anywhere. $265 or best offer. W. Calvert, WA9EZY, 21114-94th Avenue North, Port Byron, Ill. 61275.

HAMS: CUSHCRAFT HAS OPENINGS for people with experience in building and evaluating antennas. If you have experimented with antenna designs and have made gain and pattern measurements, call or write today. Cushcraft Corporation, 48 Perimeter Road, Manchester, New Hampshire 03103. Tel.: (603) 627-7877.

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COUNTS & DISPLAYS YOUR TURNS

- *99.99 Turns*
- *One Hole Panel Mount*
- *Handy Logging Area*
- *Spinner Handle Available*

Case: 2x4"; shaft ¼"x3"

TC2 $10.00	**Model TC2:** Skirt 2-1/8"; Knob 1-5/8"
TC3 $11.00	**Model TC3:** Skirt 3"; Knob 2-3/8"
Spinner Handle Add $1.50	

Prices include UPS or Parcel Post

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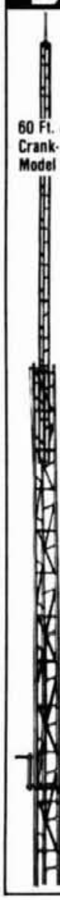
HIGHEST QUALITY ALUMINUM & STEEL



60 Ft. Aluminum. Crank-Up Model T-60-H

40' Steel Crank-Up Model SHD-40

- ★ **TELESCOPING** (CRANK UP)
- ★ **GUYED** (STACK-UP)
- ★ **TILT-OVER MODELS**

Easy to install. Low Prices. Crank-ups to 100 ft.

EXCELLENT FOR HAM COMMUNICATIONS

SPECIAL
Four Section 50 Ft. Van Mounted Crank-Up Aluma Tower

Over 36 types aluminum and steel towers made—specials designed and made—write for details

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MODEL 43

$125

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Prepaid Shipment in Continental USA Only

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713/658-0268 Nites 713/497-5683

More Details? CHECK—OFF Page 110

Coming Events

ILLINOIS: Fox River Radio League Hamfest, Kane Co. Fairgrounds Exhibition Hall, St. Charles, — Sunday, August 26th. Tickets: $1.50 advance — $2.00 at gate. Contact: Martin Schwamberger WB9TNQ, 1051 Northfield Drive, Aurora, IL 60505.

RADIO EXPO '79, September 15 and 16, Lake County Fairgrounds, Routes 120 and 45, Grays Lake, Illinois. Manufacturers' displays, flea market, seminars, ladies' programs. Advance tickets $2.00. Write EXPO, P.O. Box 305, Maywood, IL 60153. Exhibitors inquiries: EXPO Hotline (312) 345-2525.

CINCINNATI HAMFEST: 43rd Annual — Sunday, September 16, 1979 at Strickers Grove on State Route 128, one mile west of Ross (Venice) Ohio. Exhibits, prizes, food and refreshments available, Flea Market (radio related products only), Music, Good Fellowship, Hidden Transmitter Hunt and Sensational Airshow. Admission and Registration $4.00. For further information: Lillian Abbott, K8CKI, 1424 Main St., Cincinnati, Ohio 45210.

CONNECTICUT: Third annual WELI ARC Flea Market, August 25, Radio Towers Park, Benham St., Hamden. Dealers $5.00 gate; $4.00 advance. Refreshments. Admission: 50¢, under 12 free. Rain date September 1. Send preregistration to: WELI ARC, P.O. Box 85, New Haven, CT.

INDIANA: The annual LaPorte County Hamfest, Sunday, August 26, rain or shine. County Fairgrounds on Highway 2, west of LaPorte. Paved outdoor flea market. Indoor display. Tables available $1.00 each. Overnight trailer hookups for early birds. Advance tickets $2.00. SASE to P.O. Box 30, LaPorte, IN 46350.

THE SANGAMON VALLEY RADIO CLUB of Springfield, Illinois holds its Fourth Annual Hamfest on Sunday, September 23rd. Location — Sangamon County Fairgrounds in New Berlin, 16 miles west of Springfield. Indoor display area and covered pavilion. Hear Randy Rowe NØTG talk on the Navassa DX-pedition! Various exhibits, kids activities and food available. Overnite camping. First Prize: Atlas RX110/TX110 with power supply. Tickets: $1.50 advance, $2.00 gate. Information: John Sams, WA9KRL, S.V.R.C., 1025 South Sixth, Springfield, IL 62703.

KANSAS: The Kansas-Nebraska Radio Club's 28th annual Hamfest and Flea Market, Saturday, August 11 and Sunday, August 12, Cloud County Community College, Concordia. Technical talks. Banquet Saturday, 7 PM. Hawaiian style luau, Sunday noon. Big prize drawing 3 PM. For info: WØUQD, Box 404, Beloit, KS 67420.

INDIANA: The 2nd annual Hoosier Backyard Hamfest, September 9, Hensonburg School, Bloomington. ATV, ATV RPT, SSTV demonstrations, home computer show, indoor swap, refreshments, door prizes. Tickets $1.00 per head over 12. Talk-in on *147.78-18*. Inquiries to HBYH, 7381 W. Highway 46, Ellettsville, IN 47429.

BLOSSOMLAND: Fall Swap Shop, October 7, Berrien County Youth Fairgrounds, Berrien Springs, Michigan. Large convenient facilities and refreshments. Tables restricted to radio and electronic items. Advance ticket *donation* $1.50. Tables $2.00. Write Charles White, 1940 Union Ave., Benton Harbor, MI 49022. Make checks payable to Blossomland ARA.

ILLINOIS: 1979 National Quarter Century Wireless Association Convention, September 7, 8 and 9. Chicago. Scheduled tours: scenic, Central FAA facility, etc. Exhibits of early days of radio. Main banquet — Friday night. DXCC banquet, Saturday night.

THE MT. AIRY VHF Radio Club (the Packrats) is pleased to announce the establishment and sponsorship of the Sam Harris Memorial VHF Activity Award. The purpose — to promote club activity, portable operation, VHF/UHF contest operation. Rules for the award: 1. The award *will be given to the top scoring multi-operator*, portable station operating in the September ARRL VHF QSO Party; 2. Top score determined by the ARRL using their current contest rules for eligibility. The top scoring station need not be an ARRL affiliated club; 3. The winner must be a portable operation. Permanent stations are not eligible. Eligibility determined by Mt. Airy VHF Radio Club. The Award: A trophy will be retained by the winning group for a period of one year at which time it will be exchanged for a permanent, engraved trophy.

NEW JERSEY: The DeVry Tech Amateur Radio Club's third annual flea market, Saturday, August 11, in rear parking lot at DeVry Technical Institute, 479 Greet St., Woodbridge. (Between Rt. 1 and Rt. 9.) Space $2.00. Admission: Free.

OHIO: INTERSTATE QSO PARTY, August 25 and 26, 1979 2 PM to 12 PM EDT (1800Z-2400Z) each day. Out-of-state stations work Ohio stations, Ohio stations work anyone; once per mode per band. Repeater contacts permitted, but satellite contacts are not permitted. Out-of-state stations send RST, serial number of QSO and ARRL section or country. Ohio stations send RST, serial number, and county. No multi-op, multi-transmitter stations are eligible for awards. Suggested frequencies: up 5 kHx from lower end of General Class bands. Try fifteen meters on the hour and ten meters on the half-hour, 1800-2300Z. For complete information — Jeff Maass, K8ND, 4410 Norwell Drive, Columbus, Ohio 43220.

TEXAS: The Panhandle Amateur Radio Club's 1979 Golden Spread Hamfest, Friday evening, Saturday, and Sunday, August 10, 11 and 12, The Inn of Amarillo, 601 Amarillo Blvd. West, Amarillo. Preregistration $4.00 per person by August 6. At door — $6.00 per person. Swapfest, tech sessions, displays, Army/Navy MARS meetings and more. Ladies' programs, free bingo, hospitality hours. Over $2000.00 in major door prizes.

NEW JERSEY: Sussex County Amateur Radio Club Hamfest, Saturday, September 8, 9 AM to 5 PM, rain or shine, Sussex County Farm and Horse Show Grounds, off Route 206, Augusta. Large indoor selling area and tailgating. Buyers $1.00 ticket includes chance at door prizes. YL's, XYL's, harmonics free. Indoor sellers: $6.00 at door, $5.00 advance. Tailgaters: $5.00 door, $4.00 advance. Talk-in on 147.90/30 repeater and 146.52 simplex. For registration and info: Sussex County Amateur Radio Club, P.O. Box 11, Newton, NJ 07860 or AC2A, Ed Woznicki (201) 852-3268.

OHIO: Union County Amateur Radio Club's Hamfest '79, August 26, Marysville Fairgrounds, 30 miles NW of Columbus. For info: Chuck Simpson, Hamfest Chairman, 19726 Delaware County Line Rd., Marysville, OH 43040.

PENNSYLVANIA: The Mid-Atlantic Amateur Radio Club's annual J.B.M. Hamfest, August 19, Budco 309 Twin Drive-In Theater, 309 Expressway and Rt. 63, Montgomeryville, 9 AM to 4 PM. Doors open 8 AM for setup. Admission: $2.50, $1.00 additional for tailgating. Non-Hams in party free. Refreshments available. Door prizes, raffle. Talk-in on 147.45, 146.52 simplex and on club repeater, WB3JOE, 147.66/06. Information: Gene Hoenig, WB3FTJ, 717 Amherst Circle, Newtown Square, PA 19073 or call (215) 221-3666 days or (215) 353-3281 evenings or weekends.

VIRGINIA: Fourth annual Tidewater Hamfest — Computer Show — Flea Market will be held in the Norfolk, VA Cultural and Convention Center SCOPE October 20 and 21, 1979. 60,000 square feet of airconditioned exhibit and Flea Market tailgating space are available. Doors open at 9:00 AM. ARRL meetings, DX, Traffic forums, plus a CW contest are scheduled. FCC Exams are planned for amateur upgrading Saturday 9-12 AM. A special feature will be a dinner cruise and banquet on the Spirit of Norfolk Cruiseship Saturday night. Advance registrations $2.50 (SASE), $3.50 at the door. Flea Market tailgate spaces $3/day. Cruise and banquet $16 per person, $30 per couple. Tickets and information — TRC P.O. Box 7101, Portsmouth, VA 23707.

WORKSHOPS: Two expanded workshops on 8080/8085/Z80 Microcomputer Design, Microcomputer Interfacing, Software Design and Digital Electronics are being given by the editors of the popular Blacksburg books. Participants have the option of retaining the equipment used in these courses. Dates are October 1 to 6, 1979. For more information contact Dr. Linda Leffel, C.E.C., VPI and SU, Blacksburg, VA 24061 — (703) 961-5241.

PENNSYLVANIA: The Tioga County ARC's third annual Hamfest, August 25, 9 AM to 5 PM Tioga County Fairgrounds on Route 660. Open and covered Flea Market. Ladies' and harmonics' activities. Craft show and RC Models. Raffle and door prize every hour. Picnic or visit snack bar. $1.00 per head. Heads under 16 free. Talk-in WA3DPV/RPT 146.19/79, .52/52 and CB CHNL 5. For info: Wells Farr, WB3CUF, 101 Sherwood St., Mansfield, PA 16933 or Don Kimble, AE3Z, Box 109, 210 Maple Street, Knoxville, PA 16928.

PENNSYLVANIA: On August 26 the Fort Venango Mike and Key Club will be at Drake Well in Titusville to celebrate the 120th anniversary of drilling oil. An all band operation is planned with a possibility of novice bands and OSCAR. Look for club call — W3ZIC. Certificates issued to those wanting them. Send SASE to WA3YGQ.

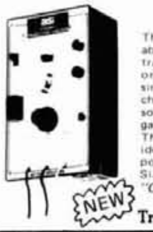
VERMONT: Burlington Amateur Radio Club's International Field Days, August 11 and 12, The Old Lantern, Charlotte. Outdoor flea market, Saturday and Sunday. Bingo, prizes. Model air show. Camping by reservation with campground. Admission: $3.00 U.S. currency at gate or write: BARC, Box 312, Burlington, VT 05402.

INDIANA: The Tippecanoe ARA's Lafayette Hamfest, Sunday, August 19, Tippecanoe County 4-H Fairgrounds located on Indiana Highway 25 in Lafayette. Advance tickets $2.00 by August 10. Please SASE to Carl Vinyard, KB9DV, 10012 SR 26 East, Lafayette, IN 47905. Preregistration prize: Wilson Mark IV Handy-Talkie and charger; grand prize: Yaesu FT 227 RA, 2M mobile transceiver and many other prizes. Flea market, forums, refreshments. Camping on grounds with limited hookups Friday, Saturday, Sunday nights only. Camping fee additional. Gates open 6:00 AM Sunday. Games for YL's and kids. Talk-in 146.13-73 repeater and 146.52 simplex.

IOWA: The Iowa 75 meter Net Picnic, August 26, Hickory Hills Park, South of Waterloo. Beginning AM with noon potluck meal and brief program in afternoon. Prizes, etc. For further info: WBØJFF.

More Details? CHECK — OFF Page 110

Transistor Checker



– Completely Assembled –
– Battery Operated –

The ASI Transistor Checker is capable of checking a wide range of transistor types, either "in circuit" or out of circuit. To operate, simply plug the transistor to be checked into the front panel socket, or connect it with the alligator clip test leads provided. The unit safely and automatically identifies low, medium and high power PNP and NPN transistors. Size: 3¼" x 6¼" x 2". "C" cell battery not included.

NEW

Trans-Check **$29.95 ea.**

Custom Cables & Jumpers

NEW NEW

DB 25 Series Cables

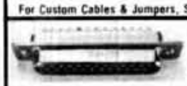
Part No.	Cable Length	Connectors	Price
DB25P-4-P	4 Ft.	2-DP25P	$15.95 ea.
DB25P-4-S	4 Ft.	1-DP25P/1-25S	$16.95 ea.
DB25S-4-S	4 ft.	2-DP25S	$17.95 ea.

Dip Jumpers

DJ14-1	1 ft.	1-14 Pin	$1.59 ea.
DJ16-1	1 ft.	1-16 Pin	1.79 ea.
DJ24-1	1 ft.	1-24 Pin	2.79 ea.
DJ14-1-14	1 ft.	2-14 Pin	2.79 ea.
DJ16-1-16	1 ft.	2-16 Pin	3.19 ea.
DJ24-1-24	1 ft.	2-24 Pin	4.95 ea.

For Custom Cables & Jumpers, See JAMECO 1979 Catalog for Pricing

CONNECTORS



25 Pin-D Subminiature

DB25P (as pictured)	PLUG (Meets RS232)	**$2.95**
DB25S	SOCKET (Meets RS232)	**$3.50**
DB51226-1	Cable Cover for DB25P or DB25S	**$1.75**

PRINTED CIRCUIT EDGE-CARD

156 Spacing-Tin-Double Read-Out – Bifurcated Contacts – Fits .054 to .070 P.C. Cards

15/30	PINS (Solder Eyelet)	**$1.95**
18/36	PINS (Solder Eyelet)	**$2.49**
22/44	PINS (Solder Eyelet)	**$2.95**
50/100 (.100 Spacing)	PINS (Wire Wrap)	**$6.95**
50/100 (.125 Spacing)	PINS (Wire Wrap) R681-1	**$6.95**

4-Digit Clock Kit

- Bright .357" ht. red display
- Sequential flashing colon
- 12 or 24 hour operation
- Extruded aluminum case (black)
- Pressure switches for hours, minutes & hold functions
- Includes all components, case and wall transformer
- Size: 3¼ x 1¾ x 1¼

JE730 **$14.95**

Jumbo 6-Digit Clock Kit

- Four .630"ht. and two .300"ht. common anode displays
- Uses MM5314 clock chip
- Switches for hours, minutes and hold functions
- Hours easily viewable to 30 feet
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hour operation
- Includes all components, case and wall transformer
- Size: 6¾ x 3⅛ x 1¾

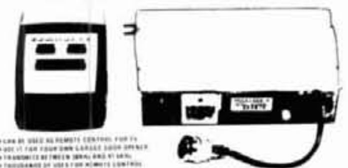
JE747 **$29.95**

- Bright .300 ht. comm. cathode display
- Uses MM5314 clock chip
- Switches for hours, minutes and hold modes
- Hrs. easily viewable to 20 ft.
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hr. operation
- Incl. all components, case & wall transformer
- Size: 6¾" x 3-1/8" x 1¾"

JE701

6-Digit Clock Kit $19.95

REMOTE CONTROL TRANSMITTER & RECEIVER



$19.95

Digital Stopwatch Kit

- Use Intersil 7205 Chip
- Plated thru double-sided P.C. Board
- LED display (red)
- Times to 59 min. 59.59 sec. with auto reset
- Quartz crystal controlled
- Three stopwatches in one: single event, split (cummulative) & taylor (sequential timing)
- Uses 3 penlite batteries
- Size: 4.5" x 2.15" x .90"

JE900 **$39.95**

MICROPROCESSOR COMPONENTS

8080A/8080A SUPPORT DEVICES

8080A	CPU	$ 9.95
8212	8-Bit Input/Output	3.25
8214	Priority Interrupt Control	5.95
8216	Bi-Directional Bus Driver	3.49
8224	Clock Generator/Driver	3.95
8226	Bus Driver	3.49
8228	System Controller/Bus Driver	5.95
8238	System Controller	5.95
8251	Prog. Comm. I/O (USART)	7.95
8253	Prog. Interval Timer	14.95
8255	Prog. Periph. I/O (PPI)	9.95
8257	Prog. DMA Control	19.95
8259	Prog. Interrupt Control	19.95

6800/6800 SUPPORT DEVICES

MC6800	MPU	$14.95
MC6802CP	MPU with Clock and Ram	24.95
MC6810API	128X8 Static Ram	5.95
MC6821	Periph. Inter. Adapt (MC6820)	7.49
MC6828	Priority Interrupt Controller	12.95
MC6830L8	1024X8 Bit ROM (MC68A30-8)	14.95
MC6850	Asynchronous Comm. Adapter	7.95
MC6852	Synchronous Serial Data Adapt.	9.95
MC6860	0-600 bps Digital MODEM	12.95
MC6862	2400 bps Modulator	14.95
MC6880A	Quad 3-State Bus. Trans. (MC8T26)	2.25

MICROPROCESSOR CHIPS—MISCELLANEOUS

Z80(780C)	CPU	$19.95
Z80A(780-1)	CPU	24.95
CDP1802	CPU	19.95
2650	MPU	19.95
6502	CPU	11.95
8035	8-Bit MPU w/clock, RAM, I/O lines	19.95
P8085	CPU	19.95
TMS9900JL	16-Bit MPU w/hardware, multiply & divide	49.95

SHIFT REGISTERS

MM500H	Dual 25 Bit Dynamic	$ .50
MM503H	Dual 50 Bit Dynamic	.50
MM504H	Dual 16 Bit Static	.50
MM506H	Dual 100 Bit Static	.50
MM510H	Dual 64 Bit Accumulator	.50
MM5016H	500/512 Bit Dynamic	.89
2504T	1024 Dynamic	3.95
2518	Hex 32 Bit Static	4.95
2522	Dual 132 Bit Static	2.95
2524	512 Static	.99
2525	1024 Dynamic	2.95
2527	Dual 256 Bit Static	2.95
2528	Dual 250 Static	4.00
2529	Dual 240 Bit Static	4.00
2532	Quad 80 Bit Static	2.95
2533	1024 Static	2.95
3341	Fifo	6.95
74LS670	4X4 Register File (TriState)	2.49

UART'S

A-Y-5-1013	30K BAUD	5.95

MICROPROCESSOR MANUALS

M-Z80	User Manual	$7.50
M-CDP1802	User Manual	7.50
M-2650	User Manual	5.00

ROM'S

2513(2140)	Character Generator(upper case)	$9.95
2513(3021)	Character Generator(lower case)	9.95
2516	Character Generator	10.95
MM5230N	2048-Bit Read Only Memory	1.95

RAM'S

1101	256X1	Static	$1.49
1103	1024X1	Dynamic	.99
2101(8101)	256X4	Static	3.95
2102	1024X1	Static	1.75
21L02	1024X1	Static	1.95
2111(8111)	256X4	Static	3.95
2112	256X4	Static MOS	4.95
2114	1024X4	Static 450ns	9.95
2114L	1024X4	Static 450ns low power	10.95
2114-3	1024X4	Static 300ns	10.95
2114L-3	1024X4	Static 300ns low power	11.95
5101	256X4	Static	7.95
5280/2107	4096X1	Dynamic	4.95
7489	16X4	Static	1.75
74S200	256X1	Static Tristate	4.95
93421	256X1	Static	2.95
UPD414 (MK4027)	4K	Dynamic 16 pin	4.95
UPD416 (MK4116)	16K	Dynamic 16 pin	9.95
TMS4044-45NL	4K	Static	14.95
TMS4045	1024X4	Static	14.95
2117	16,384X1	Dynamic 350ns (house marked)	9.95
MM5262	2KX1	Dynamic	4/1.00

PROM'S

1702A	2048	FAMOS	$5.95
2716INTEL	16K*	EPROM	59.95
TMS2516 (2716)	16K*	EPROM	49.95
	*Requires single +5V power supply		
TMS2532	4KX8	EPROM	89.95
2708	8K	EPROM	10.95
2716 T.I.	16K**	EPROM	29.95
	**Requires 3 voltages: −5V, +5V, +12V		
5203	2048	FAMOS	14.95
6301-1(7611)	1024	Tristate Bipolar	3.49
6330-1(7602)	256	Open C Bipolar	2.95
82S23	32X8	Open Collector	3.95
82S115	4096	Bipolar	19.95
82S123	32X8	Tristate	3.95
74186	512	TTL Open Collector	9.95
74188	256	TTL Open Collector	3.95
74S287	1024	Static	2.95

CSC CONTINENTAL SPECIALTIES

Proto Board 203

PB 203 **$75.00**

Proto Board 203A

PB 203A **$124.95**

Model Number	L x W x H (Inches)	Price
PB-6	6.0 x 4.5 x 1.4	$15.95
PB-100	6.0 x 4.5 x 1.4	$19.95
PB-101	6.0 x 4.5 x 1.4	$22.95

Model Number	L x W x H (Inches)	Price
PB-102	7.0 x 4.5 x 1.4	$26.95
PB-103	9.0 x 6.0 x 1.4	$44.95
PB-104	9.8 x 8.0 x 1.4	$54.95

THE SINCLAIR PDM35

DC Volts (4 ranges) Range 1mV to 1000V. Accuracy of reading 1.0% ± 1 count. Note: 10MΩ input impedance.
AC Volts (40 Hz-5 kHz) Range 1V to 500 V. Accuracy of reading 1.0% ± 2 counts.
DC Current (6 ranges) Range 1 nA to 200 mA. Accuracy of reading 1.0% ± 1 count. Note: Max. resolution 0.1 nA.
Resistance (5 ranges) Range 1Ω to 20 MΩ. Accuracy of reading 1.5% ± 1 count. Also provides 5 junction test ranges.
Dimensions: 6 in x 3 in x 1¼ in.
Weight: 6½ oz.
Power Supply: 9 V battery or Sinclair AC adapter (Battery not incl.).
Sockets: Standard 4mm for resilient plugs.

Options: AC adapter for 117 V 60 Hz power. De luxe padded carrying wallet.

PDM35: Digital Multimeter (completely assembled)	$59.95
PDM-AC: 117V AC Adapter	6.95
PDM-DP: Deluxe padded carrying case	6.95

CSC 100 MHz 8-Digit Counter

CONTINENTAL SPECIALTIES CORPORATION

- 20 Hz-100 MHz Range
- 8" LED Display
- Crystal-controlled timebase
- Fully Automatic
- Portable — completely self contained
- Size — 1.75" x 7.38" x 5.63"
- Four power sources: i.e. batteries, 110 or 220V with charger, 12V with auto lighter adapter and external 7.2-10V power supply

MAX-100 **$134.95**

ACCESSORIES FOR MAX 100:

Mobile Charger Eliminator use power from car battery — Model 100 — CLA $3.95
Charger/Eliminator use 110 V AC — Model 100 — CA1 $9.95

REGULATED POWER SUPPLY

NEW

JE200 5V-1 AMP POWER SUPPLY

- Uses LM309K
- Heat sink provided
- PC Board construction
- Provides a solid 1 amp @ 5 volts
- Can supply up to ±5V, ±9V and ±12V with JE205 Adapter
- Includes components, hardware & instructions
- Size: 3½"x5"x2"H

JE200 **$14.95**

JE205 ADAPTER BOARD

— Adapts to JE200 — ±5V, ±9V and ±12V

- DC/DC converter w/ +5V input
- Toriodal hi-speed switching XMFR
- Short circ. protection
- PC Brd. construction
- Piggy-back to JE200 board
- Size: 3½"x2"x9/16"h

JE205 **$12.95**

$10.00 Min. Order – U.S. Funds Only
Calif. Residents Add 6% Sales Tax
Postage – Add 5% plus $1 Insurance (if desired)

Spec Sheets – 25¢
1979 Catalog Available – Send 41¢ stamp

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The Incredible "Pennywhistle 103"

$139.95 Kit Only

The Pennywhistle 103 is capable of recording data to and from audio tape without critical speed requirements for the recorder and it is able to communicate directly with another modem and terminal for telephone "hamming" and communications. In addition, it is free of critical adjustments and is built with non-precision, readily available parts.

Data Transmission Method	Frequency-Shift Keying, full-duplex (half-duplex selectable)
Maximum Data Rate	300 Baud
Data Format	Asynchronous Serial (return to mark level required between each character)
Receive Channel Frequencies	2025 Hz for space; 2225 Hz for mark
Transmit Channel Frequencies	Switch selectable: Low (normal) – 1070 space, 1270 mark; High – 025 space, 2225 mark
Receive Sensitivity	−46 dbm accoustically coupled
Transmit Level	−15 dbm nominal. Adjustable from −6 dbm to −20 dbm
Receive Frequency Tolerance	Frequency reference automatically adjusts to allow for operation between 1800 Hz and 2400 Hz
Digital Data Interface	EIA RS-232C or 20 mA current loop (receiver is optoisolated and non-polar)
Power Requirements	120 VAC, single phase, 10 Watts
Physical	All components mount on a single 5" by 9" printed circuit board. All components included.

Requires a VOM, Audio Oscillator, Frequency Counter and/or Oscilloscope to align

TRS-80 16K Conversion Kit

Expand your 4K TRS-80 System to 16K. Kit comes complete with:

- 8 each UPD416-1 (16K Dynamic Rams) 250NS
- Documentation for conversion

TRS-16K $75.00

COMPUTER CASSETTES

- 6 EACH 15 MINUTE HIGH QUALITY C-15 CASSETTES
- PLASTIC CASE INCLUDED 12 CASSETTE CAPACITY
- ADDITIONAL CASSETTES AVAILABLE #C-15-$2.95 ea.

CAS-6 $14.95
(Case and 6 Cassettes)

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UHF Channel 33 TV Interface Unit Kit

Wide Band B/W or Color System

★ Converts TV to Video Display for home computers, CCTV camera, Apple II, works with Cromeco Dazzler, SOL-20, IRS-80, Challenger, etc.

MOD II is pretuned to Channel 33 (UHF).

★ Includes coaxial cable and antenna transformer.

MOD II $29.95 Kit

Function Generator Kit

- Provides 3 basic waveforms: sine, triangle & square wave
- Frequency range from 1 Hz to 100K Hz
- Output amplitude from 0-volts to over 6 volts (peak to peak)
- Uses a 12V supply or a ±6V split supply
- Incl. chip, P.C. board, components and instructions

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IDEAL FOR TRS 80 — CASSETTE CONTROLLER

"Plug/Jack interface to any computer system requiring remote control of cassette functions"

The CC100 controls cassette motor functions, monitors tape location with its internal speaker and requires no power. Eliminates the plugging and unplugging of cables during computer loading operation from cassette.

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This is a 63-key, terminal keyboard newly manufactured by a large computer manufacturer. It is unencoded with SPST keys, unattached to any kind of PC board. A very solid molded plastic 13 x 4" base suits most application. IN STOCK **$29.95/each**

Hexadecimal Unencoded Keypad

19-key pad includes 1-10 keys, ABCDEF and 2 optional keys and a shift key. **$10.95/each**

More Details? CHECK — OFF Page 110

ERC PROMISES UP TO THE MINUTE STATE-OF-THE-ART DESIGN AND PERFORMANCE WE'VE DONE IT FOR 1979

FOUR SIMULTANEOUS FILTERS IN ONE FOR UNPARALLELED QRM FREE RECEPTION (SSB & CW)
PLUS A SPECIAL PATENTED CW PROCESSOR

SL-56
AUDIO ACTIVE FILTER
(3.5 + 5.5 + 7.5 INCHES)

THE BRAND NEW SL-56 AUDIO ACTIVE FILTER SUPERCEDES OUR SL-55 IN BOTH CONCEPT AND PERFORMANCE. CONSOLIDATION OF MANY COMPONENTS HAS ALLOWED US TO MAKE 16 OPERATIONAL AMPLIFIERS (COMPARED TO 6 IN THE SL-55) INTO A FILTER GUARANTEED TO OUT PERFORM ANY OTHER AT A COST ONLY SLIGHTLY HIGHER THAN THE SL-55. THE FEATURES OF THE SL-56 ARE SO ADVANCED FROM ITS PREDECESSOR THAT CALLING IT THE SL-55A IS NOT JUSTIFIED. UNLIKE OTHER FILTERS THAT SIMPLY OFFER A CHOICE OF ONE OR TWO FILTER TYPES AT A TIME (NOTCH, BANDPASS, ETC.) SL-56 PROVIDES WHAT IS REALLY NEEDED --- THE SIMULTANEOUS ACTION OF A 6 POLE 200 Hz FIXED HIGHPASS FILTER AND A 6 POLE 1600 Hz FIXED LOWPASS FILTER WITH A 60 dB NOTCH WHICH IS TUNABLE OVER THE 200-1600 Hz RANGE. THIS 3 FILTER COMBINATION IS UNBEATABLE FOR THE ULTIMATE IN QRM FREE SSB RECEPTION. ADJACENT CHANNEL QRM IS ELIMINATED ON THE HIGH AND LOW SIDES AT THE SAME TIME AND DOES NOT INTRODUCE ANY HOLLOWNESS TO THE DESIRED SIGNAL. ON CW THE SL-56 IS A DREAM. THE LOWPASS, HIGHPASS AND NOTCH FILTERS ARE ENGAGED ALONG WITH THE TUNABLE BANDPASS FILTER (400-1600 Hz) PROVIDING THE NEEDED ACTION OF 4 SIMULTANEOUS FILTER TYPES. THE BANDPASS MAY BE MADE AS NARROW AS 14 Hz (3dB). ADDITIONALLY, A SPECIAL PATENTED CIRCUIT FOLLOWS THE FILTER SECTIONS WHICH ALLOWS ONLY THE PEAKED SIGNAL TO "GATE ITSELF" THROUGH TO THE SPEAKER OR HEADPHONES (4-2000 OHMS). RECEIVER NOISE, RING AND OTHER SIGNALS ARE REJECTED. THIS IS NOT A REGENERATOR, BUT A MODERN NEW CONCEPT IN CW RECEPTION. THE SL-56 CONNECTS IN SERIES WITH THE RECEIVER SPEAKER OUTPUT AND DRIVES ANY SPEAKER OR HEADPHONES WITH ONE WATT OF AUDIO POWER. REQUIRES 115 VAC. EASILY CONVERTED TO 12 VDC OPERATION. COLLINS GRAY CABINET AND WRINKLE GRAY PANEL.

WARRANTED ONE YEAR   FULLY RFI PROOF   FULLY WIRED AND TESTED   AVAILABLE NOW

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ERC INTRODUCES A BRAND NEW CONCEPT IN THE MEASUREMENT OF VSWR AND POWER ACCEPTED BY THE LOAD

REQUIRES 115 VAC AT LESS THAN 1/16 AMP.

COLLINS GRAY CABINET. WRINKLE PANEL - BRIGHT RED LED DIGITS (.33"). DECIMAL POINT IS THE PILOT LIGHT.

1.8-30 MHz

TWO SO-239 COAX CONNECTORS ARE AT THE REAR PANEL.

DIMENSIONS 3.5 x 5.5 x 7.5 INCHES.

WEIGHT IS 2 POUNDS.

THE MODEL SL-65* (20-2000 WATTS) AND THE QRP MODEL SL-65A* (0.2-20 WATTS) DIGITALLY INDICATE ANTENNA VSWR UNDER ANY TRANSMISSION MODE -- SSB, CW, RTTY, AM Etc. THERE IS NO CALIBRATION REQUIRED AND NO CROSSED METER NEEDLES TO INTERPRET. SIMPLY LOOK AT THE READOUT AND THAT IS THE VSWR. SPEAKING NORMALLY INTO A SSB TRANSMITTER MIC. INSTANTLY CAUSES THE VSWR TO BE DISPLAYED THROUGHOUT YOUR ENTIRE TRANSMISSION. REVERSING THE POSITION OF A FRONT PANEL TOGGLE SWITCH AND THE DISPLAY INDICATES THE NET POWER (FORWARD LESS REFLECTED) THAT IS ACCEPTED BY THE ANTENNA. THE PEAK OF THE NET PEP IS DETECTED AND DISPLAYED WITHOUT FLICKER FOR ANY MODULATION TYPE. DISPLAY UPDATE IS CONSTANT YET FLICKER FREE AS YOU MAY CHANGE THE POWER ACCORDING TO YOUR VOICE. THERE IS NOTHING LIKE THIS QUALITY INSTRUMENT AVAILABLE ANYWHERE ELSE. IT IS THE ONLY VSWR-NET POWER INDICATOR THAT LETS YOU KNOW THE STATE OF YOUR ANTENNAS AND TRANSMITTED POWER AT ALL TIMES WHILE TRANSMITTING. EITHER MODEL IS A SOPHISTICATED DEVICE CONTAINING FOUR CIRCUIT BOARDS AND THIRTEEN INTEGRATED CIRCUITS.

WARRANTY ONE YEAR

SL-65 VSWR INDICATOR

- TWO DIGIT DISPLAY SHOWS VSWR TO AN ACCURACY OF .1 FOR VALUES FROM 1.0 AND 2.2. ACCURACY IS TO .2 FOR VALUES FROM 2.3 TO 3.4 AND TO .3 FROM 3.4 TO 4.0. FROM 4.1 TO 6.2 THE INDICATION MEANS THAT VSWR IS VERY HIGH.
- FOR VSWR VALUES NEAR 1.0, THE POWER RANGE FOR A VALID READING IS 20 - 2000 WATTS OUTPUT. FOR HIGHER VALUES THE UPPER POWER LIMIT FOR A FLICKER FREE VALID READING IS SOMEWHAT LESS (35 - 1000 WATTS FOR VSWR AT 2.0).
- DIVIDE THE ABOVE POWER LEVELS BY 100 TO OBTAIN THE PERFORMANCE OF THE SL-65A QRP MODEL.

SPECIAL AUDIO VERSION AVAILABLE FOR THE SIGHTLESS • WRITE FOR DETAILS •

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- THE POWER DISPLAYED IS THE DETECTED PEAK OF THE PEP FOR ANY MODULATION. THIS IS THE POWER THAT THE TRANSMITTER IS "TALKED" UP TO. DISPLAY DECAY TIME IS ABOUT ONE SECOND.
- THE POWER DISPLAYED IS THAT WHICH IS ACCEPTED BY THE ANTENNA (FORWARD LESS REFLECTED).
- POWER IS DISPLAYED ON THE SAME TWO DIGITS AS VSWR IN TWO AUTORANGED SCALES. 20 TO 500 WATTS AND 500 TO 2000 WATTS. TRIPOVER AT THE 500 WATT LEVEL IS AUTOMATIC EX: A READING OF 1.2 COULD MEAN 120 OR 1200 WATTS. YOU MUST KNOW WHICH RANGE YOU ARE IN.
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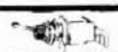

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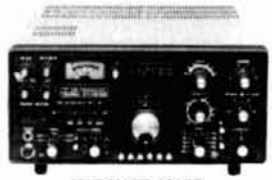

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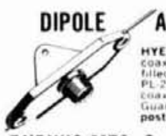

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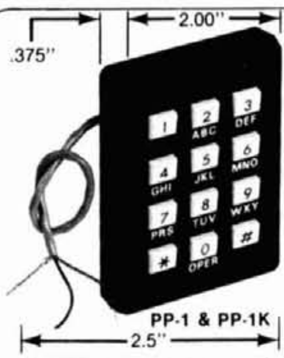

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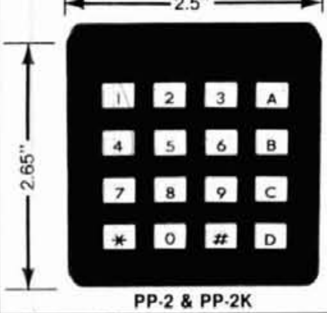

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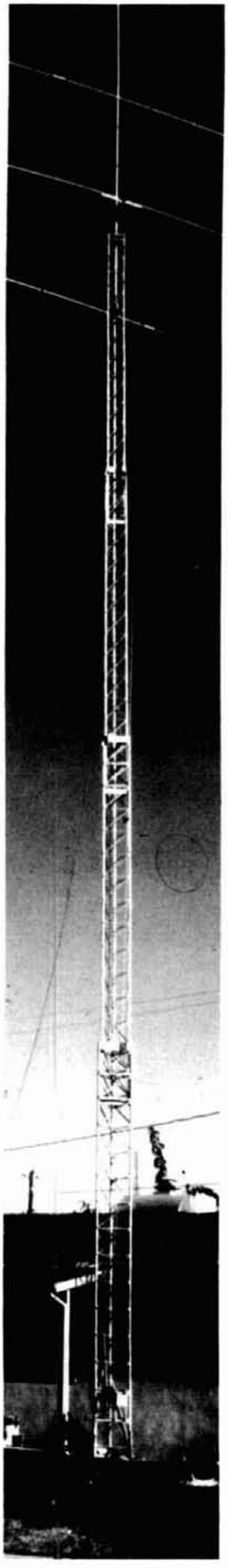

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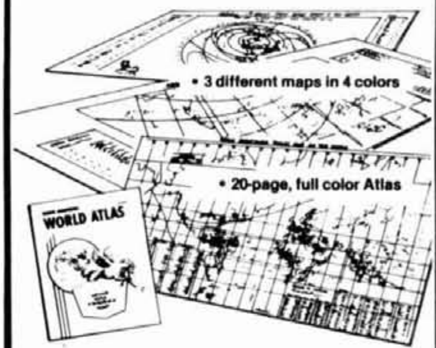

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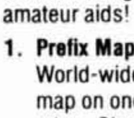

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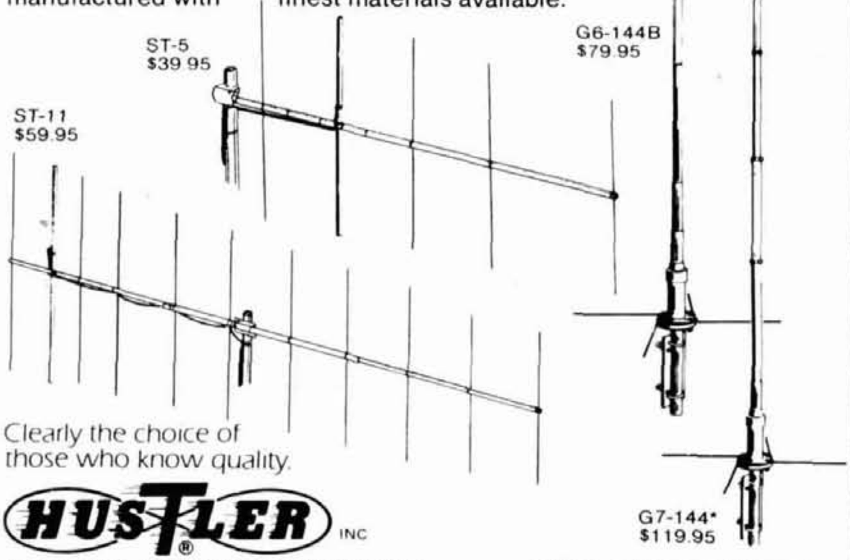

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TPL 1/4 KILOWATT LINEAR AMPLIFIER

TPL proudly presents the first true power 1/4KW SSB/AM, FM or CW solid state 2 meter linear amplifier

A remote control plug allows you to operate with the amplifier ON or OFF, or in SSB/AM, FM or CW from the dashboard.

The 2002 utilizes the latest state of the art engineering including microstrip circuitry and modular construction. The three final transistors combine to produce 250W when driven by 15W or more at 13.8VDC.

POWER INPUT:
5-20W Carrier FM or CW
20W PEP maximum SSB or AM

POWER OUTPUT:
200-250W carrier FM or CW
300W PEP SSB or AM

FREQUENCY RANGE:
144 to 148 MHz*
* will operate with slight degradation at 142-150 MHz.

HARMONIC ATTENTUATION:
All Harmonics Attenuated
60 dB or Greater

CURRENT DRAIN:
FM-40 Amps @ 250W
SSB-30 Amps @ 300W PEP

DUTY CYCLE:
FM 50% @ 150W 33% @ 250W
SSB 60% @ 150W 50% @ 250W

Model 2002 $499.00

can be ordered for repeater application for additional information contact

TPL COMMUNICATIONS INC.

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KDK 2015R KDK 2016A MIDLAND 13-510 13-513 CLEGG FM-28 YAESU FT227R ICOM IC22S KENWOOD TR7400A

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- All scanners install completely inside rig. No obtrusive external connections.
- All are easy to assemble and come complete with detailed instruction manual.
- Scanned frequency displayed on digital readout (except IC22S).
- In the scanner OFF mode the rig operates normally. In the scanner ON mode *the scanner locks on an occupied frequency, pauses for a preset time (about 5 secs.)* and then resumes scanning.
- This gives you the ability to eavesdrop all over the band without lifting a finger. When you hear something interesting, you flip the switch to the LOCK mode and the rig is ready to transmit.

AED SCANNER SPECIFICATIONS

	KDK 2015R	KDK 2016A	KENWOOD TR7400A	YAESU FT227R	MIDLAND 13-510 13-513	CLEGG FM-28	ICOM IC22S
SCAN RATE	Adjustable 100 kHz/sec-1 MHz/sec		50 kHz/sec	200 kHz/sec	100 kHz/sec	100 kHz/sec	100 kHz/sec
SWEEP WIDTH	144-148	142-149.995 or only the MHz segment you select on MHz switch	complete band or MHz you want	adjustable eg. 146-148 144-146 146-147	scans the MHz seg selected by the MHz switch	same as Midland	145.35-147.99
SCAN CONTROLS	2 mini toggle switches mounted on rig - LOCK switch may be mounted on mic		2 mini toggle switches mounted on rig	1 mini toggle switch mounted on mic or rig	2 mini toggle switches mounted on rig	same as Midland	1 mini toggle switch mounted on mic or rig
Price per kit	$39.95		$39.95	$34.95	$39.95	$39.95	$34.95
Price pre-assembled	$59.95		$59.95	$54.95	$59.95	$59.95	$54.95

Add $1.50 for postage & handling

End of Summer Special. $5.00 off kit price shown. $10.00 off pre-assembled price shown. Offer expires August 31.

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KENWOOD TS-180S solid state HF transceiver

Covers 160-10 meters, digital frequency control with 4 memories and manual scanning, 200W PEP/160W DC 160 - 15 meters and 160W PEP/140W DC on 10 meters, adaptable to new bands, IF shift, tunable noise blanker, dual RIT (VFO and memory/fix) SSB, CW, and FSK, 13.8 VDC operation, and built-in digital display to show VFO freq. and difference between VFO and M-1 memory freq.

1149.95 List. Call for quote.

DRAKE

DRAKE TR/DR7 general coverage digital R/O transceiver

Covers 160 thru 10 meters, reception from 1.5-30 MHz continuous, 0-30 MHz with optional Aux-7, modes: USB, LSB, CW, RTTY, AM equiv., true passband tuning, RIT, built-in RF wattmeter/VSWR bridge, SSB 250W PEP, CW 250W AM equiv. 80W. Power supply required for AC operation.

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KENWOOD TS-120S HF transceiver

No tune up! With digital display, cooling fan, IF shift, protection for the final transistor, VOX, noise blanker, 25 KHz marker, 80-10 meters, WWV, modes: SSB and CW, 200W PEP SSB, power requirements: R.O. 7A 13.8 VDC, T. 18A 13.8 VDC, Size: 3½"H x 9¼"W x 13½"L.

699.95 List. Call for quote.

YAESU FT-101ZD HF transceiver

Covers: 160 thru 10 meters plus WWV, modes: LSB, USB, and CW, built-in power supply, digital and analog frequency readout, 6146B final tubes, RF speech processor, variable IF bandwidth, noise blanker, heater switch, VOX, attenuator 10 dB or 20 DB selectable.

895.00 List. Call for quote.

YAESU FT-901 DM HF transceiver

Freq. coverage: 160 thru 10 meters, 200W PEP, RF speech processor, built-in VFO, reject tuning, LED freq. display with memory, built-in Curtis Keyer, 6146B final tubes. AC/DC power supply built-in audio peak freq. tuning.

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TEN-TEC Century 21 *CW transceiver*

Full break-in, 70 watts input, all solid state, built-in speaker, receives CW or SSB but transmits CW only, overload protection , offset receiver tuning, adjustable level sidetone, built-in regulated *power supply. Crystals are provided to* cover the 80 thru 10 meter bands.

349.00 List. Call for quote.

TEN-TEC Omni D transceiver

Totally solid state, covers 160 to 10 meters, digital readouts, VOX and PTT, built-in squelch, built-in 4-pos. CW/SSB filter, 2 speed break-in, power input 200 watts with 50 ohm load, 100% duty cycle, basic 12 VDC operation power supply required for 117 VAC operation, and more!

1069.00 List. Call for quote.

KENWOOD TS-820S HF transceiver

160 thru 10 meters, modes: CW, USB, LSB, FSK, input power SSB: 200W PEP, CW: 160W DC, FSK: 100W DC, power requirements: 120/220 VAC 50/60 Hz, noise blanker, speech processor, PLL, CW sidetone, and semi-break-in and digital readout built-in.

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ALL NEW

FT-101ZD

HIGH-PERFORMANCE HF TRANSCEIVER

Today's technology, backed by a proud tradition, is yours to enjoy in the all-new FT-101ZD transceiver from YAESU. A host of new features are teamed with the FT-101 heritage to bring you a top-dollar value. See your dealer today for a "hands on" demonstration of the performance-packed FT-101ZD.

SPECIFICATIONS

TRANSMITTER

PA Input Power:
180 watts DC
Carrier Suppression:
Better than 40 dB
Unwanted Sideband Suppression:
Better than 40 dB @ 1000 Hz, 14 MHz
Spurious Radiation:
Better than 40 dB below rated output
Third Order Distortion Products:
Better than −31 dB
Transmitter Frequency Response:
300-2700 Hz (−6 dB)
Stability:
Less than 300 Hz in first 30 minutes after 10 min. warmup; less than 100 Hz after 30 minutes over any 30 min. period
Negative Feedback: 6 dB @ 14 MHz
Antenna Output Impedance:
50-75 ohms, unbalanced

GENERAL

Frequency Coverage:
Amateur bands from 1.8-29.9 MHz, plus WWV/JJY (receive only)
Operating Modes:
LSB, USB, CW
Power Requirements:
100/110/117/200/220/234 volts AC, 50/60 Hz; 13.5 volts DC (with optional DC-DC converter)
Power Consumption:
AC 117V: 75 VA receive (65 VA HEATER OFF) 285 VA *transmit*; DC 13.5V: 5.5 amps receive (1.1 amps HEATER OFF), 21 amps transmit
Size:
345 (W) × 157 (H) × 326 (D) mm
Weight:
Approximately 15 kg.

COMPATIBLE WITH FT-901DM ACCESSORIES

RECEIVER

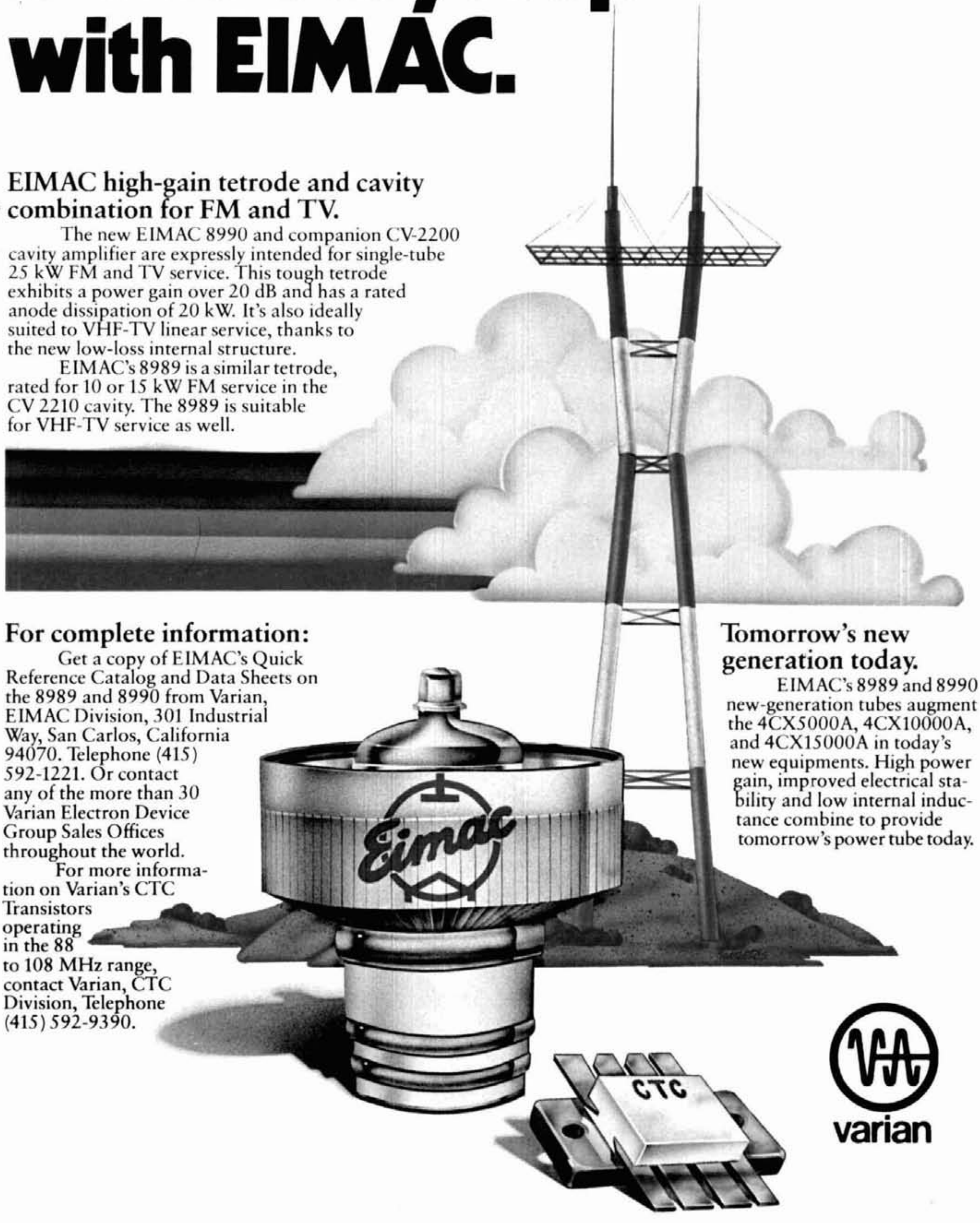
Sensitivity:
0.25 uV for S/N 10 dB
Selectivity:
2.4 KHz at 6 dB down, 4.0 KHz at 60 dB down (1.66 shape factor); Continuously variable between 300 and 2400 Hz (−6 dB); CW (with optional CW filter installed): 600 Hz at 6 dB down, 1.2 KHz at 60 dB down (2:1 shape factor)
Image Rejection:
Better than 60 dB (160-15 meters); Better than 50 dB (10 meters)
IF Rejection:
Better than 70 dB (160, 80, 20-10 m); Better than 60 dB (40 m)
Audio Output Impedance:
4-16 ohms
Audio Output Power:
3 watts @10% THD (into 4 ohms)

From transistor to 25kW is one easy step with EIMAC.

EIMAC high-gain tetrode and cavity combination for FM and TV.

The new EIMAC 8990 and companion CV-2200 cavity amplifier are expressly intended for single-tube 25 kW FM and TV service. This tough tetrode exhibits a power gain over 20 dB and has a rated anode dissipation of 20 kW. It's also ideally suited to VHF-TV linear service, thanks to the new low-loss internal structure.

EIMAC's 8989 is a similar tetrode, rated for 10 or 15 kW FM service in the CV 2210 cavity. The 8989 is suitable for VHF-TV service as well.



For complete information:

Get a copy of EIMAC's Quick Reference Catalog and Data Sheets on the 8989 and 8990 from Varian, EIMAC Division, 301 Industrial Way, San Carlos, California 94070. Telephone (415) 592-1221. Or contact any of the more than 30 Varian Electron Device Group Sales Offices throughout the world.

For more information on Varian's CTC Transistors operating in the 88 to 108 MHz range, contact Varian, CTC Division, Telephone (415) 592-9390.

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